LOW CARBON LIVING CRC

SP0016 Building Code Energy Performance Trajectory Final Technical Report

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

Disclaimer

Peer Review Statement

The CRCLCL recognises the value of knowledge exchange and the importance of objective peer review. It is committed to encouraging and supporting its research teams in this regard.

The author(s) confirm(s) that this document has been reviewed and approved by the project's steering committee and by its program leader. These reviewers evaluated its:

- originality
- methodology
- rigour
- compliance with ethical guidelines
- conclusions against results
- conformity with the principles of the Australian Code for the Responsible Conduct of Research (NHMRC 2007),

and provided constructive feedback which was considered and addressed by the author(s).

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Glossary

ABCB Australian Building Codes Board

ABS Australian Bureau of Statistics

Accelerated deployment energy efficiency scenarios and trajectories

The energy efficiency targets include all measures that are deemed to provide a material energy benefit, and assume faster deployment of energy efficiency technologies.

Accelerated deployment net energy scenarios and trajectories

Net energy performance in these scenarios assumes that the entire available roof area of each building archetype is covered with solar PV, allowing for maintenance access and installation angle for panels.

ACH Air changes per hour

AccuRate Simulation software used for residential modelling

AER Australian Energy Regulator

AHU Air Handling Unit

ASBEC Australian Sustainable Built Environment Council

BAU Business As Usual

BCR Benefit-cost ratio

BIPV Building Integrated PhotoVoltaics

COAG Council of Australian Governments

CO_2 Carbon Dioxide

Conservative energy efficiency scenarios and trajectories

These include energy efficiency targets and the potential for net energy performance through on-site renewables (assumed to be solar PV, taking into account average consumption profiles and available roof space).

COP Coefficient of Performance

CRC Cooperative Research Centre

CSIRO Commonwealth Scientific and Industrial Research Organisation

DEWHA Department of Environment, Water, Heritage and the Arts

DIS Department of Industry and Science

EA Energy Action

EER Energy Efficiency Ratio

Equivalent Star Rating

Star rating based on NatHERS assessment (energy levels) using non-standard assessment conditions, e.g. increased infiltration rate.

Energy efficiency targets

Targets for energy performance to be included in the Code, excluding any on-site renewable energy generation.

ENTR Electricity Network Transformation Roadmap.

GDP Gross Domestic Product

Greenhouse gas (GHG) emissions

Greenhouse gas emissions resulting from the operation of a building ('Scope 1' on-site energy emissions or 'Scope 2' emissions from energy procurement only).

Gross floor area

Sum of the conditioned and unconditioned floor area for each archetype or model

HStar Portal Portal where NatHERS assessment data is stored

HVAC Heating Ventilation and Air Conditioning

IES <VE> Integrated Environment Solutions (Software)

IPLV Integrated Part Load Value

kW Kilowatt

kWh Kilowatt-hour

kWth Kilowatt Thermal

MJ Megajoule

Multi-Dimensional Analysis

A range of scenario models, taking packages of the most effective technologies identified for that building archetype from the one-dimensional analysis, and integrating them into progressively stringent packages of measures that cover both existing technologies that are found to be cost-effective on current economic assumptions and likely future availability of cost-effective technologies.

MWh Megawatt-hour

NCC National Construction Code

NatHERS National House Energy Rating Scheme

NEEBP National Energy Efficiency Building Project

NEPP National Energy Productivity Plan

Net energy performance

Annual energy consumption of a building minus the annual on-site renewable energy generation

Net energy targets

Targets for net energy performance to be included in the Code, accounting for on-site renewable energy generation.

Net floor area Total conditioned floor area of the models or archetypes

Net societal benefit

The benefit gained by an individual as a result of an action, plus the benefits gained by independent parties (i.e. broader society), minus the costs borne by both the individual and broader society.

Net zero energy The annual on-site renewable energy generation is equal to or more than the annual energy consumption

NEXIS National Exposure Information System

Pa Pascal (unit of pressure)

PAC Packaged Air Conditioning

Regulated energy load

Annual energy consumption of the building from sources included in the scope of the Code (e.g. including heating and cooling but excluding plug-in appliances).

RIA Regulatory Impact Assessment

RIS Regulatory Impact Statement

Single 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.

SHGC Solar Heat Gain Coefficient, a measure of the proportion of solar heat gain that is transmitted through a window.

Societal benefit cost analysis

Benefit-to-cost analysis that incorporates both local energy and broader society (network) benefits.

Surface-to-volume ratio

Ratio of surface area to internal volume of the models

TAG Technical Advisory Group

tCO_2-e Tonnes of Carbon Dioxide – Equivalent

UoW University of Wollongong

U-value Measured in $W/m^2.K$ (Watts per area per temperature), U-value relates to the thermal resistance i.e. a higher U-value will allow more heat and visible light to transmit through the window, resulting in a higher SHGC.

VAV Variable Air Volume

VSD Variable Speed Drive

VT Visual Transmittance

WWR Window to Wall Ratio

Zero carbon Refers to a building with no net annual greenhouse gas emissions resulting from on-site energy or energy procurement (Scope 1 and Scope 2) from its operation.

Zero Carbon Ready Code

A Building Code that maximises the cost-effective potential for new construction to contribute to achieving the overarching zero carbon goal, and prepares new buildings for the 2050 zero carbon environment in which they will still be operating.

Executive Summary

The buildings sector is responsible for approximately 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 in delivering carbon emissions reductions. 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.

The goal of the analysis undertaken for this project is to assess the contribution that the Code could make towards achieving GHG emissions reductions in line with overarching zero carbon targets.

The report *Built to Perform – An industry led pathway to a zero carbon ready building code,* published on 3 July 2018, outlined a set of energy performance targets for different building types across different climates, based on societal cost-benefit analysis of energy efficiency and on-site renewable energy opportunities. It estimates these targets could reduce household bills by up to $900 per year for each household, while saving thousands of dollars each year across a whole non-residential building. This could also reduce electricity network investments across Australia by $12.6 billion between now and 2050. These benefits more than offset the upfront costs, noting that electricity market reforms would be required to enable network savings to be passed through to individual building occupants. Achieving the targets could also deliver 15 million tonnes of cumulative emissions reductions to 2030, and 78 million tonnes to 2050.

This report is the Final Technical Report for the Building Code Energy Performance Trajectory Project accompanying the *Built to Perform* report. The intent of this report is to provide more details on the underlying assumptions and results from the modelling work performed.

The study sought to identify energy efficiency measures for which the capital cost is outweighed by financial benefits ('cost-beneficial') from a societal perspective over a 40 year lifetime of the technology. In both residential and commercial buildings, a range of measures were found to individually achieve a benefit-to-cost ratio (BCR) of between 1.0 and 1.5 (where, a BCR of 1 brings the same lifetime value as cost and a BCR of 1.5 brings 1.5 times the value, e.g. $15,000 for $10,000 cost) and when measures were combined there was increased potential to implement more measures together while remaining cost beneficial. The target range of BCR was chosen so as to be consistent with the Australian Government's Best Practice Regulation guidelines[1] and Guidance Note on Cost-Benefit Analysis.[2].

The study examined multiple building archetypes located in four climate zones, covering Australia's largest population centres (climate zones 2, 5, 6 and 7). Further to the examination of energy efficiency measures, on-site solar photovoltaic (PV) systems were considered, with standard panel-based systems on both residential and commercial archetypes and building integrated PV (roof tiles, wall systems, glazing, etc.) on commercial archetypes only. Alternative generation systems such as photovoltaic thermal systems, micro wind turbines and geothermal systems have not been included in this study.

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. Baseline results for residential and commercial building energy modelling.
4. Individual cost-benefit analyses results for potential residential and commercial construction upgrades.
5. Modelling results for residential and commercial buildings, incorporating improvements that are currently cost-beneficial.
6. Assumptions for residential and commercial building energy modelling.
7. Stock model projections of the impact of proposed residential and commercial upgrades at state, territory and national levels.

Following is a summary of the two main components of the report and their key findings respectively.

Residential Component

This study assessed a range of energy efficiency opportunities across three building types: detached houses, attached townhouses and individual apartment units[3].

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

Strengthening the energy efficiency requirements of the Code could deliver between 19 and 25 per cent of the

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

[3] The apartment archetype does not include shared services or common areas – these are covered in commercial parts of this analysis as they sit within Volume 1 of the NCC.

energy savings required to achieve net zero energy in new residential buildings by 2030, compared with a baseline that complies with the deemed-to-satisfy (DtS) requirements of the 2019 Code.

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

- Across all archetypes, infiltration (air-tightness), domestic hot water and lighting energy efficiency measures were found to be cost effective today.
- There was generally a high degree of variability in the efficiency measures that were found to be cost beneficial across all archetypes and climate zones.
- In warmer climate zones (2&5) increased ventilation (ceiling fans) and additional shading (roller shutters and larger eaves) were often economic now.
- When examining future scenarios, improved insulation, shading control and thermal mass measures were found to be cost-beneficial across most of the archetypes and climate zones.
- Both attached and detached archetypes have high rooftop PV potential in all climate zones and will become net zero as a result very near into the future, as early as 2022.

Commercial Buildings

Five building types were considered in this study (office tower, hotel tower, medium retail shop, hospital ward and school building).

The study considered opportunities to improve the building fabric (external shutters, external colour, infiltration, high-mass walls, and wall insulation) and building services (air delivery system efficiencies, dewpoint coolers, heat exchangers, lifts, lighting, and economy cycle functionality).

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

Key findings in relation to the commercial study are as follows:

- Across all archetypes a lighter wall fabric colour, lighting controls and rooftop PV measures were found to be cost effective today.
- There was generally limited consistency in measures that were cost effective for each archetype across the different climate zones.
- Hotels and wards benefited from installation of external shutters in all climate zones.
- Wards and offices benefited from duct pressure reduction across many climate zones.
- There is also potential for a single-storey hospital ward to generate approximately one-third of its annual energy use through rooftop solar PV, while a single-storey school building could generate over three-quarters of its energy use.

1 Introduction

1.1 The Trajectory Project

1.1.1 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 in delivering carbon emissions reductions.[4] 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 – was a partnership between ASBEC and ClimateWorks Australia, the research providers who provided the modelling and other evidence described in this report, and other stakeholders The aim of the project was 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 Final 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.

1.1.2 Project Objectives

The key objectives of this project are as follows:

- 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 trajectories.
- 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.

1.2 Overarching Methodology

This project involved analysis of two building sectors, these being residential and commercial (i.e. non-residential). The descriptions herein of these two parallel streams of work have similar overall structures but differ

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

in detail, due in part to the fact that significant work had already been undertaken to determine current cost-effective opportunities to increase of energy requirements for commercial buildings as part of the update of the 2019 NCC led by the Australian Building Codes Board (ABCB), while no such work has been undertaken for residential buildings.

For the commercial analysis archetypes, five NCC building classes were combined with five representative building geometries to produce the simulation models. The archetypes include a 3 storey hotel (NCC building Class 3), a 10 storey office building (NCC building Class 5), a single storey retail building (NCC building Class 6), a single storey hospital ward area (NCC building Class 9a) and a single storey school building (NCC building Class 9b).

The residential analysis used three different building types namely a single-storey standalone detached house (NCC building Class 1a), a two storey attached townhouse (NCC building Class 1a) and a single level of a residential apartment dwelling (NCC building Class 2). The analysis, for both streams of modelling, was conducted over four climate zones including 2 (Brisbane), 5 (Sydney), 6 (Melbourne) and 7 (Canberra).

The modelling investigates a range of energy efficiency improvements to the building fabric and fixed equipment, and also investigates on-site renewables (PV). The measures for both the residential and commercial analysis vary, with lists of these measures presented in the respective modelling methodology sections.

The analysis was specific to Climate Zones 2, 5, 6 and 7 as defined by the ABCB.

- Zone 2: Warm humid summer, mild winter;
- Zone 5: Warm temperate;
- Zone 6: Mild temperate; and
- Zone 7: Cool temperature.
- Single sites were used to represent the above climate zones as opposed to multiple sites of the same climate zone. The representative sites selected were Brisbane, Sydney, Melbourne and Canberra.

To facilitate expedient simulation work to define the performance at fixed points in the future, a 5 year step period was used in the modelling process. Separate models were developed for building performance and economic viability at each time to determine how cost effectiveness changed for technologies over time, e.g. 0 years refers to what's cost effective today (and therefore for the 2019 Code), 5 years refers to what will be cost effective in 2024, 10 years for 2029 and 15 years refers to what will be cost effective in 2034.

The final trajectory was presented in 3 year step periods, to match the NCC revision timeframe, and the simulated results were interpolated to align with this sequence.

Economic variables such as energy pricing and technology costs are projected forwards in time (refer Appendix A -) in five-yearly increments.

After the efficiency measures were defined, a single-dimensional analysis was undertaken to gauge the benefit of changing an individual efficiency measure to the buildings. Under the single-dimensional analysis, the performance of a single measure was varied from the baseline while keeping the performance of all other measures constant. This was repeated for each individual measure. Measures which had more than a 2% impact on the annual building energy were identified for subsequent analysis. A benefit-cost analysis was performed to determine which measures are currently cost-effective.

The multi-dimensional analysis involved combining multiple measures in a single model and examining the overall impact of these measures being implemented together. The accelerated deployment models (used for the accelerated trajectory) incorporated all measures that were predicted to have an impact on building energy of greater than 2% from the single-dimensional analysis. The conservative models were identified from the single-dimensional analysis as those which had a benefit-cost ratio greater than 1. The conservative multi-dimensional models were tuned to achieve an overall benefit-cost ratio between 1 and 1.5 by adding or removing efficiency measures. This benefit cost ratio is the ratio of life cycle energy costs over capital cost less network adjustments.

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

1.3 Intended Outcomes

The results of this project will feed into the *Built to Perform* report by ASBEC and ClimateWorks[5], which form an evidence base for governments and industry to adopt time-bound targets and trajectories for Code energy requirements. The *Built to Perform* report uses the findings from this report to set out a series of feasible forward pathways for Code energy requirements that cover a range of building types and climates across Australia.

[5] https://www.asbec.asn.au/wordpress/wp-content/uploads/2018/07/180703-ASBEC-CWA-Built-to-Perform-Zero-Carbon-Ready-Building-Code-web.pdf

2 Residential Building Modelling

2.1 Modelling 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, an attached house, and a single mid-level apartment compliant with the current NCC energy requirements.

For this component of the NCC Trajectories project, the work was broken into two stages:

- ***Single-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.
- ***Multi-Dimensional Trajectory Analysis***: A range of scenario models were completed, taking packages of the most effective technologies identified for that building archetype from the one-dimensional analysis, and integrating them into progressively stringent packages of measures that cover both existing technologies that are found to be cost-effective on current economic assumptions and likely future availability of cost-effective technologies. These packages can be characterised as: i) a 'conservative' scenario employing existing technologies with extrapolations of current efficiency trends and economics, and ii) an 'accelerated deployment' scenario with relaxed economic criteria to assess the potential opportunity if costs or technologies improve faster.

Residential 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 including a standalone detached house, an attached townhouse, and an apartment (refer to Table 2-1, and Figure 1 to Figure 3). Similar models were developed and used to undertake the single-dimensional energy efficiency analysis and to benchmark the multi-dimensional energy efficiency trajectory analysis.

Table 2-1: Residential Archetype Details

Building type	Description
Standalone detached house	Class 1A, Single level, Gross floor area ≈ 213 m², Net floor area ≈ 189 m², Nominal dimensions ≈ 21.7 x 12.7 m (ceilings 2.4 m), Surface-to-Volume ratio ≈ 1.17
Attached townhouse	Class 1A, Two storey, Gross floor area ≈ 146 m², Net floor area ≈ 128 m², Nominal dimensions ≈ 10.1 x 7.3 m (ceilings 2.4 m), Surface-to-Volume ratio ≈ 0.52
Residential apartment	Class 2, Mid-level apartment, Gross floor area ≈ 90 m², Net floor area ≈ 76 m², Nominal dimensions ≈ 15.2 x 7.4 m, (ceilings 2.7 m), Surface-to-Volume ratio ≈ 0.39

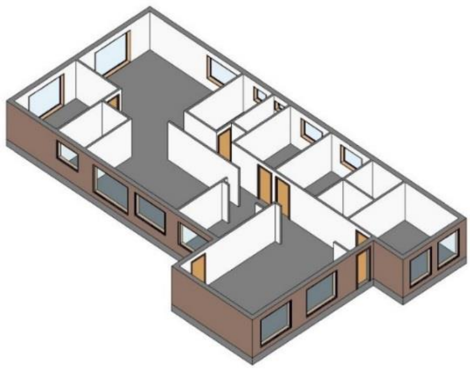


Figure 1: Detached, single storey, archetype physical geometry (courtesy of S. Beazley)

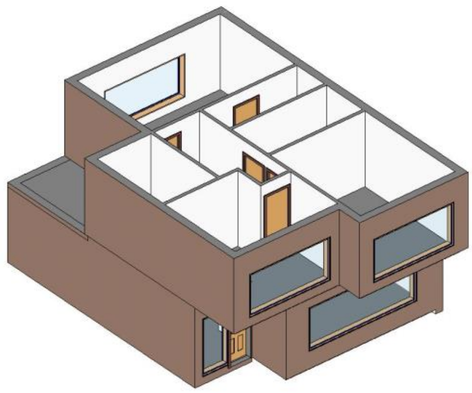


Figure 2: Attached, two storey townhouse, archetype physical geometry (courtesy of S. Beazley)

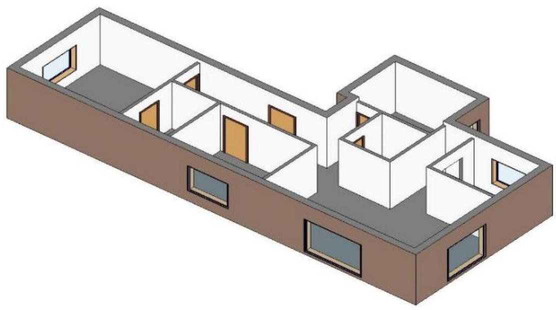


Figure 3: Apartment archetype physical geometry (courtesy of S. Beazley)

The archetype models and major inputs and assumptions (including form details, construction details and operation details) used for each archetype are presented in Residential Methodology Details. The archetypes were adjusted throughout the project in response to feedback from the project's Technical Advisory Group (TAG).

Each archetype was developed to enable 'single-dimensional' energy efficiency performance measures to be applied at various levels of stringency starting with a base case aligning with NCC 2016 requirements.

The archetypes were modelled using AccuRate Sustainability software (*V2.3.3.13 SP3 - Research Version*), a building rating tool accredited under the Nationwide House Energy Rating Scheme (NatHERS). The AccuRate Sustainability software utilises the CSIRO's Chenath Engine. A small number of modifications to the software were made by the CSIRO specifically for this project to improve access to data and modelling outcomes.

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.

2.1.1 Base Case Archetypes

The Base Case detached and attached archetypes were developed to comply with the National Construction Code 2016 Deemed-to-Satisfy (DtS) Elemental Provisions and provide a 6-Star rating under NatHERS at the default infiltration rate (i.e. as it would be entered for accreditation purposes) for each of the four climate zones considered (Climate Zones 2, 5, 6 and 7). As there are no DtS Elemental Provisions for Class 2 (apartment) buildings, the apartment archetype base case was also modelled at a 6-Star rating at the default infiltration rate. Thus all base case archetype models provided a NatHERS 6-Star rating at default infiltration rate.

For all archetypes the base case simulations were adjusted to achieve an infiltration rate of 15 ACH at 50 Pa in keeping with the estimated average infiltration rate of new residential buildings from a recent CSIRO[6] study (further details are provided in Section 2.1.1.1 Air Tightness and Infiltration).

Glazing types for base case models were initially based on details of typical windows as provided by the project's TAG. This was later adjusted to ensure better alignment with the Code DtS requirements and to match data on new builds for 2016 onwards from the Home Energy Rating System HStar portal, as provided the CSIRO. DtS requirements for glazing where relevant 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 for the single-dimensional analysis (Refer to Section B.6 in Appendix B - Residential Methodology Details).

For the modelling work the detached dwellings were assumed to have five occupants, and for the attached and apartment dwellings three occupants were assumed. Standard NatHERS Software Accreditation Protocol occupancy profiles were assumed for each of the archetypes (Refer to Appendix B - Residential Methodology Details).

2.1.1.1 Air Tightness and Infiltration

To ascertain the impact of air tightness improvements/changes, the base case archetype models were developed with air tightness values of 15 ACH that approximately matched the average from blower door survey data made available by the CSIRO in their "House Energy Efficiency Inspections Project" report[7]. 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. 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

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

[7] House Energy Efficiency Inspections Project (Ambrose & Syme 2015, p10).

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 Section B.1 of Appendix B - Residential Methodology Details. The infiltration rates in the three archetype buildings were adjusted in Accurate Sustainability 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)[8]. 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 (at 50 Pa) base case air tightness indicator (which is generally higher than the default assessment rate). 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 base case and increased stringency air tightness values since this parameter has a very significant influence on building heating and cooling energy requirements.

2.1.1.2 Glazing

Several types of glazing options for the multi-dimensional energy analysis were developed for the three building archetypes based on the following.

i) *2016 6-Star Compliant Glazing:* From glazing types available to the modellers in the AccuRate Sustainability default glazing library, six representative glazing types were chosen (refer to Table 2-2 which contains the Solar Heat Gain Coefficient (SHGC) and the heat gain/loss U-value parameters for each glass type) following relevant advice of the TAG and other stakeholders and practitioners. Typical window sizes and window-to-wall ratios (WWR) currently adopted by the industry were implemented. The cheapest representative glazing option for each façade from Glass 1 to Glass 6 from that provided the relevant archetype with a NatHERS 6-Star rating, at default infiltration rate, in all four climate zones, was used for the single-dimensional and multi-dimensional base case energy analysis.

ii) *Improved Performance Glazing*: For the same glazing types and typical window sizes and window-to-wall ratios of the 2016 6-Star Compliant Glazing, a new set of targets for glazing were established based on the principle of using the smallest and cheapest windows while maintaining the required performance stringencies, ventilation and natural lighting requirements of the NCC. This approach was initiated by the EA team and developed in conjunction with UOW modelling work. The targets were a maximum value for U_{TOT} (the area weighted U-value of the glazed and non-glazed component of each façade of the archetype) and *SHGC×WWR* (which are functions of parameters including building archetype, orientation and climate zone). Improved Performance Glazing provides close to the lowest cost in terms of construction in order to meet performance requirements. Improved Performance Glazing was used for the multi-dimensional energy analysis presented in this report (see Section B.6 of Appendix B - Residential Methodology Details for further information).

iii) *High Performance Glazing*: From glazing types available to the modellers in the AccuRate Sustainability default glazing library, four climate optimised glazing types were chosen (refer to Table 2-3) following relevant advice of the TAG and other stakeholders/practitioners. Similar to the “Improved Performance Glazing”, typical window sizes and window-to-wall ratios currently adopted by the industry were implemented. The relevant glazing option for each climate zone was used for the Accelerated deployment Energy Efficiency (EE) scenarios energy analysis (where that option provided improved energy performance over the relevant Improved Performance Glazing option). High Performance Glazing was developed to nominally represent the best in currently available window technologies.

2.1.1.3 Single-Dimensional Base Case

The following list summarises the process by which the Single-Dimensional Analysis archetype glazing base cases were determined.

a) The archetype geometries, including windows sizes, were largely derived from archetypes published in the report by Isaacs [9]. In addition, the modelling team took advice from members of the 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 (which are

[8] 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

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

required in part 3.12 of the Code i.e. >10% Window-to-Floor-Area-Ratio).

b) The same glass type was used on all facades of a given dwelling, regardless of orientation. This approach was taken to reduce the 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 in Section B.6 of Appendix B - Residential Methodology Details. Glass types were chosen following relevant advice of the TAG and other stakeholder/practitioners from the options available in the AccuRate Sustainability default glazing library. The glass types used are listed in Table 2-2 below.

The single-dimensional analysis was undertaken to enable prioritisation of the design parameters for increasing stringencies. Results of the single-dimensional analysis are provided in Appendix C - Residential Energy Modelling Details.

2.1.1.4 Multi-Dimensional Base Case

The sub-set of glazing types from the AccuRate Sustainability default glazing library remained as per the single-dimensional analysis (specified in Table 2-2). However, the glass types used in the models varied from the single-dimensional to account for an increased stringency in performance at the lowest cost via the 'Improved Performance Glazing' targets.

The initial multi-dimensional glazing base case was set using sizes representing the minimum window to floor area ratio for day lighting requirements 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. This approach was later adjusted for consistency to utilising typical WWRs based on new construction data for actual windows, provided by the CSIRO, and adjusting glazing types in each individual cardinal façade orientation on the same basis, i.e. starting with the cheapest glazing, until 6-Star compliance was achieved at the default infiltration rate. In the case of the Apartment archetype glazing was chosen in the same manner noting the NCC does not have a DtS pathway for Class 2 buildings.

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, climate zone or adjust window sizes according to visual transmittance. 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 base case for this analysis was to facilitate the evaluation of improved performance in individual building elements, not to develop the highest performance building possible.

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 were also checked for compliance with the NCC Glazing Calculator (the previous requirement being to comply in at least one cardinal orientation), and all archetypes (including the Apartment) had to achieve at least an 6-Star rating with AccuRate Sustainability at default infiltration, in at least one orientation.

For more details on the glazing selection method for the Multi-Dimensional analysis Base Case models refer to Section B.6 in Appendix B - Residential Methodology Details.

Table 2-2: Representative glazing types from the AccuRate Sustainability default glazing library

Type	U-value (W/m²K)	SHGC	VT	Frame ratio (%)	AccuRate Window Code	Description
Glass 1	6.7	0.70	0.90	0.24	ALM-002-01 A	Aluminium Frame, Single glazing (SG) clear glass
Glass 2	4.6	0.46	0.61	0.19	CMP-002-04 I	Composite frame, SG low solar gain and low-E
Glass 3	4.3	0.53	0.75	0.24	ALM-004-03 A	Al frame, double glazing (DG), air fill, glass: high solar gain, low-E, clear
Glass 4	2.3	0.25	0.45	0.20	PVC-004-04 W	uPVC frame, DG, air fill, glass: low solar gain, low-E, clear
Glass 5	2.9	0.51	0.75	0.24	ATB-006-03 B	Al frame, Thermally broken, DG, argon fill, glass: high solar gain, low-E, clear
Glass 6	2.6	0.53	0.82	0.35	TIM-006-01 W	Timber frame, DG, argon fill, glass: clear, clear

Table 2-3: High performance glazing types from the AWA AccuRate Sustainability All Windows glazing library.

Climate Zone	U-value (W/m²K)	SHGC	VT	AccuRate Window Code	Description
CZ 2	1.22	0.13	0.27	ETD-004-02 W	Cedar Tilt 'n' Turn Window, Triple Glaze, TPS Space 4SB70XL-8Ar-4-8Ar-4ET

CZ 5	1.84	0.50	0.57	MAR-028-09 W*	Clad Ultimate Glider, DG, 4clr/10Ar/4LoE 180
	1.60	0.39	0.71	CTD-004-04-W**	uPVC Fixed Windows, Double Glazed, 4-14-4SB60
CZ 6 & CZ 7	1.73	0.71	0.77	SOV-016-04 W	Single Hung Super Spacer, Double Glaze, 4/14Ar/4TiPS

* used on archetypes with similar heating and cooling demand
** used on archetypes where cooling demand was higher than heating demand

Table 2-4: Maximum DC System Size (kW) for PV Systems

Archetype	Climate Zone	Maximum DC PV System Size (kW)					
		2019 (0 yr)	2022 (3 yr)	2025 (6 yr)	2028 (9 yr)	2031 (12 yr)	2034 (15 yr)
Apartment	CZ 2	0.25	0.27	0.30	0.32	0.35	0.37
	CZ 5	0.25	0.27	0.30	0.32	0.35	0.37
	CZ 6	0.25	0.27	0.30	0.32	0.35	0.37
	CZ 7	0.25	0.27	0.30	0.32	0.35	0.37
Attached	CZ 2	3.75	4.11	4.47	4.83	5.19	5.55
	CZ 5	3.75	4.11	4.47	4.83	5.19	5.55
	CZ 6	3.75	4.11	4.47	4.83	5.19	5.55
	CZ 7	3.75	4.11	4.47	4.83	5.19	5.55
Detached	CZ 2	13.13	14.39	15.65	16.91	18.17	19.43
	CZ 5	13.13	14.39	15.65	16.91	18.17	19.43
	CZ 6	13.13	14.39	15.65	16.91	18.17	19.43
	CZ 7	14.75	16.17	17.58	19.0	20.41	21.83

2.1.2 Optimisation of Multi-Dimensional Scenarios

For the multi-dimensional trajectory analysis, two scenarios were established for each trajectory year of increasing stringency (3 yearly review periods of NCC adjustments): 'conservative' energy efficiency scenarios; and 'accelerated deployment' energy efficiency scenarios.

The 'conservative' energy efficiency scenarios were determined based on increasing stringencies using the outcomes of the single-dimensional analysis to establish which measures provided a positive energy savings performance and a suitable benefit to cost ratio (BCR) based on energy savings and peak power reductions. Measures were then prioritised for each trajectory year based on BCR, with higher BCRs preferred.

The multi-dimensional model optimization process described in this section was repeated for each archetype and each climate zone at each trajectory time step. The optimization process only applied to the 'conservative' energy efficiency scenarios, not the 'accelerated deployment' energy efficiency scenarios.

The purpose of the optimization process was to ensure that the total package of measures produced a building that had a BCR in the target range. This ensured that: opportunities for additional stringency were not lost because whole building BCRs were greater than 1.5; and excessive stringency was not imposed because whole building BCRs were less than 1. This approach of targeting a BCR range of 1-1.5 is consistent with guidelines from the Office of Best Practice Regulation. The steps for optimisation were as follows:

Step 1. Identify the worst and best performing orientations of the archetype in the relevant climate zone using NCC 2016 6-Star compliance (2016 6-Star Compliant glazing applied to the base case model). These orientations became the two 'primary' orientations carried through the optimisation process for each archetype and climate zone (and also used for the 'accelerated deployment' scenarios).

Step 2. Identify the core economic new Code measures (with a BCR>1) from the single-dimensional analyses as a starting point. For the remaining measures, including next step measures for glazing, rank these in terms of descending benefit cost ratio, and determine which, if any, are not to be considered further.

Step 3. Apply the identified core economic new Code measures derived from the single-dimensional analyses relevant to the Improved Performance Glazing archetype, climate zone and time step to the two primary orientation models.

Step 4. Calculate the overall BCR for the economic model using core new Code measures relative to the corresponding NCC 2016 6-Star compliant base case. Select the orientation model with the lowest BCR for the optimization process.

Step 5. If the BCR in Step 4 is in between 1-1.5, proceed to Step 8. Otherwise, if the BCR is greater than 1.5, select the remaining unapplied measure(s) with the highest BCR. Assess the impact of adding this measure.

- If the added measure achieves a result in the region of BCR 1-1.5, incorporate as it stands, or
- If the added measure achieves a BCR less than 1, consider scaling the scope of the measure back (reduced stringency, reduced coverage) to get the BCR in the 1-1.5 region, or
- If the added measure achieves a BCR greater than 1.5, adopt the measure in full, and
- Move to Step 7.

Step 6. If the BCR in Step 4 is less than 1, select the adopted measure with the lowest BCR. Assess the impact of removing this measure.

- If the added measure looks to achieve a result in the region of BCR 1-1.5, remove the measure, or
- If the added measure looks to achieve a BCR greater than 1.5, consider scaling the scope of the measure back (reduced stringency, reduced coverage) to get the BCR in the 1-1.5 region, or
- If it looks to achieve a BCR less than 1, discard the measure in full.

Step 7. Run the adjusted model and return to Step 5.

Step 8. With the model having a total BCR in the region of 1-1.5, apply the optimized measure set to the orientation model with the better original BCR (i.e. the model not selected in Step 4) to complete the process.

At the completion of the optimisation process, the projection forward of economic inputs and assumptions (e.g. electricity prices, technology costs, industry learning rates, etc.) to each of the trajectory years using conservative economic assumptions/inputs was completed as per the steps above, including recalculation of BCRs for existing and additional elements. The result of this analysis was the 'conservative' energy efficiency trajectory scenarios.

'Accelerated deployment' energy efficiency trajectories were produced based on selected high impact measures that had a positive energy impact greater than 2% of regulated energy load, and as a minimum included all the 'conservative' energy efficiency scenario stringency increases for the relevant archetype and climate zone, without further optimization. Accelerated deployment scenarios also included high performance glazing, where applicable, as per Section 2.1.1.2.

2.1.3 Plug-in Appliance Demand

An allowance for residential/domestic plug-in appliances were included in the total household energy use figures for the multi-dimensional analysis. Two levels of the plug-in appliance loads were determined based on occupancy rates (refer to Section B.7 for details), at 4,157 kWh/year (21.95 kWh/m²/yr) for the detached archetype[10], and 3,303 kWh/year (24.56 kWh/m²/yr and 43.22 kWh/m²/yr) for the attached[11] and apartment[12] archetypes. These were summated with the energy results from the heating and cooling modelling, domestic hot water (DHW) requirements, and lighting demand calculations to establish total household energy use. It is noted that the losses from a minimum plug–in appliance load of 1,807 kWh/year (not area adjusted) is included in the AccuRate Sustainability tool calculation of heating and cooling requirements of the archetypes.

2.1.4 PV Sizing and Analysis

The objective of the residential photovoltaic (PV) systems analysis was to determine an appropriate amount of on-site PV to be included in the 'Net Energy Trajectories', based on the maximum cost-effective amount of PV for each building type in each climate zone, with average assumptions about building occupancy, available roofspace and energy consumption patterns.

In this analysis, the PV system was assumed to be installed on the north, east and west roofs of the archetypes with sloped roofs. The maximum space available for the installation of PV systems for each residential archetype was based on roof dimensions, accounting for the slope and orientation of each archetype roof. For the apartment archetype, a portion (relative to the number of units) of the overall building (flat) roof was assumed available. A usable roof space factor of 0.5 (for detached and apartment) and 0.4 (for attached) was used to determine the maximum DC system size in increments of panel size. A mounting factor of 0.5 was also included for the apartment with panels rack-mounted facing north for all apartment orientations.

For each archetype the calculated maximum percentage export permissible while maintaining a BCR>1.25 was determined based on pricing for energy savings (internally used PV generation) and export of local PV generation to the grid, for the net energy performance of the 'conservative' energy efficiency scenarios (up to the maximum DC system size used for the 'accelerated' technologies net energy performance scenarios).

The resulting maximum DC system sizes for the PV systems for each archetype are included in Table 2-4. A panel efficiency increase (due to assumed technology development) of 2.5% every 5 years was assumed over the trajectory period.

2.2 Scenarios

2.2.1 Scenario Design Parameters: What measures were investigated?

A range of energy efficiency design factors/measures were considered by the project team, which were informed by suggestions provided by the TAG. The 'base case' selected for each measure, with the exception of glazing in some cases, was in minimum compliance with the deemed-to-satisfy (DtS) elemental provisions of NCC 2016 for the single-dimensional analysis or NatHERS 6-Star compliant (at default infiltration) for the multi-dimensional base case . These design factors are briefly described below and detailed in Table 2-5 to Table 2-7 for each archetype, showing a maximum of four levels of increased stringency for each design parameter.

[10] Detached house area used 189.39m²
[11] Attached area used 134.50
[12] Apartment area used 76.42m²

Table 2-5 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. Table 2-6 summarises the one-dimensional simulation scenarios designed for the attached archetype. Table 2-7 summarises the one-dimensional simulation scenarios designed for the detached archetype. The simulation results under the Climate Zones 2, 5, 6 and 7 are summarised in Appendix C - Residential Energy Modelling Details.

2.2.1.1 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 ceilings, walls, under floors and floor edges.

2.2.1.2 Surface Colour of Walls and Roof

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

2.2.1.3 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 heating demand, 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 was undertaken separately from the other design parameter analysis due to the complexities of glazing performance (as described above). The objective of this separate work package 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.

2.2.1.4 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 base level used was 15 ACH while the Level 1 stringency for air tightness was estimated to be approximately 6 ACH (at 50Pa)[13] from the Accurate Sustainability simulations of archetypes. 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).

2.2.1.5 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.

2.2.1.6 External Shading

External shading can have an important impact on house energy consumption, particularly in cooling dominated climates. In the 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.

2.2.1.7 HVAC Efficiency

While improvements in building performance will reduce the total heating and cooling load, improving the performance of HVAC systems reduces the actual energy required to service these loads. The highest performing split-system units on the market were analysed compared with the performance of a typical split-system unit.

2.2.1.8 Energy Efficient Appliances and Lighting Controls

The default lighting technology for each archetype was 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.

2.2.1.9 Roof Ventilation

Roof insulation slows the heat transfer between outdoors and living areas via roof materials and roof spaces, it does not prevent heat entering over an extended period of time.

[13] 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

Removal of a component of this heat transfer can be achieved through implementation of additional roof ventilation. This can be via additional vents or ventilation systems. For the single-dimensional analysis the addition of hurricane ventilators was considered as an addition to relevant roof areas to achieve two levels if increased roof ventilation.

2.2.1.10 Roof type

Roof construction type can also influence heat transfer, in addition to better understood mechanisms related to insulation and ventilation. The use of tiles was compared with various configurations (% coverage) of steel deck roofs.

2.2.1.11 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.

2.2.1.12 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[14]. Ceiling fans are included in the baseline model for the Apartment Archetype and as stringency increases for the Attached and Detached Archetypes.

2.2.1.13 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. The available apartment archetype roof area was considered as a portion of the entire roof top based on the number of apartments in the building and similar percentages of roof space available as other archetypes. Grid integration issues have not been considered in the analysis.

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

Table 2-5: Apartment archetype design parameters for single-dimensional and multi-dimensional analysis

Design parameters		Base 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 Km^2/W): 90mm of Glass fibre batts and 18mm Polystyrene extruded. Other walls (R-value 2.9 Km^2/W): 90mm of Glass fibre batts and 27mm Polystyrene extruded	Climate Zone 5 and 6: South wall (R-value 2.9 W/m^2K): 90mm of Glass fibre batts and 27mm Polystyrene extruded Other walls (R-value 3.5 m^2K/W): 90mm of Glass fibre batts and 49mm Polystyrene extruded.	Climate Zone 5 and 6: South wall: (R-value 3.5 m^2K/W): 90mm of Glass fibre batts and 49mm Polystyrene extruded. Other walls (R-value 4.2 m^2K/W): 90mm of Glass fibre batts and 73mm Polystyrene extruded.	Climate Zone 5 and 6: South wall (R-value 4.0 m^2K/W): 90mm of Glass fibre batts and 68mm Polystyrene extruded Other walls (R-value 4.9 m^2K/W): 90mm of Glass fibre batts and 92mm Polystyrene extruded	Climate Zone 5 and 6 : South wall (R-value 4.8 m^2K/W): 90mm of Glass fibre batts and 90mm Polystyrene extruded Other walls (R-value 5.8 m^2K/W): 90mm of Glass fibre batts and 118mm Polystyrene extruded
		Climate Zone 2: South wall (R-value 2.9 m^2K/W): 90mm of Glass fibre batts and 27mm Polystyrene extruded Other walls (R-value 3.4 m^2K/W): 90mm of Glass fibre batts and 47mm Polystyrene extruded	Climate Zone 2: South wall (R-value 3.5 m^2K/W): 90mm of Glass fibre batts and 49mm Polystyrene extruded. Other walls (R-value 4.2 m^2K/W): 90mm of Glass fibre batts and 73mm Polystyrene extruded	Climate Zone 2: South wall (R-value 4.2 m^2K/W): 90mm of Glass fibre batts and 73mm Polystyrene extruded. Other walls (R-value 5 m^2K/W): 90mm of Glass fibre batts and 95mm Polystyrene extruded	Climate Zone 2: South wall (R-value 4.9 m^2K/W): 90mm of Glass fibre batts and 92mm Polystyrene extruded Other walls (R-value 5.8 m^2K/W): 90mm of Glass fibre batts and 118mm Polystyrene extruded	Climate Zone 2: South wall (R-value 5.8 m^2K/W): 90 mm of glass fibre batt and 118mm of polystyrene extruded Other walls (R-value 6.8 m^2K/W): 90mm of Glass fibre batts and 145mm Polystyrene extruded
		Climate Zone 7: (R-value 2.9 m^2K/W): 90mm of Glass fibre batts and 27mm Polystyrene extruded	Climate Zone 7: (R-value 3.5 m^2K/W): 90mm of Glass fibre batts and 49mm Polystyrene extruded	Climate Zone 7: (R-value 4.2 m^2K/W): 90mm of Glass fibre batts and 73mm Polystyrene extruded	Climate Zone 7: (R-value 4.9 m^2K/W): 90mm of Glass fibre batts and 92mm Polystyrene extruded	Climate Zone 7: (R-value 5.8 m^2K/W): 90mm of Glass fibre batts and 118mm 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)				
Floor	Slab Insulation (Edge)	None				
	Slab Insulation (Under)	None				
Window Glazing+	U-value (W/m^2K) and SHGC	Double glazed, Clear glass. U-value=4.8 W/m^2K; 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 Utotal vs. WWRxSHGC analysis (see Section 4.4.4)

Table 2-6: Attached archetype design parameters for single-dimensional and multi-dimensional analysis.

Design parameters		Base 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%				
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
+ Glazing analysis was subsequently superseded by comprehensive Utotal vs. WWRxSHGC analysis (see Section 4.4.4)

Table 2-7: Detached archetype design parameters for single-dimensional and multi-dimensional analysis

Design parameters		Base case	Level 1 Change	Level 2 Change	Level 3 Change	Maximum Change
External wall	Insulation*	R-value 2.8 m²K/W: 90 mm of glass fibre batt and 27mm of polystyrene extruded	R-value 3.5 m²K/W: 90 mm of glass fibre batt and 50mm of polystyrene extruded	R-value 4.2 m²K/W: 90 mm of glass fibre batt and 70mm of polystyrene extruded	R-value 4.9 m²K/W: 90 mm of glass fibre batt and 90mm of polystyrene extruded	R-value 5.6 m²K/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			
	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 and 7: 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 and 7: 250mm of Glass fibre batts, R-value 4.24 m²K/W (Total R-value of roof and ceiling 5.7 m²K/W)	Climate 6 and 7: 305mm of Glass fibre batts, R-value 5.2 m²K/W (Total R-value of roof and ceiling 6.7 m²K/W)	Climate 6 and 7: 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 and 7: 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%				
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
+ Glazing analysis was subsequently superseded by comprehensive Utotal vs. WWRxSHGC analysis (see Section 4.4.4)

2.2.2 Conservative Energy Efficiency Scenarios: What were the cost-effective measures included?

From the optimisation process outlined in Section 2.1.2 the design parameters from the single-dimensional analysis, were combined with energy efficiency improvements to HVAC, DHW and lighting technologies. The resulting 'conservative' energy efficiency scenarios for the multi-dimensional analysis are outlined in Table 2-8, Table 2-9 and Table 2-10 for the apartment, attached and detached archetypes respectively.

Table 2-8: Conservative Energy Efficiency Trajectory Scenarios – Apartment Archetype

Climate Zone	0 years (2019)	5 years (2024)	10 years (2029)	15 years (2034)
CZ 2	Lighting 4 W/m²	Lighting 3.5 W/m²	Lighting 3 W/m²	Lighting 3 W/m²
	DHW L1 (COP 4)	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)
	EER 3.4	EER 3.9	EER 4.4	EER 4.9
	Blower test/seal	Blower test/seal	Blower test/seal	Blower test/seal
	Roller shutters west	Roller shutters west	Roller shutters west	Roller shutters west
	Roller shutters east	Roller shutters east	Roller shutters east	Roller shutters east
	Thermal mass L1 (reverse veneer)	Thermal mass L1 (reverse veneer)	Thermal mass L1 (reverse veneer)	Thermal mass L1 (reverse veneer)
				Roller shutters north
CZ 5	Lighting 4 W/m²	Lighting 3.5 W/m²	Lighting 3 W/m²	Lighting 3 W/m²
	DHW L1 (COP 4)	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)
	EER 3.4	EER 3.9	EER 4.4	EER 4.9
	Blower test/seal	Blower test/seal	Blower test/seal	Blower test/seal
	Wall insulation L4 (R4.9/R5.8)	Wall insulation L4 (R4.9/R5.8)	Wall insulation L4 (R4.9/R5.8)	Wall insulation L4 (R4.9/R5.8)
	Thermal mass L1 (reverse veneer)	Thermal mass L1 (reverse veneer)	Thermal mass L1 (reverse veneer)	Thermal mass L1 (reverse veneer)
	Roller shutters west	Roller shutters west	Roller shutters west	Roller shutters west
				Roller shutters east
CZ 6	Lighting 4 W/m²	Lighting 3.5 W/m²	Lighting 3 W/m²	Lighting 3 W/m²
	DHW L1 (COP 4)	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)
	EER 3.4	EER 3.9	EER 4.4	EER 4.9
	Blower door test/seal	Blower door test/seal	Blower door test/seal	Blower door test/seal
	Roller shutters north	Roller shutters north	Roller shutters north	Roller shutters north
	Roller shutters east	Roller shutters east	Roller shutters east	Roller shutters east
	Wall insulation L1 (R2.9/R3.5)	Wall insulation L3 (R4.2/R5.0)	Wall insulation L4 (R4.9/R5.8)	Wall insulation L4 (R4.9/R5.8)
CZ 7	Lighting 4 W/m²	Lighting 3.5 W/m²	Lighting 3 W/m²	Lighting 3 W/m²
	DHW L1 (COP 4)	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)
	EER 3.4	EER 3.9	EER 4.4	EER 4.9
	Blower door test/seal	Blower door test/seal	Blower door test/seal	Blower door test/seal
	Thermal mass L3 (increase, expose, reverse veneer)	Thermal mass L3 (increase, expose, reverse veneer)	Thermal mass L3 (increase, expose, reverse veneer)	Thermal mass L3 (increase, expose, reverse veneer)
	Wall insulation L3 (R4.9)	Wall insulation L3 (R4.9)	Wall insulation L4 (R5.8)	Wall insulation L4 (R5.8)

Table 2-9: Conservative Energy Efficiency Trajectory Scenarios – Attached Archetype

Climate Zone	0 years (2019)	5 years (2024)	10 years (2029)	15 years (2034)
CZ 2	Lighting 4 W/m²	Lighting 3.5 W/m²	Lighting 3 W/m²	Lighting 3 W/m²
	DHW L1 (COP 4)	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)
	EER 3.4	EER 3.9	EER 4.4	EER 4.9
	Ceiling fans	Ceiling fans	Ceiling fans	Ceiling fans
	Blower test/seal	Blower test/seal	Blower test/seal	Blower test/seal
	Eaves extension east (1.2m)	Eaves extension east (1.2m)	Eaves extension east (1.2m)	Eaves extension east (1.2m)
	Eave extension west (1.2m)	Eave extension west (1.2m)	Eave extension west (1.2m)	Eave extension west (1.2m)
	Slab edge (R1.5)	Slab edge (R1.5)	Slab edge (R1.5)	Slab edge (R1.5)
	Ceiling insulation L4 (R10.1)	Ceiling insulation L4 (R10.1)	Ceiling insulation L4 (R10.1)	Ceiling insulation L4 (R10.1)
		Roller shutters west	Roller shutters west	Roller shutters west
				Roller shutters east
CZ 5	Lighting 4 W/m²	Lighting 3.5 W/m²	Lighting 3 W/m²	Lighting 3 W/m²
	DHW L1 (COP 4)	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)
	EER 3.4	EER 3.9	EER 4.4	EER 4.9

Climate Zone	0 years (2019)	5 years (2024)	10 years (2029)	15 years (2034)
	Ceiling fans	Ceiling fans	Ceiling fans	Ceiling fans
	Blower test/seal	Blower test/seal	Blower test/seal	Blower test/seal
	Slab edge insulation (R1.5)	Slab edge insulation (R1.5)	Slab edge insulation (R1.5)	Slab edge insulation (R1.5)
			Ceiling insulation L4 (R10.1)	Ceiling insulation L4 (R10.1)
				Wall insulation L3 (R4.9)
CZ 6	Lighting 4 W/m²	Lighting 3.5 W/m²	Lighting 3 W/m²	Lighting 3 W/m²
	DHW L1 (COP 4)	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)
	EER 3.4	EER 3.9	EER 4.4	EER 4.9
	Blower door test/seal	Blower door test/seal	Blower door test/seal	Blower door test/seal
	Slab edge insulation R1.5	Slab edge insulation R1.5	Slab edge insulation R1.5	Slab edge insulation R1.5
	Ceiling insulation L4 (R10.1)	Ceiling L4 (R10.1)	Ceiling L4 (R10.1)	Ceiling L4 (R10.1)
	Ceiling fans	Ceiling fans	Ceiling fans	Ceiling fans
	Under slab L2 (R2)	Under slab L2 (R2)	Under slab L2 (R2)	Under slab L2 (R2)
		Wall insulation L4 (R5.8)	Wall insulation L4 (R5.8)	Wall insulation L4 (R5.8)
				Roller shutters west
CZ 7	Lighting 4 W/m²	Lighting 3.5 W/m²	Lighting 3 W/m²	Lighting 3 W/m²
	DHW L1 (COP 4)	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)
	EER 3.4	EER 3.9	EER 4.4	EER 4.9
	Blower door test/seal	Blower door test/seal	Blower door test/seal	Blower door test/seal
	Slab edge insulation R1.5	Slab edge insulation R1.5	Slab edge insulation R1.5	Slab edge insulation R1.5
	Roller shutters west	Roller shutters west	Roller shutters west	Roller shutters west
	Ceiling insulation L4 (R10.1)	Ceiling insulation L4 (R10.1)	Ceiling insulation L4 (R10.1)	Ceiling insulation L4 (R10.1)
	Under slab L2 (R2)	Under slab L2 (R2)	Under slab L2 (R2)	Under slab L2 (R2)
	Wall insulation L1 (R2.9)	Wall insulation L4 (R5.8)	Wall insulation L4 (R5.8)	Wall insulation L4 (R5.8)
			Roller shutters east	Thermal mass L3 (increase, expose, reverse veneer)

Table 2-10: Conservative Energy Efficiency Trajectory Scenarios – Detached Archetype

Climate Zone	0 years (2019)	5 years (2024)	10 years (2029)	15 years (2034)
CZ 2	Lighting 4 W/m²	Lighting 3.5 W/m²	Lighting 3 W/m²	Lighting 3 W/m²
	DHW L1 (COP 4)	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)
	EER 3.4	EER 3.9	EER 4.4	EER 4.9
	Blower door test/seal	Blower door test/seal	Blower door test/seal	Blower door test/seal
	Ceiling insulation L4 (R5.8)	Ceiling insulation L4 (R5.8)	Ceiling insulation L4 (R5.8)	Ceiling insulation L4 (R5.8)
	Ceiling fans	Ceiling fans	Ceiling fans	Ceiling fans
			Roller shutter north	Roller shutter north
			Roller shutter east	Roller shutter east
CZ 5	Lighting 4 W/m²	Lighting 3.5 W/m²	Lighting 3 W/m²	Lighting 3 W/m²
	DHW L1 (COP 4)	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)
	EER 3.4	EER 3.9	EER 4.4	EER 4.9
	Blower door test/seal	Blower door test/seal	Blower door test/seal	Blower door test/seal
	Ceiling insulation L4 (R6.9)	Ceiling insulation L4 (R6.9)	Ceiling insulation L4 (R6.9)	Ceiling insulation L4 (R6.9)
		Ceiling fans	Ceiling fans	Ceiling fans
			Slab edge (R1.5)	Slab edge (R1.5)
			Roller shutters west	Roller shutters west
CZ 6	Lighting 4 W/m²	Lighting 3.5 W/m²	Lighting 3 W/m²	Lighting 3 W/m²
	DHW L1 (COP 4)	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)
	EER 3.4	EER 3.9	EER 4.4	EER 4.9
	Blower door test/seal	Blower door test/seal	Blower door test/seal	Blower door test/seal
	Slab edge insulation R1.5	Slab edge insulation R1.5	Slab edge insulation R1.5	Slab edge insulation R1.5
	Ceiling insulation L4 (R6.9)	Ceiling insulation L4 (R6.9)	Ceiling insulation L4 (R6.9)	Ceiling insulation L4 (R6.9)
	Ceiling fans	Ceiling fans	Ceiling fans	Ceiling fans
	Roller shutters north	Roller shutters north	Roller shutters north	Roller shutters north
			Roller shutters east	Roller shutters east
			Roller shutters west	Roller shutters west

Climate Zone	0 years (2019)	5 years (2024)	10 years (2029)	15 years (2034)
CZ 7	Lighting 4 W/m²	Lighting 3.5 W/m²	Lighting 3 W/m²	Lighting 3 W/m²
	DHW L1 (COP 4)	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)
	EER 3.4	EER 3.9	EER 4.4	EER 4.9
	Blower door test/seal	Blower door test/seal	Blower door test/seal	Blower door test/seal
	Ceiling insulation (R6.9)	Ceiling insulation (R6.9)	Ceiling insulation (R6.9)	Ceiling insulation (R6.9)
	Slab edge insulation R1.5	Slab edge insulation R1.5	Slab edge insulation R1.5	Slab edge insulation R1.5
	Underslab L3 (R3)	Underslab L3 (R3)	Underslab L3 (R3)	Underslab L3 (R3)
	Roller shutters west	Roller shutters west	Roller shutters west	Roller shutters west
		Wall insulation L3 (R5.2)	Wall insulation L4 (R5.8)	Wall insulation L4 (R5.8)
			Roller shutters east	Roller shutters east

2.2.3 Accelerated Deployment Energy Efficiency Scenarios: What were the high impact measures included?

The 'Accelerated Deployment' energy efficiency scenarios implemented for the multi-dimensional analysis are outlined in Table 2-11, Table 2-12 and Table 2-13 for the apartment, attached and detached archetypes respectively.

Table 2-11: Accelerated Deployment Energy Efficiency Trajectory Scenarios – Apartment Archetype

Climate Zone	0 years (2019)	5 years (2024)	10 years (2029)	15 years (2034)
CZ 2	Lighting 3.5 W/m²	Lighting 3 W/m²	Lighting 3 W/m²	Lighting 3 W/m²
	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)	DHW L2 (COP 5.0)	DHW L2 (COP 5.0)
	EER 3.9	EER 4.4	EER 4.9	EER 5.4
	Blower door test/seal	Blower test/seal	Blower test/seal	Blower test/seal
	Roller shutters west	Roller shutters west	Roller shutters west	Roller shutters west
	Roller shutters east	Roller shutters east	Roller shutters east	Roller shutters east
	Roller shutters north	Roller shutters north	Roller shutters north	Roller shutters north
	Thermal mass L3 (increase, expose, reverse veneer)	Thermal mass L3 (increase, expose, reverse veneer)	Thermal mass L3 (increase, expose, reverse veneer)	Thermal mass L3 (increase, expose, reverse veneer)
	Wall insulation L4 (R5.8/R6.8)	Wall insulation L4 (R5.8/R6.8)	Wall insulation L4 (R5.8/R6.8)	Wall insulation L4 (R5.8/R6.8)
	Eave extension west (1.2m)	Eave extension west (1.2m)	Eave extension west (1.2m)	Eave extension west (1.2m)
	Eave extension east (1.2m)	Eave extension east (1.2m)	Eave extension east (1.2m)	Eave extension east (1.2m)
	Eave extension north (1.2m)	Eave extension north (1.2m)	Eave extension north (1.2m)	Eave extension north (1.2m)
CZ 5	Lighting 3.5 W/m²	Lighting 3 W/m²	Lighting 3 W/m²	Lighting 3 W/m²
	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)	DHW L2 (COP 5.0)	DHW L2 (COP 5.0)
	EER 3.9	EER 4.4	EER 4.9	EER 5.4
	Blower test/seal	Blower test/seal	Blower test/seal	Blower test/seal
	Wall insulation L4 (R4.9/R5.8)	Wall insulation L4 (R4.9/R5.8)	Wall insulation L4 (R4.9/R5.8)	Wall insulation L4 (R4.9/R5.8)
	Thermal mass L3 (increase, expose, reverse veneer)	Thermal mass L3 (increase, expose, reverse veneer)	Thermal mass L3 (increase, expose, reverse veneer)	Thermal mass L3 (increase, expose, reverse veneer)
	Roller shutters west	Roller shutters west	Roller shutters west	Roller shutters west
	Roller shutters east	Roller shutters east	Roller shutters east	Roller shutters east
	Roller shutters north	Roller shutters north	Roller shutters north	Roller shutters north
	Eave extension west (1.2m)	Eave extension west (1.2m)	Eave extension west (1.2m)	Eave extension west (1.2m)
	Eave extension east (1.2m)	Eave extension east (1.2m)	Eave extension east (1.2m)	Eave extension east (1.2m)
CZ 6	Lighting 3.5 W/m²	Lighting 3 W/m²	Lighting 3 W/m²	Lighting 3 W/m²
	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)	DHW L2 (COP 5.0)	DHW L2 (COP 5.0)
	EER 3.9	EER 4.4	EER 4.9	EER 5.4
	Blower door test/seal	Blower door test/seal	Blower door test/seal	Blower door test/seal
	Roller shutters north	Roller shutters north	Roller shutters north	Roller shutters north
	Roller shutters east	Roller shutters east	Roller shutters east	Roller shutters east
	Roller shutters west	Roller shutters west	Roller shutters west	Roller shutters west
	Wall insulation L4 (R4.9/R5.8)	Wall insulation L4 (R4.9/R5.8)	Wall insulation L4 (R4.9/R5.8)	Wall insulation L4 (R4.9/R5.8)
	Thermal mass L3 (increase, expose, reverse veneer)	Thermal mass L3 (increase, expose, reverse veneer)	Thermal mass L3 (increase, expose, reverse veneer)	Thermal mass L3 (increase, expose, reverse veneer)

CZ 7	Lighting 3.5 W/m²	Lighting 3 W/m²	Lighting 3 W/m²	Lighting 3 W/m²
	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)	DHW L2 (COP 5.0)	DHW L2 (COP 5.0)
	EER 3.9	EER 4.4	EER 4.9	EER 5.4
	Blower door test/seal	Blower door test/seal	Blower door test/seal	Blower door test/seal
	Thermal mass L3 (increase, expose, reverse veneer)	Thermal mass L3 (increase, expose, reverse veneer)	Thermal mass L3 (increase, expose, reverse veneer)	Thermal mass L3 (increase, expose, reverse veneer)
	Wall insulation L4 (R4.9/R5.8)	Wall insulation L4 (R4.9/R5.8)	Wall insulation L4 (R4.9/R5.8)	Wall insulation L4 (R4.9/R5.8)
	Roller shutters west	Roller shutters west	Roller shutters west	Roller shutters west
	Roller shutters north	Roller shutters north	Roller shutters north	Roller shutters north
	Roller shutters east	Roller shutters east	Roller shutters east	Roller shutters east

Table 2-12: Accelerated Deployment Energy Efficiency Trajectory Scenarios – Attached Archetype

Climate Zone	0 years (2019)	5 years (2024)	10 years (2029)	15 years (2034)
CZ 2	Lighting 3.5 W/m²	Lighting 3 W/m²	Lighting 3 W/m²	Lighting 3 W/m²
	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)	DHW L2 (COP 5.0)	DHW L2 (COP 5.0)
	EER 3.9	EER 4.4	EER 4.9	EER 5.4
	Ceiling fans	Ceiling fans	Ceiling fans	Ceiling fans
	Blower test/seal	Blower test/seal	Blower test/seal	Blower test/seal
	Eave extension east (1.2m)	Eave extension east (1.2m)	Eave extension east (1.2m)	Eave extension east (1.2m)
	Eave extension west (1.2m)	Eave extension west (1.2m)	Eave extension west (1.2m)	Eave extension west (1.2m)
	Slab edge (R1.5)	Slab edge (R1.5)	Slab edge (R1.5)	Slab edge (R1.5)
	Ceiling insulation L4 (R10.1)	Ceiling insulation L4 (R10.1)	Ceiling insulation L4 (R10.1)	Ceiling insulation L4 (R10.1)
	Roller shutters west	Roller shutters west	Roller shutters west	Roller shutters west
	Roller shutters east	Roller shutters east	Roller shutters east	Roller shutters east
	Wall insulation L4 (R5.8)	Wall insulation L4 (R5.8)	Wall insulation L4 (R5.8)	Wall insulation L4 (R5.8)
	Thermal masss L3 (increase, expose, reverse veneer)	Thermal masss L3 (increase, expose, reverse veneer)	Thermal masss L3 (increase, expose, reverse veneer)	Thermal masss L3 (increase, expose, reverse veneer)
	Roof openness L2 (highly ventilated)	Roof openness L2 (highly ventilated)	Roof openness L2 (highly ventilated)	Roof openness L2 (highly ventilated)
CZ 5	Lighting 3.5 W/m²	Lighting 3 W/m²	Lighting 3 W/m²	Lighting 3 W/m²
	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)	DHW L2 (COP 5.0)	DHW L2 (COP 5.0)
	EER 3.9	EER 4.4	EER 4.9	EER 5.4
	Ceiling Fans	Ceiling Fans	Ceiling Fans	Ceiling Fans
	Blower test/seal	Blower test/seal	Blower test/seal	Blower test/seal
	Slab edge insulation (R1.5)	Slab edge insulation (R1.5)	Slab edge insulation (R1.5)	Slab edge insulation (R1.5)
	Ceiling insulation L4 (R10.1)	Ceiling insulation L4 (R10.1)	Ceiling insulation L4 (R10.1)	Ceiling insulation L4 (R10.1)
	Wall insulation L4 (R5.8)	Wall insulation L4 (R5.8)	Wall insulation L4 (R5.8)	Wall insulation L4 (R5.8)
	Thermal mass L3 (increase, expose, reverse veneer)	Thermal mass L3 (increase, expose, reverse veneer)	Thermal mass L3 (increase, expose, reverse veneer)	Thermal mass L3 (increase, expose, reverse veneer)
	Roller shutters west	Roller shutters west	Roller shutters west	Roller shutters west
	Roller shutters east	Roller shutters east	Roller shutters east	Roller shutters east
	Roller shutters north	Roller shutters north	Roller shutters north	Roller shutters north
	Eave extension east (1.2m)	Eave extension east (1.2m)	Eave extension east (1.2m)	Eave extension east (1.2m)
	Eave extension west (1.2m)	Eave extension west (1.2m)	Eave extension west (1.2m)	Eave extension west (1.2m)
	Roof openess L2 (highly ventilated)	Roof openess L2 (highly ventilated)	Roof openess L2 (highly ventilated)	Roof openess L2 (highly ventilated)
CZ 6	Lighting 3.5 W/m²	Lighting 3 W/m²	Lighting 3 W/m²	Lighting 3 W/m²
	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)	DHW L2 (COP 5.0)	DHW L2 (COP 5.0)
	EER 3.9	EER 4.4	EER 4.9	EER 5.4
	Blower door test/seal	Blower door test/seal	Blower door test/seal	Blower door test/seal
	Slab edge insulation R1.5	Slab edge insulation R1.5	Slab edge insulation R1.5	Slab edge insulation R1.5
	Ceiling insulation L4 (R10.1)	Ceiling insulation L4 (R10.1)	Ceiling insulation L4 (R10.1)	Ceiling insulation L4 (R10.1)
	Ceiling fans	Ceiling fans	Ceiling fans	Ceiling fans
	Under slab L2 (R2)	Under slab L2 (R2)	Under slab L2 (R2)	Under slab L2 (R2)
	Wall insulation L4 (R5.8)	Wall insulation L4 (R5.8)	Wall insulation L4 (R5.8)	Wall insulation L4 (R5.8)
	Roller shutters west	Roller shutters west	Roller shutters west	Roller shutters west
	Roller shutters east	Roller shutters east	Roller shutters east	Roller shutters east
	Roller shutters north	Roller shutters north	Roller shutters north	Roller shutters north
	Eave extension east (1.2m)	Eave extension east (1.2m)	Eave extension east (1.2m)	Eave extension east (1.2m)

Climate Zone	0 years (2019)	5 years (2024)	10 years (2029)	15 years (2034)
	Thermal mass L3 (increase, expose, reverse veneer)	Thermal mass L3 (increase, expose, reverse veneer)	Thermal mass L3 (increase, expose, reverse veneer)	Thermal mass L3 (increase, expose, reverse veneer)
CZ 7	Lighting 3.5 W/m²	Lighting 3 W/m²	Lighting 3 W/m²	Lighting 3 W/m²
	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)	DHW L2 (COP 5.0)	DHW L2 (COP 5.0)
	EER 3.9	EER 4.4	EER 4.9	EER 5.4
	Blower door test/seal	Blower door test/seal	Blower door test/seal	Blower door test/seal
	Slab edge insulation R1.5	Slab edge insulation R1.5	Slab edge insulation R1.5	Slab edge insulation R1.5
	Roller shutters west	Roller shutters west	Roller shutters west	Roller shutters west
	Ceiling insulation L4 (R10.1)	Ceiling insulation L4 (R10.1)	Ceiling insulation L4 (R10.1)	Ceiling insulation L4 (R10.1)
	Under slab L2 (R2)	Under slab L2 (R2)	Under slab L2 (R2)	Under slab L2 (R2)
	Wall insulation L4 (R5.8)	Wall insulation L4 (R5.8)	Wall insulation L4 (R5.8)	Wall insulation L4 (R5.8)
	Roller shutters east	Roller shutters east	Roller shutters east	Roller shutters east
	Roller shutters north	Roller shutters north	Roller shutters north	Roller shutters north
	Thermal mass L3 (increase, expose, reverse veneer)	Thermal mass L3 (increase, expose, reverse veneer	Thermal mass L3 (increase, expose, reverse veneer)	Thermal mass L3 (increase, expose, reverse veneer)

Table 2-13: Accelerated Deployment Energy Efficiency Trajectory Scenarios – Detached Archetype

Climate Zone	0 years (2019)	5 years (2024)	10 years (2029)	15 years (2034)
CZ 2	Lighting 3.5 W/m²	Lighting 3 W/m²	Lighting 3 W/m²	Lighting 3 W/m²
	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)	DHW L2 (COP 5.0)	DHW L2 (COP 5.0)
	EER 3.9	EER 4.4	EER 4.9	EER 5.4
	Blower door test/seal	Blower door test/seal	Blower door test/seal	Blower door test/seal
	Ceiling insulation L4 (R5.8)	Ceiling insulation L4 (R5.8)	Ceiling insulation L4 (R5.8)	Ceiling insulation L4 (R5.8)
	Ceiling fans	Ceiling fans	Ceiling fans	Ceiling fans
	Roller shutters north	Roller shutters north	Roller shutters north	Roller shutters north
	Roller shutters east	Roller shutters east	Roller shutters east	Roller shutters east
	Roller shutters west	Roller shutters west	Roller shutters west	Roller shutters west
	Wall insulation L4 (R5.6)	Wall insulation L4 (R5.6)	Wall insulation L4 (R5.6)	Wall insulation L4 (R5.6)
	Thermal mass L2 (reverse veneer)	Thermal mass L2 (reverse veneer)	Thermal mass L2 (reverse veneer)	Thermal mass L2 (reverse veneer)
	Eave extension east (1.2m)	Eave extension east (1.2m)	Eave extension east (1.2m)	Eave extension east (1.2m)
	Eave extension west (1.2m)	Eave extension west (1.2m)	Eave extension west (1.2m)	Eave extension west (1.2m)
	Eave extension north (1.2m)	Eave extension north (1.2m)	Eave extension north (1.2m)	Eave extension north (1.2m)
CZ 5	Lighting 3.5 W/m²	Lighting 3 W/m²	Lighting 3 W/m²	Lighting 3 W/m²
	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)	DHW L2 (COP 5.0)	DHW L2 (COP 5.0)
	EER 3.9	EER 4.4	EER 4.9	EER 5.4
	Blower door test/seal	Blower door test/seal	Blower door test/seal	Blower door test/seal
	Ceiling insulation L4 (R5.8)	Ceiling insulation L4 (R5.8)	Ceiling insulation L4 (R5.8)	Ceiling insulation L4 (R5.8)
	Ceiling fans	Ceiling fans	Ceiling fans	Ceiling fans
	Slab edge (R1.5)	Slab edge (R1.5)	Slab edge (R1.5)	Slab edge (R1.5)
	Roller shutters west	Roller shutters west	Roller shutters west	Roller shutters west
	Roller shutters east	Roller shutters east	Roller shutters east	Roller shutters east
	Roller shutters north	Roller shutters north	Roller shutters north	Roller shutters north
	Wall insulation L4 (R5.6)	Wall insulation L4 (R5.6)	Wall insulation L4 (R5.6)	Wall insulation L4 (R5.6)
	Thermal mass L2 (reverse veneer)	Thermal mass L2 (reverse veneer)	Thermal mass L2 (reverse veneer)	Thermal mass L2 (reverse veneer)
	Eave extension east (1.2m)	Eave extension east (1.2m)	Eave extension east (1.2m)	Eave extension east (1.2m)
	Eave extension west (1.2m)	Eave extension west (1.2m)	Eave extension west (1.2m)	Eave extension west (1.2m)
	Eave extension north (1.2m)	Eave extension north (1.2m)	Eave extension north (1.2m)	Eave extension north (1.2m)
	Roof type (tiles)	Roof type (tiles)	Roof type (tiles)	Roof type (tiles)
CZ 6	Lighting 3.5 W/m²	Lighting 3 W/m²	Lighting 3 W/m²	Lighting 3 W/m²
	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)	DHW L2 (COP 5.0)	DHW L2 (COP 5.0)
	EER 3.9	EER 4.4	EER 4.9	EER 5.4
	Blower door test/seal	Blower door test/seal	Blower door test/seal	Blower door test/seal
	Slab edge insulation R1.5	Slab edge insulation R1.5	Slab edge insulation R1.5	Slab edge insulation R1.5

Climate Zone	0 years (2019)	5 years (2024)	10 years (2029)	15 years (2034)
	Ceiling insulation L4 (R6.9)	Ceiling insulation L4 (R6.9)	Ceiling insulation L4 (R6.9)	Ceiling insulation L4 (R6.9)
	Ceiling fans	Ceiling fans	Ceiling fans	Ceiling fans
	Roller shutters north	Roller shutters north	Roller shutters north	Roller shutters north
	Roller shutters east	Roller shutters east	Roller shutters east	Roller shutters east
	Roller shutters west	Roller shutters west	Roller shutters west	Roller shutters west
	Wall insulation L4 (R5.6)	Wall insulation L4 (R5.6)	Wall insulation L4 (R5.6)	Wall insulation L4 (R5.6)
	Thermal mass L3 (increase, expose, reverse veneer)	Thermal mass L3 (increase, expose, reverse veneer)	Thermal mass L3 (increase, expose, reverse veneer)	Thermal mass L3 (increase, expose, reverse veneer)
CZ 7	Lighting 3.5 W/m²	Lighting 3 W/m²	Lighting 3 W/m²	Lighting 3 W/m²
	DHW L2 (COP 4.5)	DHW L2 (COP 4.5)	DHW L2 (COP 5.0)	DHW L2 (COP 5.0)
	EER 3.9	EER 4.4	EER 4.9	EER 5.4
	Blower door test/seal	Blower door test/seal	Blower door test/seal	Blower door test/seal
	Ceiling insulation (R6.9)	Ceiling insulation (R6.9)	Ceiling insulation (R6.9)	Ceiling insulation (R6.9)
	Slab edge insulation R1.5	Slab edge insulation R1.5	Slab edge insulation R1.5	Slab edge insulation R1.5
	Under slab L4 (R4)	Under slab L4 (R4)	Under slab L4 (R4)	Under slab L4 (R4)
	Roller shutters west	Roller shutters west	Roller shutters west	Roller shutters west
	Roller shutters east	Roller shutters east	Roller shutters east	Roller shutters east
	Roller shutters north	Roller shutters north	Roller shutters north	Roller shutters north
	Wall insulation L4 (R5.6)	Wall insulation L4 (R5.6)	Wall insulation L4 (R5.6)	Wall insulation L4 (R5.6)
	Thermal mass L2 (reverse brick veneer)	Thermal mass L2 (reverse brick veneer)	Thermal mass L2 (reverse brick veneer)	Thermal mass L2 (reverse brick veneer)

2.3 Benefit Cost Ratios

The residential benefit-cost ratios for the multi-dimensional analysis are presented in

Table 2-14 and Table 2-15 below. These tables contain the cost benefit results from the tuned scenarios (for the orientations chosen for the tuning process) presented in Table 2-8 to Table 2-10 (conservative) and Table 2-11 to Table 2-13 (accelerated). 0 years refers to what's cost effective in 2019 and 15 years refers to what will be cost effective in 2034 (refer 1.2). For the conservative trajectory, the BCRs for the years 2019, 2024, 2029 and 2034 were taken from the orientation which have the BCR between 1 and 1.5 for each archetype in the same climate zone. In the case where the BCRs were between 1 and 1.5 for both orientations, the one closer to 1.25 was chosen. On the other hand, for the accelerated deployment trajectory the BCRs are the average of the BCRs for the two orientations. The BCRs for the years 2022, 2025, 2028 and 2031 are the interpolations of the BCRs for the years 2019, 2024, 2029 and 2034. A comprehensive table including capital costs, network savings, energy savings and benefit cost ratios without network adjustments are presented in Appendix D - Residential Multi-Dimensional Economic Details. For explanation on how these are calculated, refer to D.1 Benefit Cost Analysis.

Table 2-14: Conservative multi-dimensional benefit-cost analysis results.

Economic Measures' Benefit Cost Ratios									
CZ	Archetype	0 yrs (2019)	3 yrs (2022)	5 yrs (2024)	6 yrs (2025)	9 yrs (2028)	10 yrs (2029)	12 yrs (2031)	15 yrs (2034)
2	Attached	1.31	1.13	1.00	1.06	1.25	1.31	1.27	1.19
2	Detached House	1.49	1.24	1.08	1.15	1.38	1.45	1.30	1.06
2	Apartment	1.45	1.50	1.54	1.45	1.20	1.11	1.16	1.23
5	Attached	1.16	1.08	1.02	1.03	1.06	1.07	1.14	1.24
5	Detached House	1.02	1.12	1.19	1.15	1.01	0.96	1.04	1.15
5	Apartment	1.16	1.09	1.05	1.12	1.34	1.41	1.37	1.31
6	Attached	1.13	1.11	1.09	1.11	1.17	1.19	1.20	1.21
6	Detached House	1.06	1.15	1.22	1.19	1.13	1.10	1.18	1.30
6	Apartment	1.43	1.37	1.33	1.35	1.40	1.42	1.52	1.66
7	Attached	1.29	1.30	1.31	1.26	1.11	1.06	1.06	1.06

7	Detached House	1.36	1.26	1.20	1.19	1.17	1.16	1.24	1.37
7	Apartment	1.32	1.32	1.32	1.30	1.22	1.20	1.27	1.37

Table 2-15: Accelerated multi-dimensional benefit-cost analysis results.

Accelerated Technology Measures' Benefit Cost Ratios									
CZ	Archetype	0 yrs (2019)	3 yrs (2022)	5 yrs (2024)	6 yrs (2025)	9 yrs (2028)	10 yrs (2029)	12 yrs (2031)	15 yrs (2034)
2	Attached	0.13	0.14	0.15	0.16	0.18	0.18	0.19	0.20
2	Detached House	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.18
2	Apartment	0.14	0.16	0.17	0.18	0.20	0.21	0.22	0.23
5	Attached	0.12	0.14	0.15	0.15	0.17	0.18	0.18	0.19
5	Detached House	0.11	0.12	0.13	0.14	0.15	0.16	0.16	0.17
5	Apartment	0.20	0.22	0.23	0.24	0.28	0.29	0.30	0.32
6	Attached	0.25	0.27	0.29	0.30	0.33	0.34	0.36	0.39
6	Detached House	0.16	0.18	0.20	0.20	0.22	0.23	0.24	0.26
6	Apartment	0.38	0.41	0.43	0.44	0.49	0.51	0.53	0.57
7	Attached	0.30	0.33	0.35	0.37	0.41	0.42	0.44	0.48
7	Detached House	0.32	0.35	0.38	0.39	0.43	0.44	0.46	0.49
7	Apartment	0.40	0.44	0.46	0.48	0.53	0.54	0.57	0.61

2.4 Energy Efficiency Trajectories: Energy Consumption after implementation of energy efficiency measures

The 'Conservative' energy efficiency trajectory total household energy results are presented in

Table 2-16 to Table 2-18 for Climate Zones 2, 5, 6 and 7 for apartment, attached and detached archetypes. These results are the total household energy consumption (heating and cooling, domestic hot water, lighting and plug appliance demand) after implementation of the measures outlined in Table 2-8 to Table 2-10 above. Figure 4 illustrates the gradual decrease in energy consumption over the period analysed through application of the 'Conservative' energy efficiency trajectory scenarios.

The 'Accelerated Deployment' energy efficiency trajectory total household energy results are presented in Table 2-19 to Table 2-21 for Climate Zones 2, 5, 6 and 7 for apartment, attached and detached archetypes. These results are the total household energy consumption after implementation of the measures outlined in Table 2-11 to Table 2-13 above. Figure 5 illustrates the gradual decrease in energy consumption over the period analysed through application of the 'Accelerated Deployment' energy efficiency trajectory scenarios.

Table 2-16: Conservative Energy Efficiency Trajectory Household Energy (Heating and Cooling + DHW + Lighting + Plug Appliances)

Climate Zone	Archetype	Base Case (kWh/m²/yr)	2019 (kWh/m²/yr)	2022 (kWh/m²/yr)	2025 (kWh/m²/yr)	2028 (kWh/m²/yr)	2031 (kWh/m²/yr)	2034 (kWh/m²/yr)
CZ 2	Apartment	63.4	57.0	56.0	55.2	54.9	54.7	54.6
	Attached	41.3	36.0	35.2	34.5	34.1	34.0	33.9
	Detached	37.4	32.6	31.8	31.2	30.7	30.6	30.5
CZ 5	Apartment	63.1	56.6	55.7	54.9	54.6	54.4	54.3
	Attached	40.3	35.6	34.9	34.3	34.0	33.8	33.7
	Detached	37.2	32.5	31.5	30.7	30.3	30.1	30.0
CZ 6	Apartment	73.3	60.0	58.6	57.6	57.0	56.7	56.5
	Attached	47.3	38.0	36.9	36.0	35.5	35.3	35.1
	Detached	45.6	35.7	34.7	33.8	33.2	32.9	32.6
CZ 7	Apartment	77.0	60.2	59.0	58.0	57.4	57.0	56.8
	Attached	50.3	39.5	38.2	37.3	36.7	36.4	36.1

	Detached	50.5	37.2	35.6	34.3	33.6	33.2	33.0

Table 2-17: Conservative Energy Efficiency Trajectory Peak Heating Power

Climate Zone	Archetype	Base Case (kW)	2019 (kW)	2022 (kW)	2025 (kW)	2028 (kW)	2031 (kW)	2034 (kW)
CZ 2	Apartment	0.77	0.20	0.19	0.17	0.16	0.15	0.14
	Attached	0.89	0.36	0.29	0.24	0.22	0.20	0.19
	Detached	1.92	0.88	0.81	0.75	0.69	0.65	0.61
CZ 5	Apartment	1.09	0.27	0.25	0.23	0.21	0.20	0.19
	Attached	1.28	0.50	0.47	0.43	0.39	0.35	0.30
	Detached	2.30	0.96	0.89	0.81	0.71	0.64	0.60
CZ 6	Apartment	1.65	0.69	0.62	0.55	0.51	0.47	0.44
	Attached	2.07	0.83	0.71	0.62	0.58	0.54	0.51
	Detached	3.66	1.96	1.81	1.67	1.55	1.45	1.36
CZ 7	Apartment	2.01	0.66	0.61	0.56	0.51	0.48	0.45
	Attached	2.48	1.08	0.96	0.87	0.81	0.73	0.64
	Detached	4.85	2.55	2.21	1.93	1.79	1.67	1.56

Table 2-18: Conservative Energy Efficiency Trajectory Peak Cooling Power

Climate Zone	Archetype	Base Case (kW)	2019 (kW)	2022 (kW)	2025 (kW)	2028 (kW)	2031 (kW)	2034 (kW)
CZ 2	Apartment	1.76	0.73	0.67	0.62	0.58	0.53	0.49
	Attached	2.28	1.41	1.29	1.17	1.09	1.02	0.95
	Detached	3.33	2.36	2.18	2.04	2.01	1.92	1.80
CZ 5	Apartment	1.71	0.86	0.80	0.74	0.68	0.61	0.53
	Attached	2.46	1.45	1.34	1.23	1.12	1.04	0.98
	Detached	3.83	1.86	1.79	1.67	1.46	1.34	1.25
CZ 6	Apartment	2.00	1.08	0.95	0.82	0.70	0.64	0.60
	Attached	2.05	1.25	1.19	1.12	1.04	1.00	0.98
	Detached	3.15	1.52	1.41	1.28	1.16	1.07	1.00
CZ 7	Apartment	2.44	0.60	0.55	0.51	0.47	0.44	0.41
	Attached	1.98	0.83	0.74	0.67	0.63	0.55	0.45
	Detached	3.89	1.71	1.48	1.31	1.24	1.17	1.10

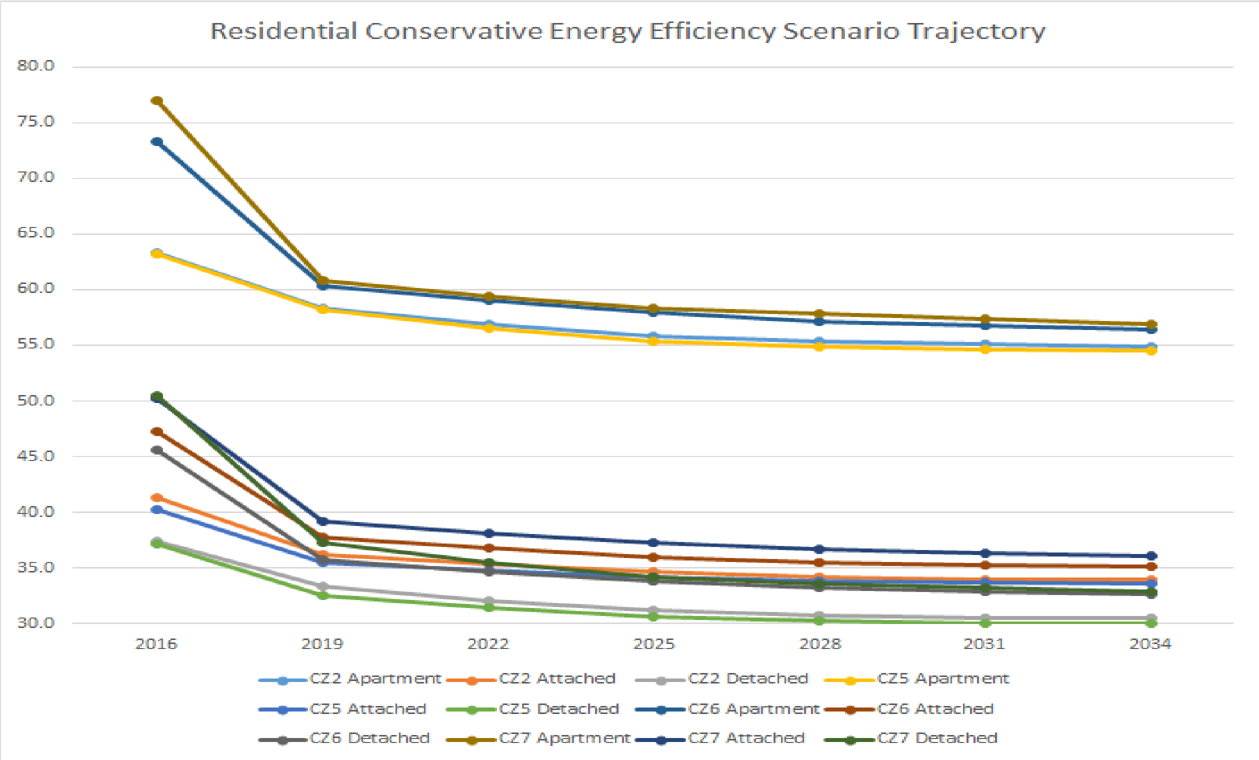


Figure 4: Graphical representation of Residential Conservative Energy Efficiency Scenario Trajectory

Table 2-19: Accelerated Deployment Energy Efficiency Trajectory Household Energy (Heating and Cooling + DHW + Lighting + Plug Appliances)

Climate Zone	Archetype	Base Case (kWh/m²/yr)	2019 (kWh/m²/yr)	2022 (kWh/m²/yr)	2025 (kWh/m²/yr)	2028 (kWh/m²/yr)	2031 (kWh/m²/yr)	2034 (kWh/m²/yr)
CZ 2	Apartment	63.4	55.2	54.8	54.4	53.9	53.7	53.6
	Attached	41.3	34.0	33.7	33.4	33.1	33.0	33.0
	Detached	37.4	30.4	30.1	29.8	29.4	29.3	29.3
CZ 5	Apartment	63.1	54.7	54.4	54.0	53.5	53.3	53.3
	Attached	40.3	33.7	33.4	33.1	32.9	32.8	32.7
	Detached	37.2	30.2	29.9	29.6	29.3	29.2	29.2
CZ 6	Apartment	73.3	55.2	54.8	54.4	53.9	53.7	53.6
	Attached	47.3	34.8	34.5	34.1	33.8	33.6	33.6
	Detached	45.6	31.7	31.3	30.9	30.5	30.3	30.2
CZ 7	Apartment	77.0	55.8	55.4	55.0	54.4	54.2	54.1
	Attached	50.3	35.7	35.3	34.9	34.5	34.3	34.2
	Detached	50.5	31.9	31.5	31.1	30.7	30.5	30.4

Table 2-20 Accelerated Deployment Energy Efficiency Trajectory Peak Heating Power

Climate Zone	Archetype	Base Case (kW)	2019 (kW)	2022 (kW)	2025 (kW)	2028 (kW)	2031 (kW)	2034 (kW)
CZ 2	Apartment	0.77	0.11	0.10	0.09	0.09	0.08	0.08
	Attached	0.89	0.11	0.10	0.09	0.09	0.08	0.08
	Detached	1.92	0.20	0.19	0.18	0.17	0.16	0.15
CZ 5	Apartment	1.09	0.09	0.08	0.08	0.07	0.07	0.06
	Attached	1.28	0.04	0.03	0.03	0.03	0.03	0.03
	Detached	2.30	0.09	0.08	0.07	0.07	0.07	0.06
CZ 6	Apartment	1.65	0.78	0.73	0.68	0.64	0.60	0.57
	Attached	2.07	1.29	1.20	1.12	1.05	0.99	0.93

Climate Zone	Archetype	Base Case (kW)	2019 (kW)	2022 (kW)	2025 (kW)	2028 (kW)	2031 (kW)	2034 (kW)
	Detached	3.66	2.00	1.86	1.73	1.63	1.53	1.44
CZ 7	Apartment	2.01	1.44	1.34	1.25	1.17	1.10	1.04
	Attached	2.48	2.13	1.98	1.85	1.73	1.63	1.54
	Detached	4.85	2.09	1.94	1.81	1.70	1.60	1.51

Table 2-21 Accelerated Deployment Energy Efficiency Trajectory Peak Cooling Power

Climate Zone	Archetype	Base Case (kW)	2019 (kW)	2022 (kW)	2025 (kW)	2028 (kW)	2031 (kW)	2034 (kW)
CZ 2	Apartment	1.76	0.57	0.53	0.50	0.47	0.44	0.41
	Attached	2.28	0.43	0.40	0.38	0.35	0.33	0.31
	Detached	3.33	0.48	0.45	0.42	0.39	0.37	0.35
CZ 5	Apartment	1.71	0.74	0.69	0.64	0.60	0.57	0.53
	Attached	2.46	0.11	0.10	0.13	0.23	0.19	0.08
	Detached	3.83	0.42	0.39	0.37	0.34	0.32	0.31
CZ 6	Apartment	2.00	0.70	0.65	0.61	0.57	0.53	0.50
	Attached	2.05	0.17	0.16	0.15	0.14	0.13	0.12
	Detached	3.15	0.14	0.13	0.12	0.11	0.11	0.10
CZ 7	Apartment	2.44	0.73	0.68	0.64	0.60	0.56	0.53
	Attached	1.98	0.27	0.25	0.23	0.22	0.20	0.19
	Detached	3.89	0.30	0.28	0.26	0.24	0.23	0.22

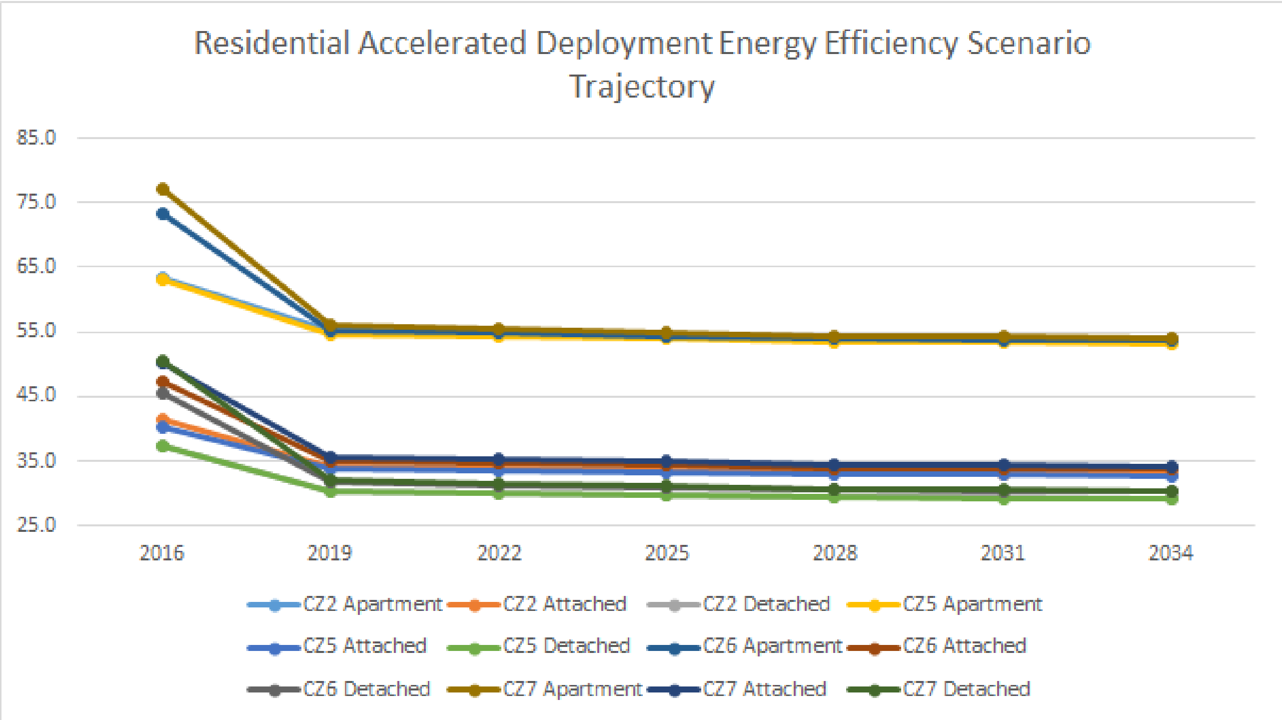


Figure 5: Graphical representation of Residential Accelerated Deployment Energy Efficiency Scenario Trajectory

2.5 Net Energy Trajectories: Energy consumption after implementation of energy efficiency plus on-site generation measures

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

Net Energy Trajectories were established for the residential archetypes by combining the whole of house energy trajectories (heating and cooling, domestic hot water, lighting and plug appliances) of the conservative and accelerated deployment energy efficiency scenarios with generation energy trajectories for on-site renewable based generation systems for each of the residential archetypes.

Net Energy Trajectories demonstrate the ability of the archetypes to reach net zero energy.

On-site generation is dependent on available space and resources for renewable based generation systems. For the residential Net Energy Trajectories only on-site solar photovoltaic (PV) standard panel based systems were considered, i.e. alternative generation systems such as building integrated PV (roof tiles, wall systems, glazing, etc.), photovoltaic thermal systems, micro wind turbines, geothermal systems, etc. have not been included in this study.

Table 2-22 and Table 2-23 contain the Net Energy Trajectories for the apartment, attached and detached archetypes across Climate Zones 2, 5, 6 and 7. A negative number indicates that annual on-site generation is greater than annual building demand. Results for Net Energy Trajectories are the average of the two primary orientations for energy demand (nominally the best and worst energy demand) combined with the average of the two primary orientations best and worst on-site generation.

For the conservative energy efficiency trajectories the attached archetypes reached net zero across all climate zones

Table 2-22: Conservative Technology Energy Efficiency Trajectory Net Household Energy (Heating and Cooling + DHW + Lighting + Plug Appliances - PV)

Climate Zone	Archetype	Base Case (kWh/m²/yr)	2019 (kWh/m²/yr)	2022 (kWh/m²/yr)	2025 (kWh/m²/yr)	2028 (kWh/m²/yr)	2031 (kWh/m²/yr)	2034 (kWh/m²/yr)
CZ 2	Apartment	63.4	52.0	50.6	49.4	48.6	47.9	47.3
	Attached	41.3	10.1	-3.5	-13.9	-18.1	-22.2	-26.1
	Detached	37.4	9.1	-17.0	-46.7	-83.6	-102.1	-111.4
CZ 5	Apartment	63.1	52.1	50.7	49.5	48.8	48.2	47.6
	Attached	40.3	15.3	1.2	-9.5	-13.3	-17.0	-20.7
	Detached	37.2	14.0	-3.7	-29.2	-70.7	-90.1	-98.4
CZ 6	Apartment	73.3	55.6	53.8	52.3	51.3	50.5	49.9
	Attached	47.3	17.1	3.3	-7.1	-11.0	-14.8	-18.4
	Detached	45.6	16.1	-1.7	-26.9	-66.6	-85.4	-93.8
CZ 7	Apartment	77.0	55.2	53.5	52.0	50.9	50.1	49.4
	Attached	50.3	10.3	-1.9	-11.6	-16.0	-20.3	-24.5
	Detached	50.5	11.2	-16.2	-46.5	-82.4	-100.8	-110.3

Table 2-23: Accelerated Deployment Energy Efficiency Trajectory Net Household Energy (Heating and Cooling + DHW + Lighting + Plug Appliances - PV)

Climate Zone	Archetype	Base Case (kWh/m²/yr)	2019 (kWh/m²/yr)	2022 (kWh/m²/yr)	2025 (kWh/m²/yr)	2028 (kWh/m²/yr)	2031 (kWh/m²/yr)	2034 (kWh/m²/yr)
CZ 2	Apartment	63.4	50.2	49.4	48.6	47.6	46.9	46.3
	Attached	41.3	-6.6	-10.7	-14.9	-19.1	-23.1	-27.1
	Detached	37.4	-65.5	-75.0	-84.5	-94.1	-103.4	-112.6
CZ 5	Apartment	63.1	50.2	49.4	48.6	47.7	47.1	46.6
	Attached	40.3	-3.1	-6.9	-10.6	-14.4	-18.0	-21.6
	Detached	37.2	-56.6	-65.2	-73.9	-82.5	-91.0	-99.3
CZ 6	Apartment	73.3	50.7	50.0	49.1	48.2	47.5	47.1
	Attached	47.3	-1.3	-5.1	-9.0	-12.8	-16.4	-19.9
	Detached	45.6	-53.7	-62.3	-70.9	-79.5	-87.9	-96.2
CZ 7	Apartment	77.0	50.8	49.9	49.0	47.9	47.2	46.6
	Attached	50.3	-5.3	-9.6	-13.9	-18.3	-22.4	-26.4
	Detached	50.5	-64.9	-74.6	-84.3	-94.0	-103.4	-112.8

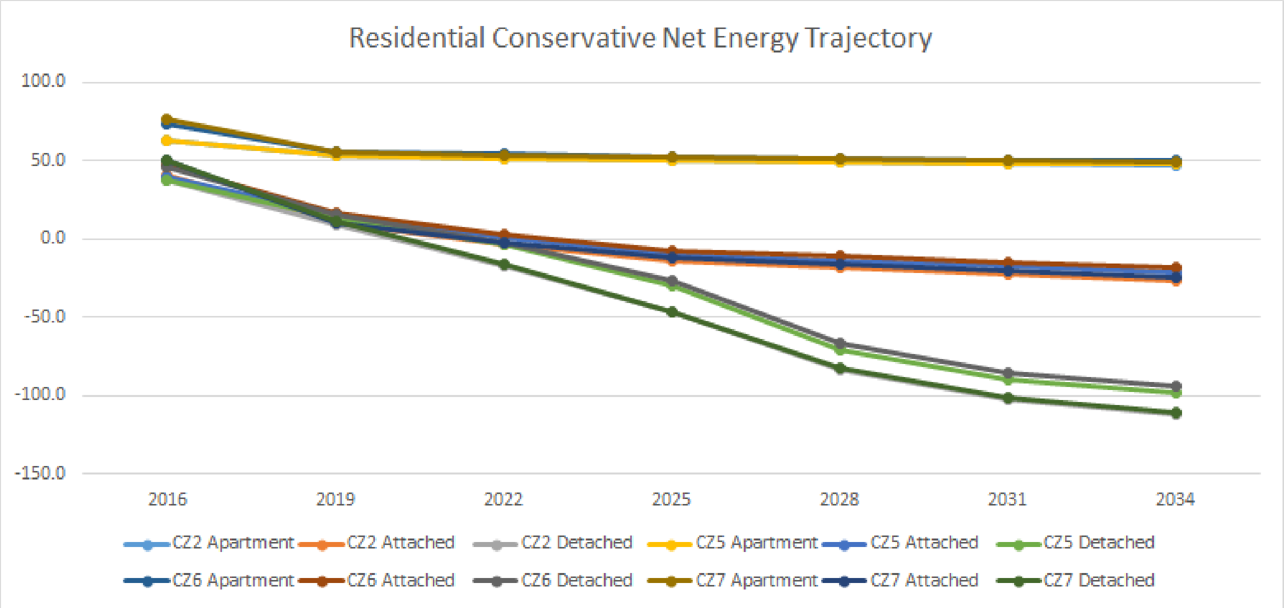


Figure 6: Graphical representation of Residential Conservative Net Energy Trajectory

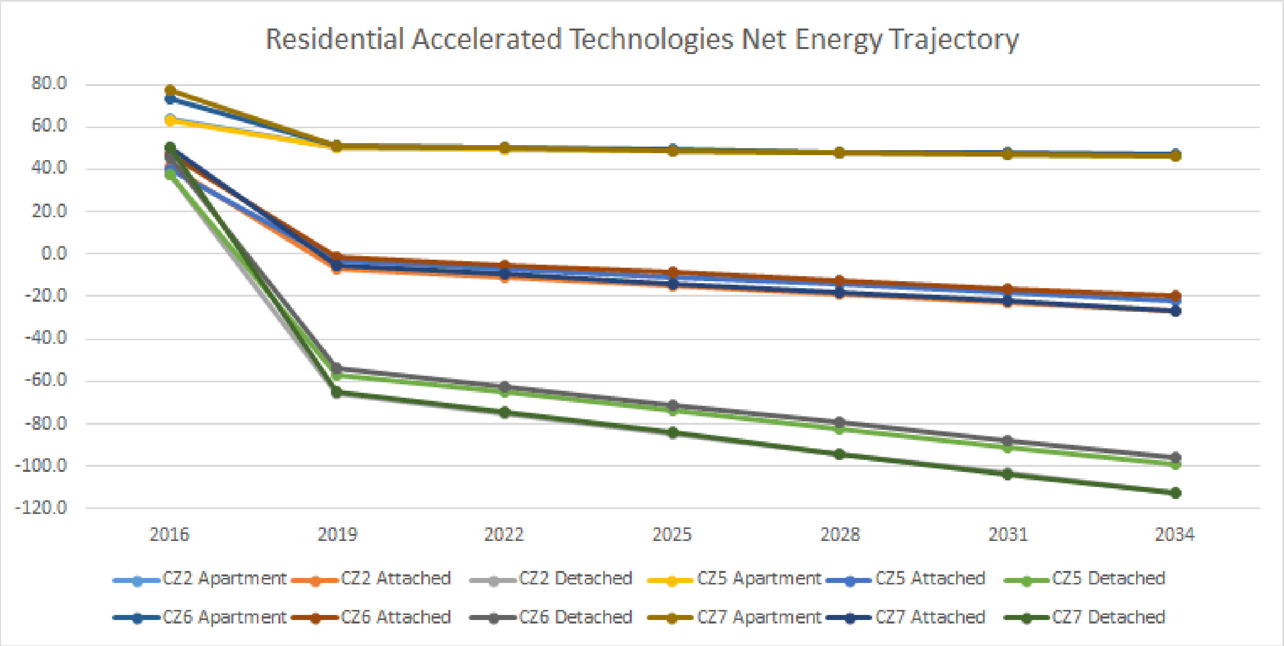


Figure 7: Graphical representation of Residential Accelerated deployment Net Energy Trajectory

3 Commercial Building Modelling

3.1 Modelling Methodology

The building typologies that were used as the basis of the investigations are as listed in Table 3-1 below.

Table 3-1: The archetypes to be used in the analysis. Area figures are gross floor areas.

Building	Description
Office	10,000m² office, 10 levels, 31.6m x 31.6m floor plate, 3.6m floor-floor, VAV system with central plant
School	200m², 1 level, 20m x 10m floor plate, 3.3m floor-ceiling, packaged AC with opening windows
Hotel	2000m², 3 level, 36.5m x 18.3m floor plate, 3.6m floor-floor, Fan coils with central plant
Shop	1000m², 1 level, 31.6m x 31.6m floor plate, 6 m floor-ceiling, packaged AC with economy cycle
Ward	500m², 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.

With respect to the second bullet point, it is noted that the archetypes are not necessarily designed to fully represent the building category; they are more a representation of a ratio of internal loads and surface area to volume ratio that happens to be represented by the particular archetype that happens to be modelled as that building type. Thus for instance, the ward model does not represent a hospital and the school model represents a classroom not a school.

IES <VE> Software version 17.4.0.0 was used for all of the commercial 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.

As noted in previous section, single-dimensional analysis was undertaken to prioritise measures – these results are in Appendix I - This section summarises the multi-dimensional results used to construct the trajectories.

The overall process for the model technical development is described below.

Single-dimensional Analysis: In the single-dimensional analysis, two processes were undertaken:

- The NCC2019 models were tested with a range of new measures not previously assessed. The modelling details of the single-dimensional measures are provided in Appendix I - Commercial Economic Modelling Details.

- The BCRs for measures previously assessed under NCC2019 were updated to reflect the economic parameters being used for this study. These include slightly different electricity prices and an avoided cost of network augmentation.

At the end of single-dimensional analysis, the BCRs for all measures were tabulated, and those with a BCR>1 were selected for incorporation into Multi-dimensional analysis. Note that for each measure, the BCR was evaluated at 0, 5, 10 and 15 year points (refer 1.2).

Multi-dimensional Trajectory Analysis: In this stage, for modelling the conservative scenario, the NCC2019 base models were updated to include all measures identified in single-dimensional analysis that have a BCR>1. This included some technologies (such as lighting and chillers) where a progressive improvement in efficiency at no extra cost is expected over time, based on underlying technology improvements. The models were then rerun to determine the overall BCR of the measures in combination. A tuning process was then conducted as follows:

- Where the combined model BCR<1, the lowest BCR measures are progressively removed until the BCR>1.

- Where the combined model BCR>1.5, the highest BCR measures not already adopted (thus with a single-dimensional BCR<1) are progressively incorporated into the model until the BCR<1.5. Typically thermal mass and insulation were used to improve the energy performance of the building whilst reducing the benefit cost ratio.

- Each time a new measure was identified in the tuning process at one point in time, it was automatically locked in for future years.

In practice, the limited granularity of measures meant that in some cases the model BCR was greater than 1.5.

For the ‘Accelerated Deployment’ scenario, the analysis follows a similar methodology as described above. The single-dimensional measures investigated with a ‘high impact’ on building energy i.e. an energy reduction of 2% or more. The final tuning measures identified for the conservative scenario for each archetype were similarly applied to the corresponding accelerated models.

Solar PV Analysis: The solar analysis was undertaken by evaluating two figures, being:

- The maximum available space for incorporation of PV.
- The amount of PV that can be incorporated while maintaining the BCR of the PV installation at or close to 1.25.

The lower of these two capacities was used in the analysis. The following important details are noted:

- The percentage of export was derived based on hourly predictions of solar generation and building energy use taken from the simulation models.
- A feed-in tariff of 35% of the grid power tariff (5.5c/kWh) was assumed.
- PV was modelled as having learning rates for both cost and efficiency, with the result that the amount of PV increases in the later analysis years.
- BCR for PV was determined as a function of energy cost savings and capital construction cost for the array.

3.2 Scenarios Design Parameters: What measures were investigated?

The single-dimensional measures combined in the multi-dimensional models vary across climate zone, archetype and defined year scenario. The façade provisions and HVAC stringencies applied to these models were based on the proposed NCC2019 Section J revision work completed prior to the public comment draft V1.1[15]. Figure 8 and Figure 9 below identify the façade U-Value and SHGCxWWR targets used in the commercial analysis.

	East		North		South		West	
	U_Total	SHGC x WWR	U_Total	SHGC x WWR	U_Total	SHGC x WWR	U_Total	SHGC x WWR
CZ1	2.5	0.16	2.5	0.16	2.5	0.16	2.5	0.16
CZ2	2.5	0.13	2.5	0.13	2.5	0.13	2.5	0.13
CZ3	2.5	0.16	2.5	0.16	2.5	0.16	2.5	0.16
CZ4	2.5	0.13	2.5	0.13	2.5	0.13	2.5	0.13
CZ5	2.5	0.13	2.5	0.13	2.5	0.13	2.5	0.13
CZ6	2.5	0.13	2.5	0.13	2.5	0.13	2.5	0.13
CZ7	2.5	0.13	2.5	0.13	2.5	0.13	2.5	0.13
CZ8	2.5	0.20	2.5	0.20	2.4	0.42	2.4	0.36

Figure 8: Daytime building operation facade provisions used in the commercial modelling.

[15] The Australian Building Codes Board, 2018. NCC 2019 Public Comment Draft.

	East		North		South		West	
	U_Total	SHGC x WWR	U_Total	SHGC x WWR	U_Total	SHGC x WWR	U_Total	SHGC x WWR
CZ1	1.1	0.11	1.1	0.11	2.5	0.16	1.1	0.11
CZ2	2.5	0.16	2.5	0.16	2.5	0.16	2.5	0.16
CZ3	1.1	0.11	1.1	0.11	1.1	0.11	1.1	0.11
CZ4	1.1	0.11	1.1	0.11	0.9	0.11	1.1	0.11
CZ5	2.5	0.16	2.5	0.16	2.5	0.16	2.5	0.16
CZ6	1.1	0.11	1.1	0.11	0.9	0.11	1.1	0.11
CZ7	0.9	0.11	1.1	0.11	0.9	0.13	0.9	0.11
CZ8	0.6	0.13	0.6	0.13	0.6	0.13	0.6	0.13

Figure 9: Overnight building operation facade provisions used in the commercial modelling.

A full list of the single-dimensional measures tested in the commercial analysis is provided in Table 3-2 below, which includes the tuning measures. A comprehensive list of the measures selected for each multidimensional conservative and accelerated model is presented in the following tables.

Table 3-2: Individual measures used in multidimensional analysis.

Measure	Description
Artificial lighting	Illumination power density reduction
BIPV (Wall)	Solar generation from wall mounted PV systems
BIPV (Window)	Solar generation from transparent façade mounted PV systems
Chiller COP/IPLV improvement	Moving from NCC compliant performance to industry best practice
CO2 control	Modulation of outside air provisions based on zone CO2 content
Daylight harvesting	Perimeter zone daylight harvesting
Daylight harvesting and light shelves	Light shelf installation and daylight harvesting
Daylight harvesting and shading	WWR increase to 150% of base case, shades installed to keep SHGC constant, daylight harvesting
Dewpoint cooler	Installation of dewpoint cooler (office building only)
Ductwork pressure reduction	AHU system ductwork pressure reduction
Economy cycle	Installation of economy cycle provisions
Electrochromic glazing	Installation of electrochromic glazing
External shading	Shading with an overhang of 0.5 P/H ratio
External shutters	Shutters close when zone temperature increases above threshold
External wall fabric colour (light colour)	Changing the wall absorptivity to reflect more solar radiation
External wall insulation	R-Value increase for external wall insulation
Heat exchanger installation	Heat exchanger installed to outside air ductwork
Heat exchanger performance upgrade	Heat exchanger efficiency increase (70%)
Lift upgrade	Lift technology upgrade, vehicle weight reduction
Occupancy sensor	Lighting gain modulated by occupancy sensor
Overnight ventilation	Overnight ventilation, infiltration and insulation optimisation
PAC COP improvement	Packaged Air Conditioning units COP improvement to best practice
Rooftop PV	Installation of rooftop PV
Thermal mass increase	100-250mm concrete added to either external walls or internal walls

3.2.1 Conservative Energy Efficiency Scenarios: What were the cost-effective measures included?

The conservative energy efficiency scenarios implemented for the multi-dimensional analysis are outlined from Table 3-3 to Table 3-7 for the different archetypes.

Table 3-3: Conservative measures selection for the hotel (3B) archetype.

3B	2019	2024	2029	2034
CZ2	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV
	External shutters	External shutters	External shutters	External shutters
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	200mm concrete internal wall thermal mass	Chiller COP 5.98/IPLV 9.95	Chiller COP 7.48/IPLV 11.45	Chiller COP 8.23/IPLV 12.2
	R3 external wall insulation	125mm concrete internal wall thermal mass	Cost effective BIPV (Wall)	Lighting power density reduced by 40%
	External wall fabric colour (light colour)	125mm concrete external wall thermal mass	Lighting power density reduced by 20%	Cost effective BIPV (Wall)
		R1 external wall insulation	125mm concrete internal wall thermal mass	125mm concrete internal wall thermal mass
		External wall fabric colour (light colour)	125mm concrete external wall thermal mass	125mm concrete external wall thermal mass
			R2 external wall insulation	R3 external wall insulation
			External wall fabric colour (light colour)	External wall fabric colour (light colour)
CZ5	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV
	External shutters	External shutters	External shutters	External shutters
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	200mm concrete internal wall thermal mass	Chiller COP 5.98/IPLV 9.95	Chiller COP 7.48/IPLV 11.45	Chiller COP 8.23/IPLV 12.2
	R3 external wall insulation	200mm concrete internal wall thermal mass	Cost effective BIPV (Wall)	Lighting power density reduced by 40%
	External wall fabric colour (light colour)	R6 external wall insulation	Lighting power density reduced by 20%	Cost effective BIPV (Wall)
		External wall fabric colour (light colour)	150mm concrete external wall thermal mass	150mm concrete external wall thermal mass
			R4 external wall insulation	R4 external wall insulation
			External wall fabric colour (light colour)	External wall fabric colour (light colour)
CZ6	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV
	External shutters	External shutters	External shutters	External shutters
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	Heat exchanger efficiency increase (70%)	Heat exchanger efficiency increase (70%)	Heat exchanger efficiency increase (70%)	Heat exchanger efficiency increase (70%)
	R3 external wall insulation	Chiller COP 5.98/IPLV 9.95	Chiller COP 7.48/IPLV 11.45	Chiller COP 8.23/IPLV 12.2
	External wall fabric colour (light colour)	100mm concrete internal wall thermal mass	Cost effective BIPV (Wall)	Lighting power density reduced by 40%

		R2 external wall insulation	Lighting power density reduced by 20%	Cost effective BIPV (Wall)
		External wall fabric colour (light colour)	150mm concrete internal wall thermal mass	150mm concrete internal wall thermal mass
			R3 external wall insulation	R4 external wall insulation
			External wall fabric colour (light colour)	External wall fabric colour (light colour)
CZ7	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV
	External shutters	External shutters	External shutters	External shutters
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	100mm concrete internal wall thermal mass	Chiller COP 5.98/IPLV 9.95	Chiller COP 7.48/IPLV 11.45	Chiller COP 8.23/IPLV 12.2
		150mm concrete internal wall thermal mass	Cost effective BIPV (Wall)	Lighting power density reduced by 40%
		R2 external wall insulation	Lighting power density reduced by 20%	Cost effective BIPV (Wall)
			150mm concrete internal wall thermal mass	150mm concrete internal wall thermal mass
			R4 external wall insulation	R6 external wall insulation

Table 3-4: Conservative measures selection for the office (5A) archetype.

5A	2019	2024	2029	2034
CZ2	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV
	Overnight ventilation + low infiltration	Overnight ventilation + low infiltration	Overnight ventilation + low infiltration	Overnight ventilation + low infiltration
	Perimeter zone daylight harvesting (max visible transmissivity)	Perimeter zone daylight harvesting (max visible transmissivity)	Perimeter zone daylight harvesting (max visible transmissivity)	Perimeter zone daylight harvesting (max visible transmissivity)
	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	External wall fabric colour (light colour)	External wall fabric colour (light colour)	External wall fabric colour (light colour)	External wall fabric colour (light colour)
	Economy cycle used for all AHUs	Economy cycle used for all AHUs	Economy cycle used for all AHUs	Economy cycle used for all AHUs
		Chiller COP 6.33/IPLV 10.12	Chiller COP 7.83/IPLV 12.12	Chiller COP 8.58/IPLV 12.87
		R4 external wall insulation	R4 external wall insulation	R4 external wall insulation
			100mm concrete internal wall thermal mass	100mm concrete internal wall thermal mass
			Lighting power density reduced by 20%	Lighting power density reduced by 40%
			Cost effective BIPV (Wall)	Cost effective BIPV (Wall)
CZ5	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV
	Overnight ventilation + low infiltration	Overnight ventilation + low infiltration	Overnight ventilation + low infiltration	Overnight ventilation + low infiltration
	Perimeter zone daylight harvesting (max visible transmissivity)	Perimeter zone daylight harvesting (max visible transmissivity)	Perimeter zone daylight harvesting (max visible transmissivity)	Perimeter zone daylight harvesting (max visible transmissivity)
	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction

	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	External wall fabric colour (light colour)	External wall fabric colour (light colour)	External wall fabric colour (light colour)	External wall fabric colour (light colour)
	Economy cycle used for all AHUs	Economy cycle used for all AHUs	Economy cycle used for all AHUs	Economy cycle used for all AHUs
		Chiller COP 6.33/IPLV 10.12	Chiller COP 7.83/IPLV 12.12	Chiller COP 8.58/IPLV 12.87
		R2 external wall insulation	R4 external wall insulation	R4 external wall insulation
			Lighting power density reduced by 20%	Lighting power density reduced by 40%
			Cost effective BIPV (Wall)	Cost effective BIPV (Wall)
CZ6	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV
	Overnight ventilation + low infiltration	Overnight ventilation + low infiltration	Overnight ventilation + low infiltration	Overnight ventilation + low infiltration
	Perimeter zone daylight harvesting (max visible transmissivity)	Perimeter zone daylight harvesting (max visible transmissivity)	Perimeter zone daylight harvesting (max visible transmissivity)	Perimeter zone daylight harvesting (max visible transmissivity)
	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction
	R3.5 external wall insulation	R3.5 external wall insulation	R3.5 external wall insulation	R3.5 external wall insulation
	External wall fabric colour (light colour)	External wall fabric colour (light colour)	External wall fabric colour (light colour)	External wall fabric colour (light colour)
		Chiller COP 6.33/IPLV 10.12	Chiller COP 7.83/IPLV 12.12	Chiller COP 8.58/IPLV 12.87
			100mm concrete internal wall thermal mass	100mm concrete internal wall thermal mass
			Lighting power density reduced by 20%	Lighting power density reduced by 40%
			Cost effective BIPV (Wall)	Cost effective BIPV (Wall)
			100mm concrete internal wall thermal mass	100mm concrete internal wall thermal mass
CZ7	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV
	Overnight ventilation + low infiltration	Overnight ventilation + low infiltration	Overnight ventilation + low infiltration	Overnight ventilation + low infiltration
	Perimeter zone daylight harvesting (max visible transmissivity)	Perimeter zone daylight harvesting (max visible transmissivity)	Perimeter zone daylight harvesting (max visible transmissivity)	Perimeter zone daylight harvesting (max visible transmissivity)
	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction
	Heat exchanger installed	Heat exchanger installed	Heat exchanger installed	Heat exchanger installed
		Chiller COP 6.33/IPLV 10.12	Chiller COP 7.83/IPLV 12.12	Chiller COP 8.58/IPLV 12.87
		R3.5 external wall insulation	R3.5 external wall insulation	R5 external wall insulation
			Lighting power density reduced by 20%	Lighting power density reduced by 40%
			Cost effective BIPV (Wall)	Cost effective BIPV (Wall)
			100mm concrete internal wall thermal mass	100mm concrete internal wall thermal mass

Table 3-5: Conservative measures selection for the retail (6C) archetype.

6C	2019	2024	2029	2034
CZ2	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV
	External wall fabric colour (light colour)	External wall fabric colour (light colour)	Cost effective BIPV (Wall)	Cost effective BIPV (Wall)
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	External wall fabric colour (light colour)	External wall fabric colour (light colour)
	150mm concrete internal wall thermal mass	200mm concrete internal wall thermal mass	Lighting control by occupancy sensor	Lighting control by occupancy sensor
		PAC COP 4.3	150mm concrete internal wall thermal mass	R4 external wall insulation
		R4 external wall insulation	150mm concrete external wall thermal mass	150mm concrete internal wall thermal mass
			PAC COP 4.8	150mm concrete external wall thermal mass
			Lighting power density reduced by 20%	PAC COP 5.05
				Lighting power density reduced by 40%
CZ5	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV
	External wall fabric colour (light colour)	External wall fabric colour (light colour)	Cost effective BIPV (Wall)	Cost effective BIPV (Wall)
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	External wall fabric colour (light colour)	External wall fabric colour (light colour)
		R2 external wall insulation	Lighting control by occupancy sensor	Lighting control by occupancy sensor
		150mm concrete internal wall thermal mass	R8 external wall insulation	150mm concrete internal wall thermal mass
		PAC COP 4.3	150mm concrete internal wall thermal mass	150mm concrete external wall thermal mass
			PAC COP 4.8	PAC COP 5.05
			Lighting power density reduced by 20%	Lighting power density reduced by 40%
CZ6	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV
	External wall fabric colour (light colour)	External wall fabric colour (light colour)	Cost effective BIPV (Wall)	Cost effective BIPV (Wall)
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	External wall fabric colour (light colour)	External wall fabric colour (light colour)
	Heat exchanger installed	Heat exchanger installed	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	R1 external wall insulation	R1 external wall insulation	Heat exchanger installed	Heat exchanger installed
		100mm concrete internal wall thermal mass	R6 external wall insulation	150mm concrete external wall thermal mass
		PAC COP 4.3	100mm concrete internal wall thermal mass	PAC COP 5.05
			PAC COP 4.8	Lighting power density reduced by 40%
			Lighting power density reduced by 20%	
CZ7	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV
	External wall fabric colour (light colour)	External wall fabric colour (light colour)	Cost effective BIPV (Wall)	Cost effective BIPV (Wall)

	Lighting control by occupancy sensor	Lighting control by occupancy sensor	External wall fabric colour (light colour)	External wall fabric colour (light colour)
	Heat exchanger installed	Heat exchanger installed	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	150mm concrete internal wall thermal mass	R2 external wall insulation	Heat exchanger installed	Heat exchanger installed
		200mm concrete internal wall thermal mass	R6 external wall insulation	R2 external wall insulation
		PAC COP 4.3	200mm concrete internal wall thermal mass	100mm concrete external wall thermal mass
		Economy Cycle on central PACs only	PAC COP 4.8	PAC COP 5.05
			Economy Cycle on central PACs only	Economy Cycle on central PACs only
			Lighting power density reduced by 20%	Lighting power density reduced by 40%

Table 3-6: Conservative measures selection for the ward area (9aD) archetype.

9aD	2019	2024	2029	2034
CZ2	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV
	External shutters	External shutters	External shutters	External shutters
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction
	Economy cycle installed	Economy cycle installed	Economy cycle installed	Economy cycle installed
	External wall fabric colour (light colour)	External wall fabric colour (light colour)	External wall fabric colour (light colour)	External wall fabric colour (light colour)
	R8 external wall insulation	Best practice chiller	Expected best practice chiller in 10 years	Expected best practice chiller in 15 years
		R8 external wall insulation	BIPV (Wall)	BIPV (Wall)
			Lighting power density reduced by 20%	Lighting power density reduced by 40%
			R8 external wall insulation	R10 external wall insulation
			150mm concrete internal wall thermal mass	200mm concrete internal wall thermal mass
CZ5	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV
	External shutters	External shutters	External shutters	External shutters
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction
	Economy cycle installed	Economy cycle installed	Economy cycle installed	Economy cycle installed
	External wall fabric colour (light colour)	External wall fabric colour (light colour)	External wall fabric colour (light colour)	External wall fabric colour (light colour)
	R4 external wall insulation	Best practice chiller	Expected best practice chiller in 10 years	Expected best practice chiller in 15 years
	150mm concrete internal wall thermal mass	R5 external wall insulation	BIPV (Wall)	BIPV (Wall)
		150mm concrete internal wall thermal mass	Lighting power density reduced by 20%	Lighting power density reduced by 40%
			R6 external wall insulation	R8 external wall insulation

			150mm concrete internal wall thermal mass	150mm concrete internal wall thermal mass
CZ6	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV
	External shutters	External shutters	External shutters	External shutters
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction
	External wall fabric colour (light colour)	External wall fabric colour (light colour)	External wall fabric colour (light colour)	External wall fabric colour (light colour)
		Best practice chiller	Expected best practice chiller in 10 years	Expected best practice chiller in 15 years
		Heat exchanger installed	BIPV (Wall)	BIPV (Wall)
		R2 external wall insulation	Lighting power density reduced by 20%	Lighting power density reduced by 40%
			Heat exchanger installed	Heat exchanger installed
			R3 external wall insulation	R4 external wall insulation
CZ7	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV
	External shutters	External shutters	External shutters	External shutters
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction
	Heat exchanger installed	Best practice chiller	Expected best practice chiller in 10 years	Expected best practice chiller in 15 years
	R2 external wall insulation	Heat exchanger installed	BIPV (Wall)	BIPV (Wall)
		R2.5 external wall insulation	Lighting power density reduced by 20%	Lighting power density reduced by 40%
			Heat exchanger installed	Heat exchanger installed
			R3 external wall insulation	R3.5 external wall insulation

Table 3-7: Conservative measures selection for the school (9bE) archetype.

9bE	2019	2024	2029	2034
CZ2	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV
	External wall fabric colour (light colour)	External wall fabric colour (light colour)	Cost effective BIPV (Wall)	Cost effective BIPV (Wall)
	Perimeter zone daylight harvesting (max visible transmissivity)	Perimeter zone daylight harvesting (max visible transmissivity)	External wall fabric colour (light colour)	External wall fabric colour (light colour)
	Heat exchanger installed	Heat exchanger installed	Perimeter zone daylight harvesting (max visible transmissivity)	Perimeter zone daylight harvesting (max visible transmissivity)
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Heat exchanger installed	Heat exchanger installed
	R3 external wall insulation	100mm concrete internal wall thermal mass	Lighting control by occupancy sensor	Lighting control by occupancy sensor
		PAC COP 4.3	100mm concrete internal wall thermal mass	100mm concrete internal wall thermal mass
		R3 external wall insulation	PAC COP 4.8	PAC COP 5.05
			R3 external wall insulation	R4.5 external wall insulation

			Lighting power density reduced by 20%	Lighting power density reduced by 40%
CZ5	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV
	External wall fabric colour (light colour)	External wall fabric colour (light colour)	Cost effective BIPV (Wall)	Cost effective BIPV (Wall)
	Perimeter zone daylight harvesting (max visible transmissivity)	Perimeter zone daylight harvesting (max visible transmissivity)	External wall fabric colour (light colour)	External wall fabric colour (light colour)
	Heat exchanger installed	Heat exchanger installed	Perimeter zone daylight harvesting (max visible transmissivity)	Perimeter zone daylight harvesting (max visible transmissivity)
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Heat exchanger installed	Heat exchanger installed
		PAC COP 4.3	Lighting control by occupancy sensor	Lighting control by occupancy sensor
		R8 external wall insulation	PAC COP 4.8	PAC COP 5.05
			R8 external wall insulation	R10 external wall insulation
			Lighting power density reduced by 20%	Lighting power density reduced by 40%
CZ6	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV
	External wall fabric colour (light colour)	External wall fabric colour (light colour)	Cost effective BIPV (Wall)	Cost effective BIPV (Wall)
	Perimeter zone daylight harvesting (max visible transmissivity)	Perimeter zone daylight harvesting (max visible transmissivity)	External wall fabric colour (light colour)	External wall fabric colour (light colour)
	Heat exchanger installed	Heat exchanger installed	Perimeter zone daylight harvesting (max visible transmissivity)	Perimeter zone daylight harvesting (max visible transmissivity)
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Heat exchanger installed	Heat exchanger installed
		PAC COP 4.3	Lighting control by occupancy sensor	Lighting control by occupancy sensor
		R6 external wall insulation	PAC COP 4.8	PAC COP 5.05
			R8 external wall insulation	R10 external wall insulation
			Lighting power density reduced by 20%	Lighting power density reduced by 40%
CZ7	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV	Cost effective roof PV
	Perimeter zone daylight harvesting (max visible transmissivity)	Perimeter zone daylight harvesting (max visible transmissivity)	Cost effective BIPV (Wall)	Cost effective BIPV (Wall)
	Heat exchanger installed	Heat exchanger installed	Perimeter zone daylight harvesting (max visible transmissivity)	Perimeter zone daylight harvesting (max visible transmissivity)
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Heat exchanger installed	Heat exchanger installed
	R1 external wall insulation	PAC COP 4.3	Lighting control by occupancy sensor	Lighting control by occupancy sensor
		R6 external wall insulation	PAC COP 4.8	PAC COP 5.05
			R6 external wall insulation	R8 external wall insulation
			Lighting power density reduced by 20%	Lighting power density reduced by 40%

3.2.2 Accelerated Deployment Energy Efficiency Scenarios: What were the high impact measures included?

The Accelerated Deployment energy efficiency scenarios implemented for the multi-dimensional analysis are outlined from Table 3-3 to Table 3-7 for the different archetypes.

Table 3-8: Accelerated measures selection for the hotel (3B) archetype.

3B	2019	2024	2029	2034
CZ2	Max roof PV	Max roof PV	Max roof PV	Max roof PV
	External shutters	External shutters	External shutters	External shutters
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	200mm concrete internal wall thermal mass	Chiller COP 6.73/IPLV 10.7	Chiller COP 7.48/IPLV 11.45	Chiller COP 8.23/IPLV 12.2
	R3 external wall insulation	125mm concrete internal wall thermal mass	Max BIPV (Wall)	Lighting power density reduced by 40%
	Chiller COP 5.98/IPLV 9.95	125mm concrete external wall thermal mass	Lighting power density reduced by 26%	Max BIPV (Wall)
	Lift upgrade	R1 external wall insulation	125mm concrete internal wall thermal mass	125mm concrete internal wall thermal mass
		Lift upgrade	125mm concrete external wall thermal mass	125mm concrete external wall thermal mass
		Lighting power density reduced by 13%	R2 external wall insulation	R3 external wall insulation
			Lift upgrade	Lift upgrade
CZ5	Max roof PV	Max roof PV	Max roof PV	Max roof PV
	External shutters	External shutters	External shutters	External shutters
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	200mm concrete internal wall thermal mass	Chiller COP 6.73/IPLV 10.7	Chiller COP 7.48/IPLV 11.45	Chiller COP 8.23/IPLV 12.2
	R3 external wall insulation	200mm concrete internal wall thermal mass	Max BIPV (Wall)	Lighting power density reduced by 40%
	Heat exchanger installed	R6 external wall insulation	Lighting power density reduced by 26%	Max BIPV (Wall)
	Chiller COP 5.98/IPLV 9.95	Heat exchanger installed	150mm concrete external wall thermal mass	150mm concrete external wall thermal mass
	Lift upgrade	Lift upgrade	R4 external wall insulation	R4 external wall insulation
		Lighting power density reduced by 13%	Heat exchanger installed	Heat exchanger installed
			Lift upgrade	Lift upgrade
CZ6	Max roof PV	Max roof PV	Max roof PV	Max roof PV
	External shutters	External shutters	External shutters	External shutters
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	Heat exchanger efficiency increase (70%)	Heat exchanger efficiency increase (70%)	Heat exchanger efficiency increase (70%)	Heat exchanger efficiency increase (70%)
	R3 external wall insulation	Chiller COP 6.73/IPLV 10.7	Chiller COP 7.48/IPLV 11.45	Chiller COP 8.23/IPLV 12.2
	Chiller COP 5.98/IPLV 9.95	100mm concrete internal wall thermal mass	Max BIPV (Wall)	Lighting power density reduced by 40%

	Lift upgrade	R2 external wall insulation	Lighting power density reduced by 26%	Max BIPV (Wall)
		Lift upgrade	150mm concrete internal wall thermal mass	150mm concrete internal wall thermal mass
		Lighting power density reduced by 13%	R3 external wall insulation	R4 external wall insulation
			Lift upgrade	Lift upgrade
CZ7	Max roof PV	Max roof PV	Max roof PV	Max roof PV
	External shutters	External shutters	External shutters	External shutters
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	100mm concrete internal wall thermal mass	Chiller COP 6.73/IPLV 10.7	Chiller COP 7.48/IPLV 11.45	Chiller COP 8.23/IPLV 12.2
	Chiller COP 5.98/IPLV 9.95	150mm concrete internal wall thermal mass	Max BIPV (Wall)	Lighting power density reduced by 40%
	Lift upgrade	R2 external wall insulation	Lighting power density reduced by 26%	Max BIPV (Wall)
		Lift upgrade	150mm concrete internal wall thermal mass	150mm concrete internal wall thermal mass
		Lighting power density reduced by 13%	R6 external wall insulation	R6 external wall insulation
			Lift upgrade	Lift upgrade

Table 3-9: Accelerated measures selection for the office (5A) archetype.

5A	2019	2024	2029	2034
CZ2	Max roof PV	Max roof PV	Max roof PV	Max roof PV
	Overnight ventilation	Overnight ventilation	Overnight ventilation	Overnight ventilation
	Perimeter zone daylight harvesting (max visible transmissivity)	Perimeter zone daylight harvesting (max visible transmissivity)	Perimeter zone daylight harvesting (max visible transmissivity)	Perimeter zone daylight harvesting (max visible transmissivity)
	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	Chiller COP 6.33/IPLV 10.12	Lighting power density reduced by 13%	Lighting power density reduced by 26%	Lighting power density reduced by 40%
	Dewpoint cooler	Dewpoint cooler	Dewpoint cooler	Dewpoint cooler
	Lift upgrade	Chiller COP 7.08/IPLV 11.12	Chiller COP 7.83/IPLV 12.12	Chiller COP 8.58/IPLV 12.87
	150mm concrete internal wall thermal mass	R4 external wall insulation	R4 external wall insulation	R4 external wall insulation
	150mm concrete external wall thermal mass	Lift upgrade	Lift upgrade	Lift upgrade
		150mm concrete internal wall thermal mass	150mm concrete internal wall thermal mass	150mm concrete internal wall thermal mass
		150mm concrete external wall thermal mass	150mm concrete external wall thermal mass	150mm concrete external wall thermal mass
			Max BIPV (Wall)	Max BIPV (Wall)
CZ5	Max roof PV	Max roof PV	Max roof PV	Max roof PV
	Overnight ventilation	Overnight ventilation	Overnight ventilation	Overnight ventilation

	Perimeter zone daylight harvesting (WWR x 1.5 + shades)	Perimeter zone daylight harvesting (WWR x 1.5 + shades)	Perimeter zone daylight harvesting (WWR x 1.5 + shades)	Perimeter zone daylight harvesting (WWR x 1.5 + shades)
	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	Chiller COP 6.33/IPLV 10.12	Lighting power density reduced by 13%	Lighting power density reduced by 26%	Lighting power density reduced by 40%
	Dewpoint cooler	Dewpoint cooler	Dewpoint cooler	Dewpoint cooler
	Lift upgrade	Chiller COP 7.08/IPLV 11.12	Chiller COP 7.83/IPLV 12.12	Chiller COP 8.58/IPLV 12.87
	150mm concrete internal wall thermal mass	R2 external wall insulation	R4 external wall insulation	R4 external wall insulation
	150mm concrete external wall thermal mass	Lift upgrade	Lift upgrade	Lift upgrade
		150mm concrete internal wall thermal mass	150mm concrete internal wall thermal mass	150mm concrete internal wall thermal mass
		150mm concrete external wall thermal mass	150mm concrete external wall thermal mass	150mm concrete external wall thermal mass
			Max BIPV (Wall)	Max BIPV (Wall)
CZ6	Max roof PV	Max roof PV	Max roof PV	Max roof PV
	Overnight ventilation	Overnight ventilation	Overnight ventilation	Overnight ventilation
	Perimeter zone daylight harvesting (WWR x 1.5 + shades)	Perimeter zone daylight harvesting (WWR x 1.5 + shades)	Perimeter zone daylight harvesting (WWR x 1.5 + shades)	Perimeter zone daylight harvesting (WWR x 1.5 + shades)
	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction
	R3.5 external wall insulation	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	Heat exchanger installed	Lighting power density reduced by 13%	Lighting power density reduced by 26%	Lighting power density reduced by 40%
	Lighting control by occupancy sensor	Chiller COP 7.08/IPLV 11.12	Chiller COP 7.83/IPLV 12.12	Chiller COP 8.58/IPLV 12.87
	Chiller COP 6.33/IPLV 10.12	Dewpoint cooler	Dewpoint cooler	Dewpoint cooler
	Dewpoint cooler	R3.5 external wall insulation	R3.5 external wall insulation	R3.5 external wall insulation
	Lift upgrade	Lift upgrade	Lift upgrade	Lift upgrade
	150mm concrete internal wall thermal mass	150mm concrete internal wall thermal mass	150mm concrete internal wall thermal mass	150mm concrete internal wall thermal mass
	150mm concrete external wall thermal mass	150mm concrete external wall thermal mass	150mm concrete external wall thermal mass	150mm concrete external wall thermal mass
		Heat exchanger installed	Heat exchanger installed	Heat exchanger installed
			Max BIPV (Wall)	Max BIPV (Wall)
CZ7	Max roof PV	Max roof PV	Max roof PV	Max roof PV
	Overnight ventilation	Overnight ventilation	Overnight ventilation	Overnight ventilation
	Perimeter zone daylight harvesting (WWR x 1.5 + shades)	Perimeter zone daylight harvesting (WWR x 1.5 + shades)	Perimeter zone daylight harvesting (WWR x 1.5 + shades)	Perimeter zone daylight harvesting (WWR x 1.5 + shades)
	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction
	Heat exchanger installed	Heat exchanger installed	Heat exchanger installed	Heat exchanger installed
	R0.83 external wall insulation	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor

	Lighting control by occupancy sensor	Lighting power density reduced by 13%	Lighting power density reduced by 26%	Lighting power density reduced by 26%
	Chiller COP 6.33/IPLV 10.12	Chiller COP 7.08/IPLV 11.12	Chiller COP 7.83/IPLV 12.12	Chiller COP 7.83/IPLV 12.12
	Dewpoint cooler	Dewpoint cooler	Dewpoint cooler	Dewpoint cooler
	Lift upgrade	R3.5 external wall insulation	R3.5 external wall insulation	R5 external wall insulation
	150mm concrete internal wall thermal mass	Lift upgrade	Lift upgrade	Lift upgrade
	150mm concrete external wall thermal mass	150mm concrete internal wall thermal mass	150mm concrete internal wall thermal mass	150mm concrete internal wall thermal mass
		150mm concrete external wall thermal mass	150mm concrete external wall thermal mass	150mm concrete external wall thermal mass
			Max BIPV (Wall)	Max BIPV (Wall)

Table 3-10: Accelerated measures selection for the retail (6C) archetype.

6C	2019	2024	2029	2034
CZ2	Max roof PV	Max roof PV	Max roof PV	Max roof PV
	External wall fabric colour (light colour)	External wall fabric colour (light colour)	Max BIPV (Wall)	Max BIPV (Wall)
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	External wall fabric colour (light colour)	External wall fabric colour (light colour)
	150mm concrete internal wall thermal mass	200mm concrete internal wall thermal mass	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	PAC COP 4.3	PAC COP 4.55	150mm concrete internal wall thermal mass	R4 external wall insulation
	Economy Cycle	Economy Cycle	150mm concrete external wall thermal mass	150mm concrete internal wall thermal mass
		R4 external wall insulation	PAC COP 4.8	150mm concrete external wall thermal mass
		Lighting power density reduced by 13%	Economy Cycle	PAC COP 5.05
			Lighting power density reduced by 26%	Economy Cycle
				Lighting power density reduced by 40%
CZ5	Max roof PV	Max roof PV	Max roof PV	Max roof PV
	External wall fabric colour (light colour)	External wall fabric colour (light colour)	Max BIPV (Wall)	Max BIPV (Wall)
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	External wall fabric colour (light colour)	External wall fabric colour (light colour)
	150mm concrete internal wall thermal mass	R2 external wall insulation	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	PAC COP 4.3	150mm concrete internal wall thermal mass	R8 external wall insulation	150mm concrete internal wall thermal mass
	Economy Cycle	PAC COP 4.55	150mm concrete internal wall thermal mass	150mm concrete external wall thermal mass
	Overnight Ventilation	Economy Cycle	PAC COP 4.8	PAC COP 5.05
		Overnight Ventilation	Economy Cycle	Economy Cycle
		Lighting power density reduced by 13%	Overnight Ventilation	Overnight Ventilation
			Lighting power density reduced by 26%	Lighting power density reduced by 40%

CZ6	Max roof PV	Max roof PV	Max roof PV	Max roof PV
	External wall fabric colour (light colour)	External wall fabric colour (light colour)	Max BIPV (Wall)	Max BIPV (Wall)
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	External wall fabric colour (light colour)	External wall fabric colour (light colour)
	Heat exchanger installed	Heat exchanger installed	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	R1 external wall insulation	R1 external wall insulation	Heat exchanger installed	Heat exchanger installed
	150mm concrete internal wall thermal mass	150mm concrete internal wall thermal mass	R8 external wall insulation	150mm concrete internal wall thermal mass
	150mm concrete external wall thermal mass	150mm concrete external wall thermal mass	150mm concrete internal wall thermal mass	150mm concrete external wall thermal mass
	PAC COP 4.3	PAC COP 4.55	150mm concrete external wall thermal mass	PAC COP 5.05
	Economy Cycle	Economy Cycle	PAC COP 4.8	Economy Cycle
	Overnight Ventilation	Overnight Ventilation	Economy Cycle	Overnight Ventilation
		Lighting power density reduced by 13%	Overnight Ventilation	Lighting power density reduced by 40%
			Lighting power density reduced by 26%	
CZ7	Max roof PV	Max roof PV	Max roof PV	Max roof PV
	External wall fabric colour (light colour)	External wall fabric colour (light colour)	Max BIPV (Wall)	Max BIPV (Wall)
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	External wall fabric colour (light colour)	External wall fabric colour (light colour)
	Heat exchanger installed	Heat exchanger installed	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	150mm concrete internal wall thermal mass	R2 external wall insulation	Heat exchanger installed	Heat exchanger installed
	150mm concrete external wall thermal mass	200mm concrete internal wall thermal mass	R6 external wall insulation	R2 external wall insulation
	PAC COP 4.3	150mm concrete external wall thermal mass	200mm concrete internal wall thermal mass	150mm concrete internal wall thermal mass
	Economy Cycle	PAC COP 4.55	150mm concrete external wall thermal mass	150mm concrete external wall thermal mass
	Overnight Ventilation	Economy Cycle	PAC COP 4.8	PAC COP 5.05
		Overnight Ventilation	Economy Cycle	Economy Cycle
		Lighting power density reduced by 13%	Overnight Ventilation	Overnight Ventilation
			Lighting power density reduced by 26%	Lighting power density reduced by 40%

Table 3-11: Conservative measures selection for the ward area (9aD) archetype.

9aD	2019	2024	2029	2034
CZ2	Max roof PV	Max roof PV	Max roof PV	Max roof PV
	External shutters	External shutters	External shutters	External shutters
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction
	Economy cycle installed	Economy cycle installed	Economy cycle installed	Economy cycle installed

	External wall fabric colour (light colour)	External wall fabric colour (light colour)	External wall fabric colour (light colour)	External wall fabric colour (light colour)
	Chiller 6.33/IPLV 10.12	Chiller 7.08/IPLV 11.12	Chiller 7.83/IPLV 12.12	Chiller 8.58/IPLV 12.87
	Heat exchanger installed	Heat exchanger installed	Heat exchanger installed	Heat exchanger installed
	R8 external wall insulation	Lighting power density reduced by 13%	Lighting power density reduced by 26%	Lighting power density reduced by 40%
		R8 external wall insulation	R8 external wall insulation	R10 external wall insulation
			150mm concrete internal wall thermal mass	200mm concrete internal wall thermal mass
CZ5	Max roof PV	Max roof PV	Max roof PV	Max roof PV
	External shutters	External shutters	External shutters	External shutters
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction
	Economy cycle installed	Economy cycle installed	Economy cycle installed	Economy cycle installed
	Chiller 6.33/IPLV 10.12	Chiller 7.08/IPLV 11.12	Chiller 7.83/IPLV 12.12	Chiller 8.58/IPLV 12.87
	Heat exchanger installed	Heat exchanger installed	Heat exchanger installed	Heat exchanger installed
	R4 external wall insulation	Lighting power density reduced by 13%	Lighting power density reduced by 26%	Lighting power density reduced by 40%
	150mm concrete internal wall thermal mass	R5 external wall insulation	R6 external wall insulation	R8 external wall insulation
		150mm concrete internal wall thermal mass	150mm concrete internal wall thermal mass	150mm concrete internal wall thermal mass
CZ6	Max roof PV	Max roof PV	Max roof PV	Max roof PV
	Perimeter zone daylight harvesting (WWR x 1.5 + shades)	Perimeter zone daylight harvesting (WWR x 1.5 + shades)	Perimeter zone daylight harvesting (WWR x 1.5 + shades)	Perimeter zone daylight harvesting (WWR x 1.5 + shades)
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction
	Economy cycle installed	Economy cycle installed	Economy cycle installed	Economy cycle installed
	Chiller 6.33/IPLV 10.12	Chiller 7.08/IPLV 11.12	Chiller 7.83/IPLV 12.12	Chiller 8.58/IPLV 12.87
	Heat exchanger installed	Heat exchanger installed	Heat exchanger installed	Heat exchanger installed
		Lighting power density reduced by 13%	Lighting power density reduced by 26%	Lighting power density reduced by 40%
		R2 external wall insulation	R3 external wall insulation	R4 external wall insulation
CZ7	Max roof PV	Max roof PV	Max roof PV	Max roof PV
	External shutters	External shutters	External shutters	External shutters
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction	Ductwork pressure reduction
	Chiller 6.33/IPLV 10.12	Chiller 7.08/IPLV 11.12	Chiller 7.83/IPLV 12.12	Chiller 8.58/IPLV 12.87
	Heat exchanger installed	Heat exchanger installed	Heat exchanger installed	Heat exchanger installed
	R2 external wall insulation	Lighting power density reduced by 13%	Lighting power density reduced by 26%	Lighting power density reduced by 40%
		R2.5 external wall insulation	R3 external wall insulation	R3.5 external wall insulation

Table 3-12: Conservative measures selection for the school (9bE) archetype.

9bE	2019	2024	2029	2034
CZ2	Max roof PV	Max roof PV	Max roof PV	Max roof PV
	External wall fabric colour (light colour)	External wall fabric colour (light colour)	Max BIPV (Wall)	Max BIPV (Wall)
	Perimeter zone daylight harvesting (WWR x 1.5 + shades)	Perimeter zone daylight harvesting (WWR x 1.5 + shades)	External wall fabric colour (light colour)	External wall fabric colour (light colour)
	Heat exchanger installed	Heat exchanger installed	Perimeter zone daylight harvesting (WWR x 1.5 + shades)	Perimeter zone daylight harvesting (WWR x 1.5 + shades)
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Heat exchanger installed	Heat exchanger installed
	150mm concrete internal wall thermal mass	150mm concrete internal wall thermal mass	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	150mm concrete external wall thermal mass	150mm concrete external wall thermal mass	150mm concrete internal wall thermal mass	150mm concrete internal wall thermal mass
	PAC COP 4.3	PAC COP 4.55	150mm concrete external wall thermal mass	150mm concrete external wall thermal mass
	R3 external wall insulation	R3 external wall insulation	PAC COP 4.8	PAC COP 5.05
		Lighting power density reduced by 13%	R3 external wall insulation	R4.5 external wall insulation
			Lighting power density reduced by 26%	Lighting power density reduced by 40%
CZ5	Max roof PV	Max roof PV	Max roof PV	Max roof PV
	Perimeter zone daylight harvesting (max visible transmissivity)	Perimeter zone daylight harvesting (max visible transmissivity)	Max BIPV (Wall)	Max BIPV (Wall)
	Heat exchanger installed	Heat exchanger installed	Perimeter zone daylight harvesting (max visible transmissivity)	Perimeter zone daylight harvesting (max visible transmissivity)
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Heat exchanger installed	Heat exchanger installed
	150mm concrete internal wall thermal mass	150mm concrete internal wall thermal mass	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	150mm concrete external wall thermal mass	150mm concrete external wall thermal mass	150mm concrete internal wall thermal mass	150mm concrete internal wall thermal mass
	PAC COP 4.3	PAC COP 4.55	150mm concrete external wall thermal mass	150mm concrete external wall thermal mass
		R8 external wall insulation	PAC COP 4.8	PAC COP 5.05
		Lighting power density reduced by 13%	R8 external wall insulation	R10 external wall insulation
			Lighting power density reduced by 26%	Lighting power density reduced by 40%
CZ6	Max roof PV	Max roof PV	Max roof PV	Max roof PV
	Perimeter zone daylight harvesting (WWR x 1.5 + shades)	Perimeter zone daylight harvesting (WWR x 1.5 + shades)	Max BIPV (Wall)	Max BIPV (Wall)
	Heat exchanger installed	Heat exchanger installed	Perimeter zone daylight harvesting (WWR x 1.5 + shades)	Perimeter zone daylight harvesting (WWR x 1.5 + shades)
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Heat exchanger installed	Heat exchanger installed

	PAC COP 4.3	PAC COP 4.55	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	R0.83 external wall insulation	R6 external wall insulation	PAC COP 4.8	PAC COP 5.05
		Lighting power density reduced by 13%	R8 external wall insulation	R10 external wall insulation
			Lighting power density reduced by 26%	Lighting power density reduced by 40%
CZ7	Max roof PV	Max roof PV	Max roof PV	Max roof PV
	Perimeter zone daylight harvesting (WWR x 1.5 + shades)	Perimeter zone daylight harvesting (WWR x 1.5 + shades)	Max BIPV (Wall)	Max BIPV (Wall)
	Heat exchanger installed	Heat exchanger installed	Perimeter zone daylight harvesting (WWR x 1.5 + shades)	Perimeter zone daylight harvesting (WWR x 1.5 + shades)
	Lighting control by occupancy sensor	Lighting control by occupancy sensor	Heat exchanger installed	Heat exchanger installed
	PAC COP 4.3	PAC COP 4.55	Lighting control by occupancy sensor	Lighting control by occupancy sensor
	R0.83 external wall insulation	R6 external wall insulation	PAC COP 4.8	PAC COP 5.05
		Lighting power density reduced by 13%	R6 external wall insulation	R8 external wall insulation
			Lighting power density reduced by 26%	Lighting power density reduced by 40%

3.3 Benefit Cost Ratios

The benefit-cost ratios for the conservative and accelerated multi-dimensional models, for both the energy efficiency and net trajectories are presented in Table 3-13 to Table 3-16 below. 0 years refers to what's cost effective in 2019 and 15 years refers to what will be cost effective in 2034 (refer 1.2). Please note that the 3 year steps presented in these tables were interpolated to match NCC period for the expected revision timeline for the Code. The actual simulation was in 5 year steps (refer 1.2).

Table 3-13: Conservative BCRs

Climate Zone	Model	Base case	2019	2022	2024	2025	2028	2029	2031	2034
CZ2	Hotel	-	1.43	1.20	1.04	1.08	1.19	1.23	1.28	1.35
CZ2	Office	-	1.08	1.10	1.12	1.10	1.06	1.05	1.18	1.38
CZ2	Retail	-	1.32	1.25	1.20	1.16	1.05	1.02	1.06	1.12
CZ2	Hospital Ward	-	1.04	1.26	1.40	1.40	1.37	1.37	1.35	1.31
CZ2	School	-	1.20	1.17	1.15	1.21	1.38	1.44	1.42	1.39
CZ5	Hotel	-	1.41	1.43	1.44	1.39	1.24	1.19	1.26	1.37
CZ5	Office	-	1.02	1.08	1.12	1.16	1.28	1.32	1.22	1.07
CZ5	Retail	-	1.19	1.31	1.40	1.33	1.14	1.07	1.08	1.10
CZ5	Hospital Ward	-	1.09	1.23	1.32	1.32	1.33	1.33	1.29	1.24
CZ5	School	-	1.29	1.24	1.21	1.26	1.41	1.47	1.39	1.27
CZ6	Hotel	-	1.25	1.18	1.14	1.15	1.20	1.22	1.25	1.30
CZ6	Office	-	1.02	1.30	1.48	1.39	1.11	1.02	1.18	1.41
CZ6	Retail	-	1.43	1.31	1.23	1.19	1.09	1.05	1.08	1.12
CZ6	Hospital Ward	-	1.16	1.32	1.42	1.41	1.37	1.35	1.37	1.39
CZ6	School	-	1.03	1.28	1.45	1.43	1.35	1.33	1.31	1.28
CZ7	Hotel	-	1.04	1.10	1.14	1.14	1.13	1.12	1.10	1.08
CZ7	Office	-	1.17	1.32	1.43	1.35	1.14	1.07	1.16	1.29
CZ7	Retail	-	1.10	1.08	1.06	1.06	1.08	1.09	1.13	1.19
CZ7	Hospital Ward	-	1.09	1.20	1.27	1.29	1.36	1.38	1.41	1.45
CZ7	School	-	1.03	1.09	1.12	1.18	1.35	1.40	1.34	1.24

Table 3-14: Accelerated BCRs

Climate Zone	Model	Base case	2019	2022	2024	2025	2028	2029	2031	2034
CZ2	Hotel	-	1.78	1.37	1.09	1.12	1.21	1.24	1.29	1.36
CZ2	Office	-	0.28	0.32	0.35	0.36	0.40	0.41	0.44	0.49
CZ2	Retail	-	1.97	1.64	1.41	1.34	1.11	1.04	1.05	1.07
CZ2	Hospital Ward	-	1.12	1.27	1.37	1.36	1.33	1.32	1.30	1.28
CZ2	School	-	0.18	0.21	0.22	0.23	0.25	0.26	0.27	0.29
CZ5	Hotel	-	1.59	1.48	1.42	1.36	1.19	1.14	1.24	1.40
CZ5	Office	-	0.14	0.16	0.17	0.18	0.19	0.20	0.21	0.24
CZ5	Retail	-	0.89	1.01	1.08	1.04	0.93	0.89	0.90	0.90
CZ5	Hospital Ward	-	1.24	1.29	1.32	1.33	1.37	1.39	1.34	1.28
CZ5	School	-	0.29	0.29	0.30	0.30	0.33	0.33	0.35	0.36
CZ6	Hotel	-	1.73	1.39	1.16	1.17	1.19	1.20	1.23	1.27
CZ6	Office	-	0.13	0.15	0.17	0.17	0.19	0.20	0.22	0.24
CZ6	Retail	-	0.25	0.24	0.23	0.24	0.27	0.28	0.37	0.51
CZ6	Hospital Ward	-	0.20	0.23	0.25	0.26	0.28	0.29	0.30	0.32
CZ6	School	-	0.35	0.36	0.36	0.37	0.38	0.39	0.40	0.42
CZ7	Hotel	-	1.22	1.19	1.18	1.17	1.14	1.13	1.11	1.09
CZ7	Office	-	0.16	0.18	0.19	0.20	0.22	0.23	0.24	0.26
CZ7	Retail	-	0.34	0.31	0.28	0.29	0.33	0.34	0.47	0.66
CZ7	Hospital Ward	-	0.92	1.00	1.05	1.07	1.13	1.15	1.17	1.22
CZ7	School	-	0.32	0.34	0.35	0.36	0.39	0.40	0.41	0.43

Table 3-15: Conservative Net BCRs

Climate Zone	Model	Base case	2019	2022	2024	2025	2028	2029	2031	2034
CZ2	Hotel	-	1.82	1.48	1.26	1.33	1.53	1.59	1.65	1.73
CZ2	Office	-	1.41	1.42	1.43	1.54	1.88	2.00	2.19	2.47
CZ2	Retail	-	4.10	3.34	2.84	2.68	2.21	2.05	1.97	1.84
CZ2	Hospital Ward	-	1.52	1.74	1.89	1.87	1.79	1.77	1.72	1.66
CZ2	School	-	6.62	3.97	2.19	2.27	2.50	2.58	2.49	2.36
CZ5	Hotel	-	1.73	1.74	1.74	1.69	1.56	1.51	1.60	1.73
CZ5	Office	-	1.44	1.51	1.55	1.81	2.59	2.85	2.52	2.04
CZ5	Retail	-	3.99	3.75	3.60	3.33	2.51	2.24	2.07	1.82
CZ5	Hospital Ward	-	1.53	1.64	1.72	1.72	1.70	1.70	1.64	1.55
CZ5	School	-	9.45	4.98	1.99	2.06	2.24	2.30	2.16	1.94
CZ6	Hotel	-	1.96	1.72	1.56	1.60	1.74	1.78	1.81	1.86
CZ6	Office	-	1.43	1.84	2.11	2.15	2.24	2.27	2.47	2.78
CZ6	Retail	-	4.36	3.71	3.28	3.07	2.45	2.24	2.11	1.92
CZ6	Hospital Ward	-	2.40	2.17	2.02	1.98	1.89	1.86	1.84	1.82
CZ6	School	-	3.55	2.65	2.05	2.00	1.85	1.80	1.76	1.69
CZ7	Hotel	-	1.53	1.56	1.58	1.60	1.66	1.68	1.64	1.58
CZ7	Office	-	1.85	1.98	2.07	2.14	2.34	2.41	2.44	2.47
CZ7	Retail	-	3.23	2.97	2.79	2.69	2.39	2.29	2.18	2.02
CZ7	Hospital Ward	-	1.65	1.74	1.80	1.82	1.88	1.89	1.91	1.94
CZ7	School	-	2.43	2.01	1.74	1.81	2.02	2.09	1.98	1.82

Table 3-16: Accelerated Net BCRs

Climate Zone	Model	Base case	2019	2022	2024	2025	2028	2029	2031	2034
CZ2	Hotel	-	2.13	1.62	1.28	1.34	1.52	1.58	1.63	1.70
CZ2	Office	-	0.36	0.40	0.43	0.48	0.63	0.68	0.72	0.77
CZ2	Retail	-	4.49	3.47	2.79	2.62	2.12	1.96	1.88	1.75
CZ2	Hospital Ward	-	1.43	1.60	1.71	1.70	1.64	1.63	1.60	1.55
CZ2	School	-	0.28	0.32	0.34	0.35	0.38	0.39	0.41	0.43
CZ5	Hotel	-	1.88	1.74	1.65	1.61	1.48	1.44	1.51	1.61
CZ5	Office	-	0.18	0.21	0.22	0.25	0.32	0.34	0.36	0.39
CZ5	Retail	-	2.01	2.07	2.11	2.02	1.74	1.65	1.57	1.45
CZ5	Hospital Ward	-	1.53	1.57	1.60	1.61	1.65	1.67	1.60	1.51
CZ5	School	-	0.44	0.43	0.43	0.44	0.47	0.48	0.49	0.50
CZ6	Hotel	-	2.38	1.86	1.51	1.55	1.68	1.72	1.74	1.76
CZ6	Office	-	0.17	0.20	0.22	0.23	0.29	0.30	0.32	0.34
CZ6	Retail	-	0.57	0.50	0.45	0.47	0.51	0.52	0.65	0.84
CZ6	Hospital Ward	-	0.34	0.37	0.39	0.40	0.43	0.44	0.45	0.46
CZ6	School	-	0.47	0.46	0.46	0.47	0.48	0.49	0.50	0.51
CZ7	Hotel	-	1.61	1.55	1.51	1.54	1.60	1.62	1.58	1.53
CZ7	Office	-	0.21	0.23	0.25	0.26	0.31	0.32	0.33	0.35
CZ7	Retail	-	0.83	0.68	0.57	0.59	0.64	0.65	0.83	1.10
CZ7	Hospital Ward	-	1.30	1.39	1.45	1.47	1.54	1.56	1.58	1.62
CZ7	School	-	0.49	0.50	0.51	0.53	0.57	0.58	0.59	0.61

3.4 Energy Efficiency Trajectories: Energy consumption after implementation of energy efficiency measures

The trajectories (whole building energy combining gas and electricity) for the conservative and accelerated models are presented in Table 3-17 and Table 3-18 below. The energy has been normalised by floor area in a similar manner to the residential modelling.

Table 3-17: Conservative Trajectory (kWh/m²)

Climate Zone	Model	Base case	2019	2022	2024	2025	2028	2029	2031	2034
CZ2	Hotel	130.32	95.21	89.69	86.00	85.10	82.38	81.47	80.46	78.94
CZ2	Office	99.60	85.70	83.24	81.60	80.70	78.01	77.12	75.68	73.54
CZ2	Retail	129.05	107.60	99.81	94.62	91.60	82.54	79.52	74.16	66.11
CZ2	Hospital Ward	138.46	89.40	85.94	83.63	82.89	80.68	79.94	79.12	77.88
CZ2	School	93.46	73.46	57.81	47.37	46.55	44.11	43.29	42.38	41.01
CZ5	Hotel	127.21	89.64	84.95	81.82	81.00	78.56	77.74	77.02	75.95
CZ5	Office	91.37	80.33	77.83	76.17	75.42	73.17	72.42	71.16	69.27
CZ5	Retail	116.94	97.19	92.43	89.25	86.50	78.25	75.50	70.42	62.80
CZ5	Hospital Ward	140.29	92.03	89.20	87.32	86.88	85.54	85.10	84.36	83.26
CZ5	School	76.68	54.04	41.64	33.37	32.92	31.57	31.13	30.65	29.94
CZ6	Hotel	99.22	82.33	78.98	76.74	76.23	74.69	74.18	73.45	72.35
CZ6	Office	88.54	73.28	72.31	71.67	70.99	68.95	68.27	66.98	65.03
CZ6	Retail	109.02	89.27	86.52	84.69	82.12	74.40	71.83	67.60	61.25
CZ6	Hospital Ward	128.91	120.54	103.14	91.54	91.40	90.98	90.84	89.45	87.38
CZ6	School	77.93	50.94	40.03	32.75	32.28	30.88	30.41	29.41	27.91
CZ7	Hotel	102.03	87.40	83.83	81.45	80.92	79.30	78.77	78.25	77.49
CZ7	Office	93.10	83.30	76.57	72.08	71.41	69.39	68.71	67.47	65.61
CZ7	Retail	110.03	87.51	85.36	83.93	81.45	74.00	71.52	67.36	61.12
CZ7	Hospital Ward	144.12	107.63	106.27	105.37	105.05	104.07	103.75	103.25	102.50
CZ7	School	90.23	61.26	50.83	43.88	43.15	40.97	40.24	39.71	38.92

Table 3-18: Accelerated Trajectory (kWh/m²)

Climate Zone	Model	Base case	2019	2022	2024	2025	2028	2029	2031	2034
CZ2	Hotel	130.32	82.85	81.37	80.38	79.82	78.12	77.56	76.70	75.42
CZ2	Office	99.60	74.17	72.44	71.29	71.03	70.24	69.98	68.97	67.45
CZ2	Retail	129.05	94.85	89.01	85.11	83.23	77.60	75.72	71.84	66.01
CZ2	Hospital Ward	138.46	71.29	70.17	69.42	69.01	67.78	67.37	66.69	65.67
CZ2	School	93.46	43.28	41.98	41.11	40.76	39.71	39.36	38.61	37.49
CZ5	Hotel	127.21	78.68	77.16	76.14	75.64	74.13	73.62	71.72	68.86
CZ5	Office	91.37	69.17	67.94	67.11	66.99	66.63	66.52	65.52	64.02
CZ5	Retail	116.94	86.68	81.57	78.17	76.44	71.26	69.53	66.18	61.15
CZ5	Hospital Ward	140.29	67.68	66.57	65.83	65.46	64.35	63.98	63.36	62.43
CZ5	School	76.68	35.47	33.42	32.05	31.96	31.68	31.59	30.78	29.55
CZ6	Hotel	99.22	73.48	72.59	72.00	71.67	70.68	70.35	69.72	68.78
CZ6	Office	88.54	62.30	61.23	60.52	60.20	59.25	58.93	58.17	57.02
CZ6	Retail	109.02	83.19	78.70	75.71	74.09	69.22	67.60	64.72	60.39
CZ6	Hospital Ward	128.91	79.60	76.79	74.92	74.40	72.85	72.33	71.48	70.21
CZ6	School	77.93	28.66	27.72	27.09	26.71	25.56	25.17	24.92	24.54
CZ7	Hotel	102.03	74.76	73.13	72.04	71.68	70.60	70.24	69.62	68.70
CZ7	Office	93.10	61.27	60.07	59.27	58.88	57.70	57.31	56.60	55.55
CZ7	Retail	110.03	83.54	78.96	75.91	74.33	69.60	68.02	65.09	60.70
CZ7	Hospital Ward	144.12	76.65	74.90	73.74	73.24	71.73	71.23	70.36	69.06
CZ7	School	90.23	41.96	39.97	38.65	38.32	37.34	37.01	36.51	35.77

3.5 Net Energy Trajectories: Energy consumption after implementation of energy efficiency plus on-site generation measures

The net trajectories (whole building energy combining gas and electricity) for the conservative and accelerated models are presented in Table 3-19 and Table 3-20 below. The energy has been normalised by floor area in a similar manner to the residential modelling.

Table 3-19: Conservative Net Trajectory (kWh/m²)

Climate Zone	Model	Base case	2019	2022	2024	2025	2028	2029	2031	2034
CZ2	Hotel	130.32	82.56	76.48	72.43	70.34	64.06	61.97	60.74	58.89
CZ2	Office	99.60	81.22	78.31	76.38	71.58	57.18	52.38	50.06	46.59
CZ2	Retail	129.05	65.54	54.43	47.02	41.79	26.10	20.87	18.83	15.78
CZ2	Hospital Ward	138.46	52.74	50.69	49.32	48.64	46.62	45.94	45.36	44.49
CZ2	School	93.46	23.87	13.58	6.72	6.07	4.13	3.49	3.20	2.77
CZ5	Hotel	127.21	78.04	72.86	69.41	67.70	62.59	60.88	59.99	58.66
CZ5	Office	91.37	75.93	72.99	71.03	66.60	53.31	48.88	46.72	43.48
CZ5	Retail	116.94	56.52	49.61	45.01	40.42	26.66	22.07	19.94	16.74
CZ5	Hospital Ward	140.29	61.84	59.59	58.08	57.61	56.20	55.73	55.13	54.23
CZ5	School	76.68	12.60	7.81	4.62	4.37	3.63	3.39	3.21	2.93
CZ6	Hotel	99.22	70.82	66.97	64.41	63.01	58.80	57.40	56.50	55.15
CZ6	Office	88.54	69.11	67.73	66.81	62.54	49.74	45.47	43.30	40.05
CZ6	Retail	109.02	50.85	46.01	42.79	38.50	25.62	21.32	19.66	17.15
CZ6	Hospital Ward	128.91	93.18	75.97	64.51	64.33	63.79	63.61	62.38	60.53
CZ6	School	77.93	16.58	11.12	7.49	7.09	5.92	5.52	5.06	4.37
CZ7	Hotel	102.03	75.11	71.01	68.29	66.70	61.94	60.35	59.69	58.69
CZ7	Office	93.10	78.43	71.21	66.40	61.55	47.03	42.18	39.97	36.64
CZ7	Retail	110.03	45.39	41.64	39.13	35.15	23.21	19.23	17.75	15.53
CZ7	Hospital Ward	144.12	79.04	78.11	77.49	77.10	75.95	75.56	75.20	74.64
CZ7	School	90.23	18.69	13.28	9.67	8.97	6.89	6.19	5.86	5.36

Table 3-20: Accelerated Net Trajectory (kWh/m²)

Climate Zone	Model	Base case	2019	2022	2024	2025	2028	2029	2031	2034
CZ2	Hotel	130.32	70.44	69.05	68.12	66.20	60.44	58.52	57.79	56.69
CZ2	Office	99.60	67.30	65.57	64.42	59.93	46.45	41.96	41.13	39.88
CZ2	Retail	129.05	53.58	45.65	40.37	36.21	23.73	19.58	18.06	15.79
CZ2	Hospital Ward	138.46	38.72	38.06	37.62	37.03	35.23	34.63	34.26	33.71
CZ2	School	93.46	7.00	5.86	5.10	4.70	3.48	3.08	2.87	2.56
CZ5	Hotel	127.21	67.28	65.84	64.88	63.32	58.65	57.09	56.55	55.74
CZ5	Office	91.37	62.37	61.14	60.32	56.17	43.71	39.56	38.73	37.47
CZ5	Retail	116.94	47.72	41.78	37.82	34.26	23.59	20.03	18.58	16.39
CZ5	Hospital Ward	140.29	39.80	39.01	38.49	37.94	36.29	35.74	35.34	34.73
CZ5	School	76.68	6.06	4.97	4.24	4.05	3.49	3.30	3.08	2.76
CZ6	Hotel	99.22	62.15	61.34	60.81	59.44	55.34	53.98	53.48	52.72
CZ6	Office	88.54	55.71	54.66	53.96	49.96	37.95	33.94	33.27	32.25
CZ6	Retail	109.02	46.20	40.69	37.02	33.69	23.71	20.38	19.05	17.06
CZ6	Hospital Ward	128.91	50.57	48.26	46.72	45.97	43.72	42.97	42.34	41.39
CZ6	School	77.93	5.45	4.95	4.62	4.35	3.54	3.28	3.16	2.98
CZ7	Hotel	102.03	62.70	61.15	60.12	58.55	53.84	52.28	51.77	51.00
CZ7	Office	93.10	54.00	52.80	52.01	47.45	33.78	29.22	28.61	27.68
CZ7	Retail	110.03	42.40	37.38	34.04	30.86	21.34	18.17	17.06	15.39
CZ7	Hospital Ward	144.12	48.58	47.18	46.24	45.49	43.23	42.47	41.83	40.87
CZ7	School	90.23	8.62	7.39	6.56	6.13	4.83	4.40	4.18	3.85

The corresponding charts for the trajectories in the tables above are illustrated in Figure 10 to Figure 13 below. Both the conservative and accelerated energy efficiency and net trajectories are presented for each commercial archetype and climate zone modelled.

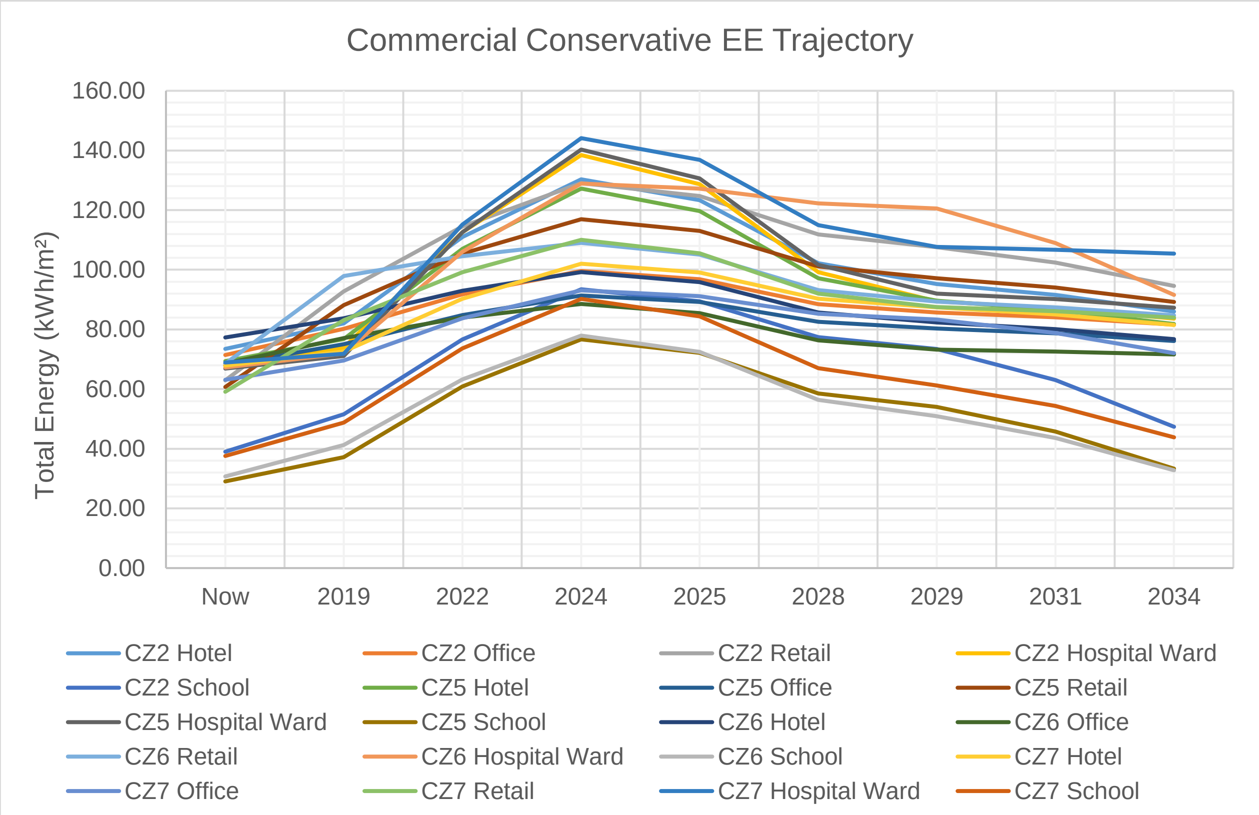


Figure 10: Conservative Energy trajectories for Commercial archetypes

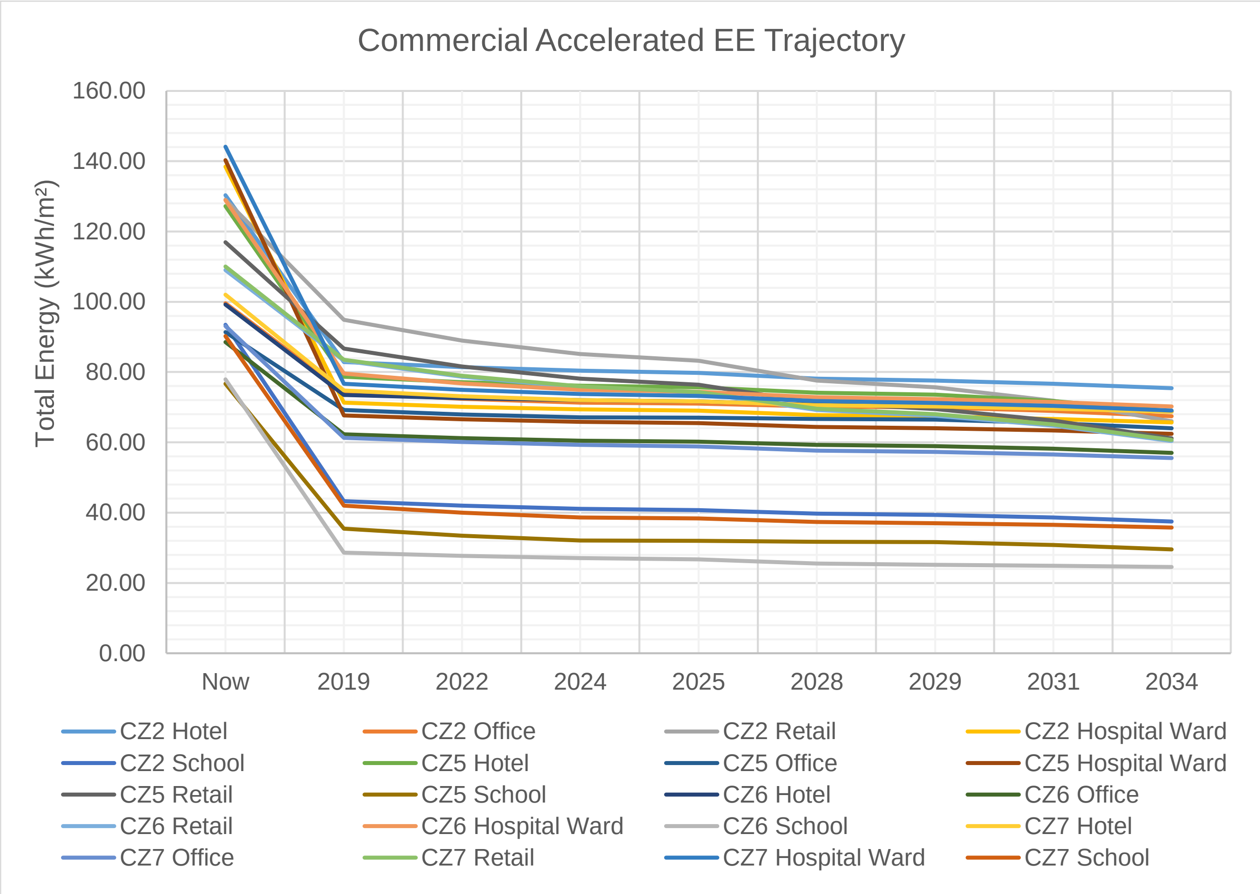


Figure 11: Accelerated Energy trajectories for commercial archetype.

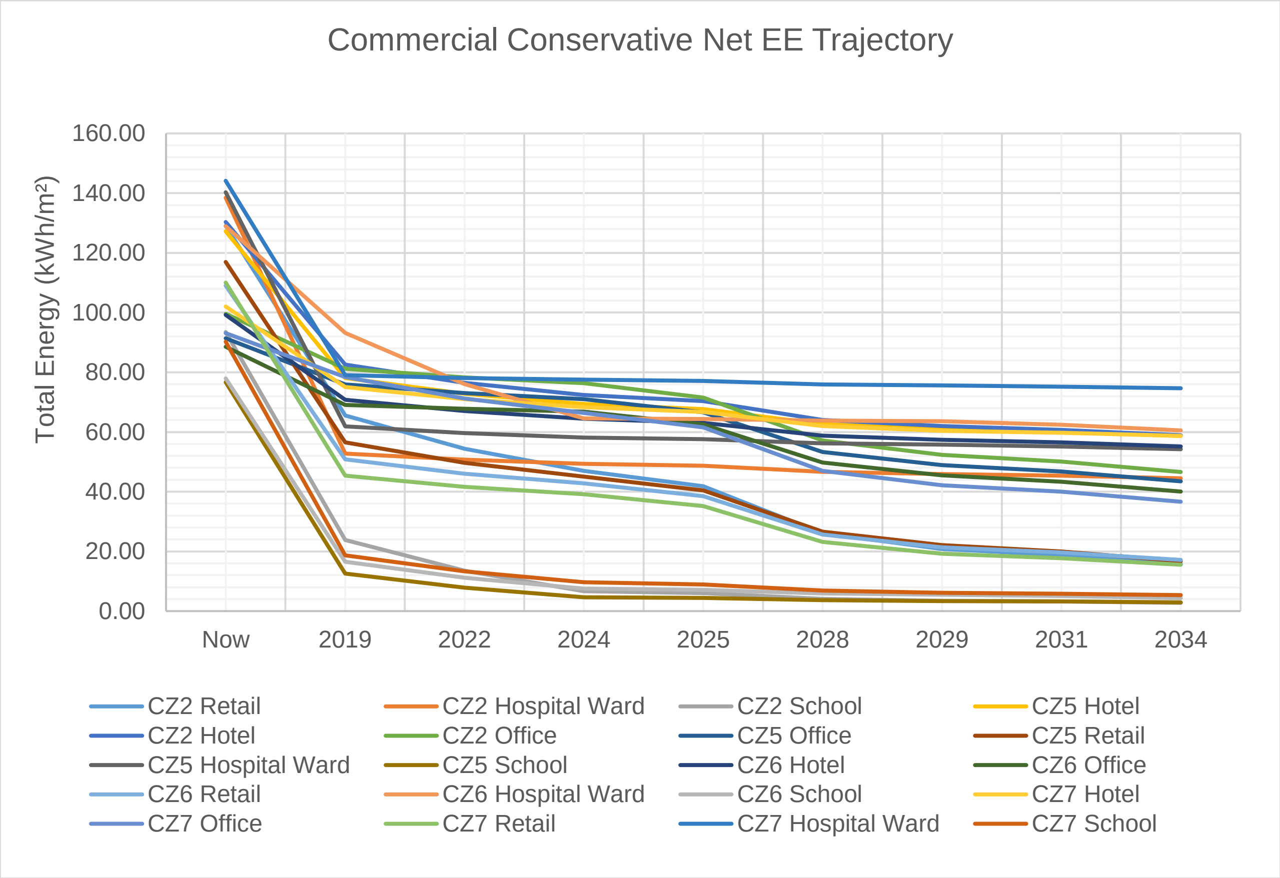


Figure 12: Conservative Net Energy trajectories for the commercial archetype.

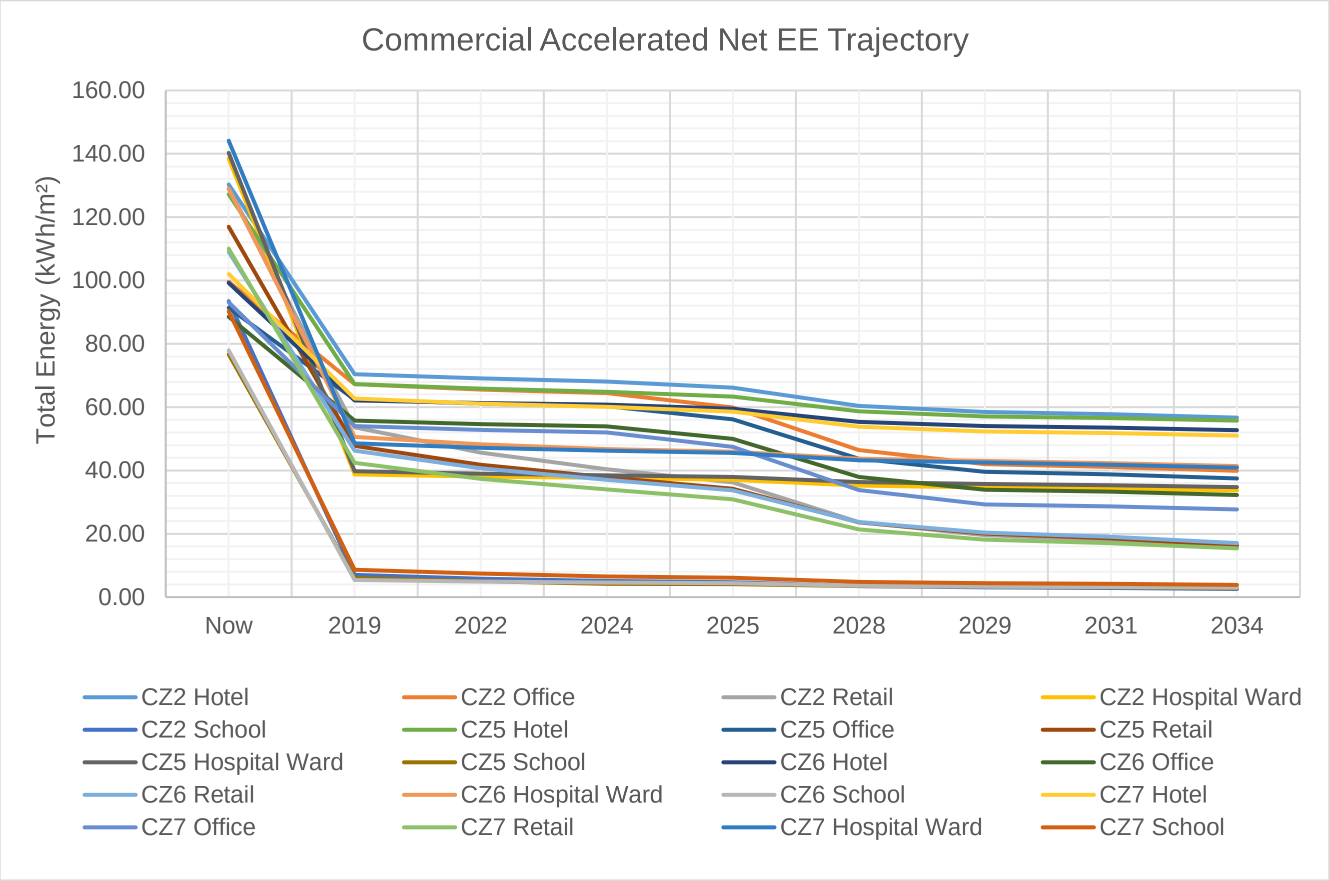


Figure 13: Accelerated Net Energy trajectories for the commercial archetype.

4 National Estimation

4.1 Methodology

The general approach to estimating the national consequences of achieving the modelling improvements in building-level energy performance involves the following steps. Further details on the building stock model and translation from modelled to non-modelled climate zones and building forms is provided in Appendix K.

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.

The national estimation was undertaken for the following scenarios as presented in Sections 2 and 3:

- Conservative energy efficiency (EE) trajectory
- Accelerated deployment EE trajectory
- Conservative net trajectory
- Accelerated deployment net trajectory

4.2 Energy Savings

The energy savings are categorised according to the classes of buildings outlined in Sections 2 and 3. The energy savings of residential and commercial buildings are calculated based on the differential between the baseline energy intensity (2016 NCC requirements for the residential archetypes and the proposed 2019 NCC requirements for the commercial archetypes) and the estimated energy intensity for each NCC upgrade, multiplied by the cumulative annual additions to the building stock of each class. It is assumed that periodic changes to the NCC are applied to new builds with a one-year lag, starting from the 2022 NCC.

4.2.1 Residential sector

Figure 4-1 shows the energy savings from the Conservative EE trajectory for 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 residential builds are not using natural gas.

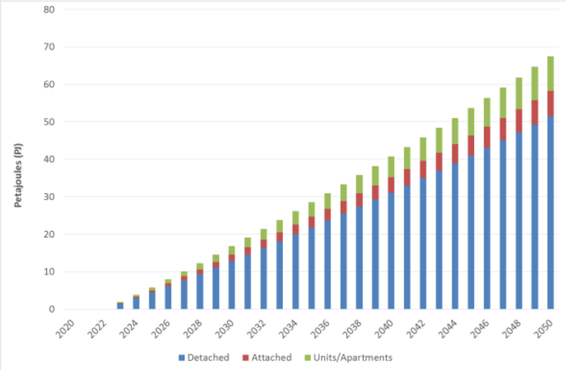


Figure 4-1: Conservative EE Trajectory, Residential Building Energy Savings by Type, Australia (PJ), 2023-2050

Detached occupies the largest energy savings, followed by Units/Apartments and Attached. The energy savings for residential buildings increases from around 17 PJ in 2030 to 67 PJ in 2050. By 2050, the NCC trajectory code change results in around 51 PJ, 8 PJ and 9 PJ of energy savings in Detached, Attached and Units/Apartments respectively.

Energy savings in residential buildings vary by state and territory over the projection period. Decadal snapshot years starting from 2020 and ending in 2050 have been chosen to reflect the change (Figure 4-2).

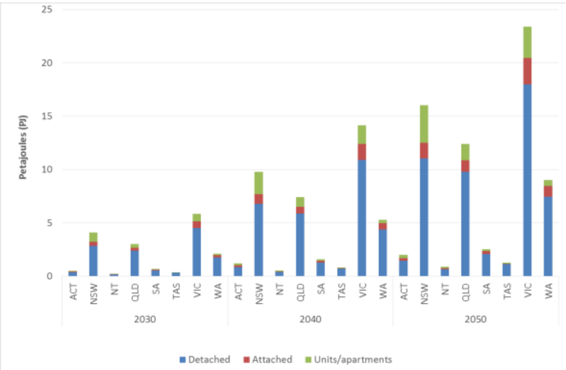


Figure 4-2: Conservative EE Trajectory, Residential Building Energy Savings by Type, State/Territory (PJ), 2030, 2040, 2050

The greatest energy savings are in VIC, NSW and QLD reflecting percentage growth in new builds off a large base. By the end of 2050, VIC has around 23.5 PJ energy savings, NSW has 16 PJ energy savings, and QLD has 12.3 PJ energy savings respectively. 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, VIC and QLD, which complies with the national results. While in WA and SA, the Attached energy savings share is larger than Units/Apartments energy savings share.

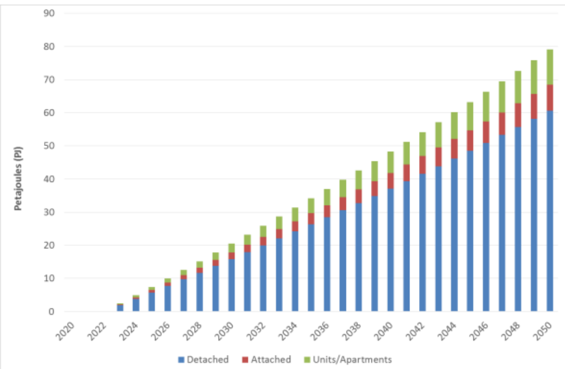


Figure 4-3: Accelerated EE Trajectory, Residential Building Energy Savings by Type, Australia (PJ), 2023-2050

For the Accelerated EE trajectory (Figure 4-3), the energy savings for residential buildings increases from around 20 PJ in 2030 to 79 PJ in 2050. By 2050, the NCC trajectory code changes results in around 61 PJ, 8 PJ and 10 PJ of energy savings in Detached, Attached and Units/Apartments respectively.

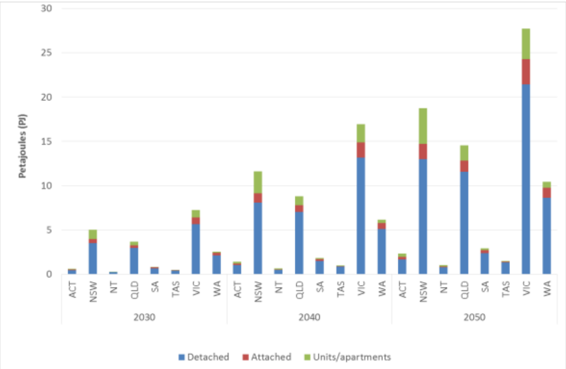


Figure 4-4: Accelerated EE Trajectory, Residential Building Energy Savings by Type, State/Territory (PJ), 2030, 2040, 2050

Similar to the national results, Detached dominate the energy savings in all the states/territories (Figure 4-4). The Attached energy savings share is less than the Units/Apartments energy savings share in NSW, VIC and QLD, which complies with the national results. While in WA and SA, the Attached energy savings share is larger than Units/Apartments energy savings share.

In regard to the Conservative Net trajectory (Figure 4-5), the energy savings for residential buildings increases significantly from around 124 PJ in 2030 to 740 PJ in 2050. By 2050, the NCC trajectory code change results in around 685 PJ, 43 PJ and 14 PJ of energy savings in Detached, Attached and Units/Apartments respectively.

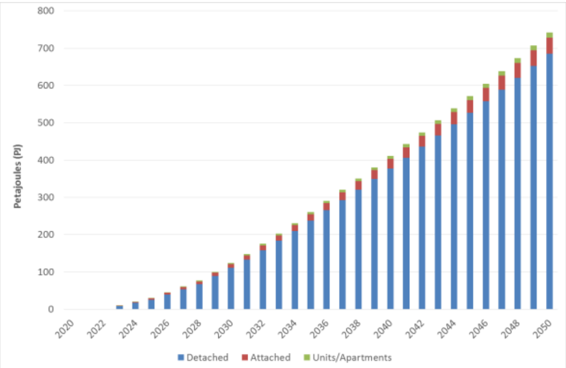


Figure 4-5: Conservative Net Trajectory, Residential Building Energy Savings by Type, Australia (PJ), 2023-2050

The significant increase, particularly in Detached, reflects the scale of rooftop solar PV deployment in this scenario. All detached new builds from 2023 onwards, and all attached new builds from 2026 onwards, produce more electricity than they consume on an annual basis. The amount of surplus electricity production increases with every code change in the trajectory. Accordingly, “energy savings” has a different meaning in this scenario, reducing the consumption of grid electricity.

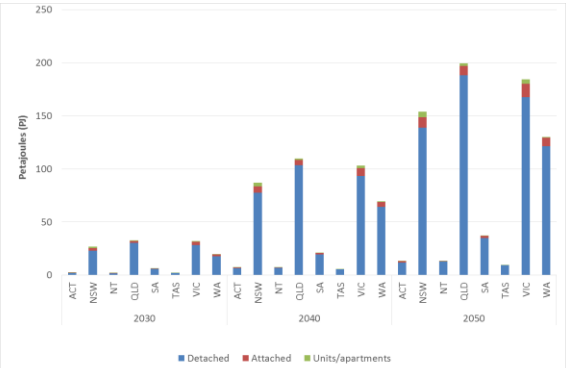


Figure 4-6: Conservative Net Trajectory, Residential Building Energy Savings by Type, State/Territory (PJ), 2030, 2040, 2050

The scale of the energy savings for residential is also evident in the state and territory estimates (Figure 4-6). However, QLD dominates reflecting the superior solar resource in that state, significantly increasing the energy savings from Detached dwellings. This influence is also evident for WA.

For the Accelerated Net trajectory (Figure 4-7), the energy savings for residential buildings increases significantly from around 180 PJ in 2030 to 770 PJ in 2050. By 2050, the NCC trajectory code change results in around 707 PJ, 46 PJ and 15 PJ of energy savings in Detached, Attached and Units/Apartments respectively.

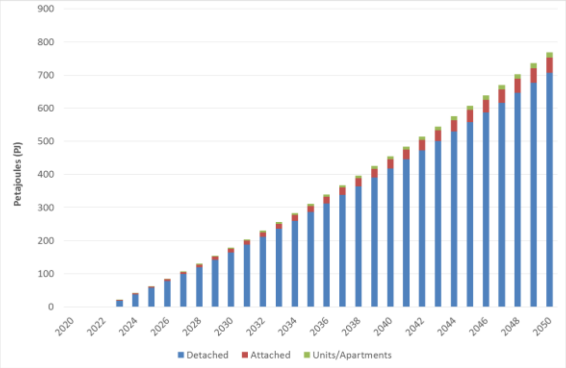


Figure 4-7: Accelerated Net Trajectory, Residential Building Energy Savings by Type, Australia (PJ), 2023-2050

Similar to the Conservative Net trajectory, the amount of surplus electricity production increases with every code change in the trajectory, reducing the consumption of grid electricity. In regard to the state and territory estimates (Figure 4-8), the distribution of energy savings is similar to the Conservative Net trajectory.

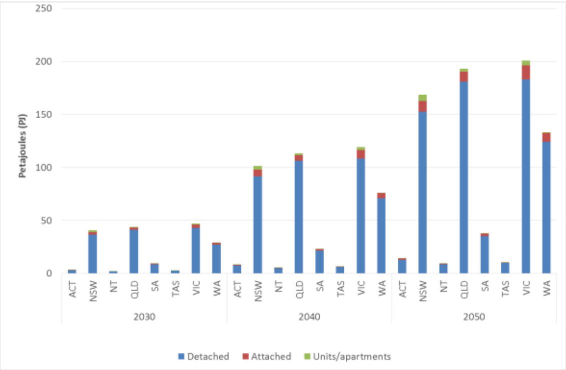


Figure 4-8: Accelerated Net Trajectory, Residential Building Energy Savings by Type, State/Territory (PJ), 2030, 2040, 2050

4.2.2 Commercial sector

Figure 4-9 shows the energy savings from the Conservative EE trajectory for the nine classes of commercial building examined: Hotels, Offices, Retail, Warehouses, Laboratories, Hospitals, Schools, Aged care, and Public Buildings. It should be noted here, energy savings refer to electricity and gas savings.

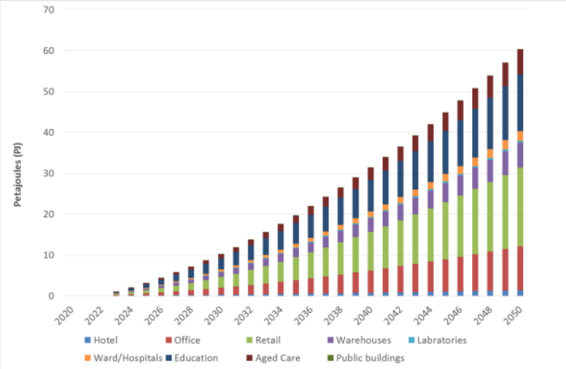


Figure 4-9: Conservative EE Trajectory, Commercial Building Energy Savings by Type, Australia (PJ), 2023-2050

Retail occupies the largest energy savings, followed by Schools, Offices and Aged Care. The energy savings for commercial buildings increases from around 10 PJ in 2030 to 60 PJ in 2050. By 2050, the NCC trajectory code change results in energy savings of around 1.4 PJ in Hotels, 10.8 PJ in Offices, 19.2 PJ in Retail, 6.1 PJ in Warehouses, 0.5 PJ in Laboratories, 2.4 PJ in Hospitals, 13.9 PJ in Schools, 6.1 PJ in Aged care, and 0.07 PJ in Public Buildings.

Energy savings for commercial buildings vary by state and territory over the projection period. Decadal snapshot years starting from 2030 and ending in 2050 have been chosen to reflect the change.

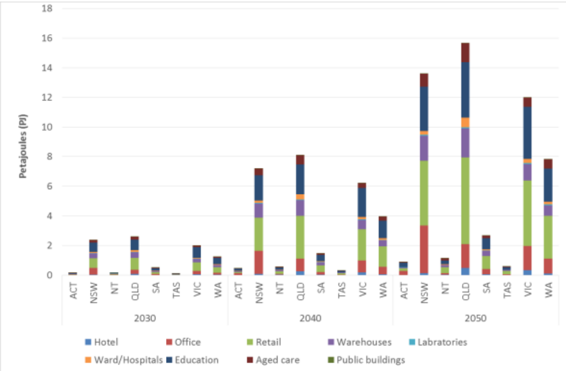


Figure 4-10: Conservative EE Trajectory, Commercial Building Energy Savings by Type, State/Territory (PJ), 2030, 2040, 2050

The largest share of retail building energy savings occurs in QLD, then NSW followed by VIC. The result for QLD reflects high expected growth rates in new builds and higher savings per new build due to the dominance of climate zone 2 in the state.

The largest share of office building energy savings occurs in NSW, then VIC followed by QLD. The result for NSW reflects high expected growth rates in new builds off a large base.

The largest share of education building energy savings occurs in QLD, then VIC followed by NSW. The result for QLD reflects higher expected growth rates than the other states.

For the Accelerated EE trajectory (Figure 4-11), the energy savings for commercial buildings increases from around 11 PJ in 2030 to 70 PJ in 2050. By 2050, the NCC trajectory code change results in energy savings of around 1.2 PJ in Hotels, 11.8 PJ in Offices, 20.3 PJ in Retail, 6.2 PJ in Warehouses, 0.4 PJ in Laboratories, 1.3 PJ in Hospitals, 14.9 PJ in Schools, 3.3 PJ in Aged care, and 0.06 PJ in Public Buildings.

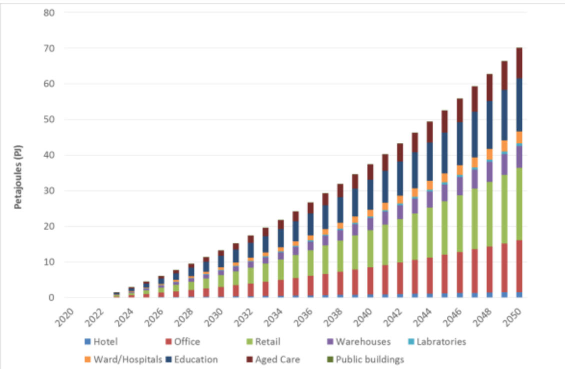


Figure 4-11: Accelerated EE Trajectory, Commercial Building Energy Savings by Type, Australia (PJ), 2023-2050

Energy savings for commercial buildings vary by state and territory over the projection period, but follow a similar pattern to the Conservative EE trajectory (Figure 4-12).

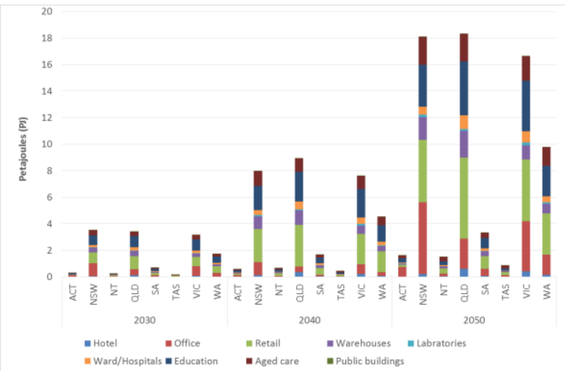


Figure 4-12: Accelerated EE Trajectory, Commercial Building Energy Savings by Type, State/Territory (PJ), 2030, 2040, 2050

In regard to the Conservative Net trajectory (Figure 4-13), the energy savings for commercial buildings increases from around 18 PJ in 2030 to 104 PJ in 2050. By 2050, the NCC trajectory code change results in energy savings of around 2.1 PJ in Hotels, 19.2 PJ in Offices, 38.1 PJ in Retail, 10.8 PJ in Warehouses, 0.6 PJ in Laboratories, 2.9 PJ in Hospitals, 22.4 PJ in Schools, 7.4 PJ in Aged care, and 0.1 PJ in Public Buildings.

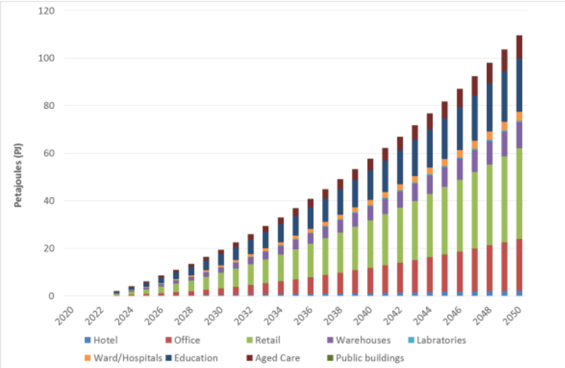


Figure 4-13: Conservative Net Trajectory, Commercial Building Energy Savings by Type, Australia (PJ), 2030, 2040, 2050

Energy savings for commercial buildings vary by state and territory over the projection period, but follow a similar pattern to the Conservative EE and Accelerated EE trajectories (Figure 4-14).

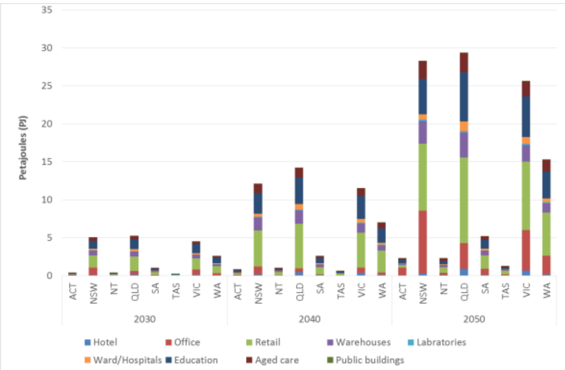


Figure 4-14: Conservative Net Trajectory, Commercial Building Energy Savings by Type, State/Territory (PJ), 2030, 2040, 2050

For the Accelerated Net trajectory (Figure 4-15), the energy savings for commercial buildings increases from around 22 PJ in 2030 to 117 PJ in 2050. By 2050, the NCC trajectory code change results in energy savings of around 2.2 PJ in Hotels, 25.8 PJ in Offices, 38.7 PJ in Retail, 9.1 PJ in Warehouses, 0.9 PJ in Laboratories, 4.7 PJ in Hospitals, 23.0 PJ in Schools, 12.1 PJ in Aged care, and 0.1 PJ in Public Buildings.

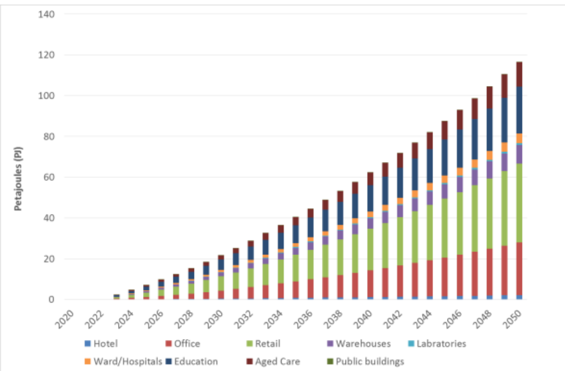


Figure 4-15: Accelerated Net Trajectory, Commercial Building Energy Savings by Type, Australia (PJ), 2023-2050

Energy savings for commercial buildings vary by state and territory over the projection period, but follow a similar pattern to the Conservative Net trajectory (Figure 4-16).

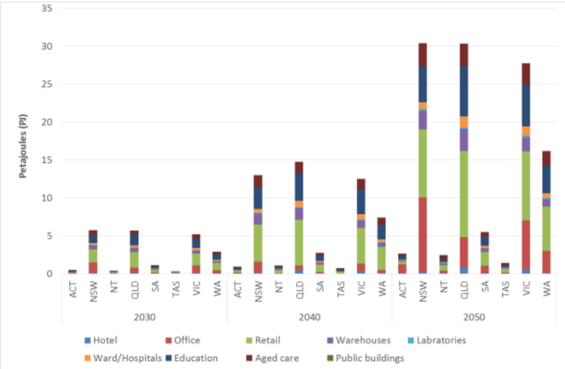


Figure 4-16: Accelerated Net Trajectory, Commercial Building Energy Savings by Type, State/Territory (PJ), 2030, 2040, 2050

4.3 Energy Cost Savings

The energy cost savings are categorised according to the classes of buildings outlined in Sections 2 and 3. The energy cost savings of residential and commercial buildings are calculated based on the energy savings discussed in Section 4.2 multiplied by estimates of future retail prices for electricity and natural gas as detailed in Appendix A. These energy cost savings are then discounted at 7% per annum in real terms.

4.3.1 Residential sector

The energy cost savings from the Conservative EE trajectory for the three classes of residential building: Detached, Attached, and Units/Apartments; show that savings are greatest for detached dwellings (Figure 4-17).

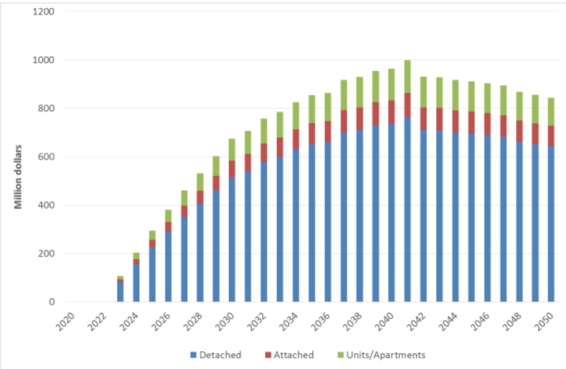


Figure 4-17: Conservative EE Trajectory, Residential Building Energy Cost Savings by Type, Australia (M$), 2023-2050

Residential energy cost savings peak at around $1 billion near the year 2040. After which, the combination of no additional energy savings (i.e. no NCC improvements were modelled beyond 2034), the flattening out of retail energy prices, and the influence of discounting, means that annual energy cost savings decline for the remainder of the projection period.

Similar to the energy savings by state and territory, the energy cost savings show a similar pattern among the states and territories as the aggregation analysis is using an average national energy price projection (Figure 4-18).

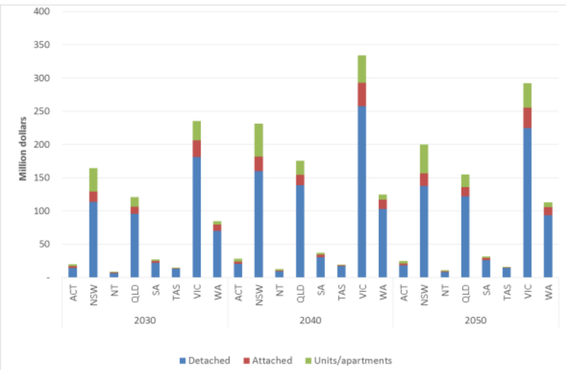


Figure 4-18: Conservative EE Trajectory, Residential Building Energy Cost Savings by Type, State/Territory (M$), 2030, 2040, 2050

In regard to the Accelerated EE trajectory (Figure 4-19), residential energy cost savings peak at around $1.2 billion near the year 2040. Similar to the Conservative EE trajectory the flattening out of retail energy prices, and the influence of discounting, means that annual energy cost savings decline for the remainder of the projection period from that point.

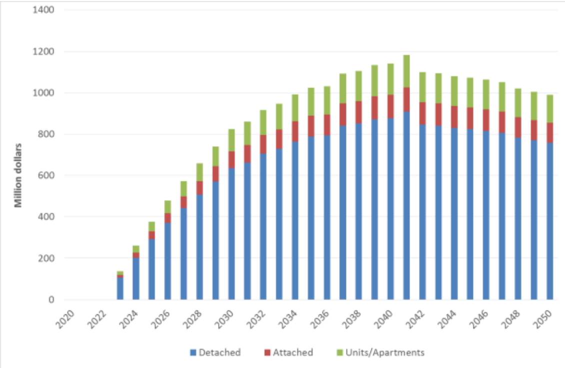


Figure 4-19: Accelerated EE Trajectory, Residential Building Energy Cost Savings by Type, Australia (M$), 2023-2050

The energy cost savings show a similar pattern among the states and territories in the Accelerated EE trajectory (Figure 4-20) as the aggregation analysis is using an average national energy price projection, with maximum savings in VIC of around $400 million.

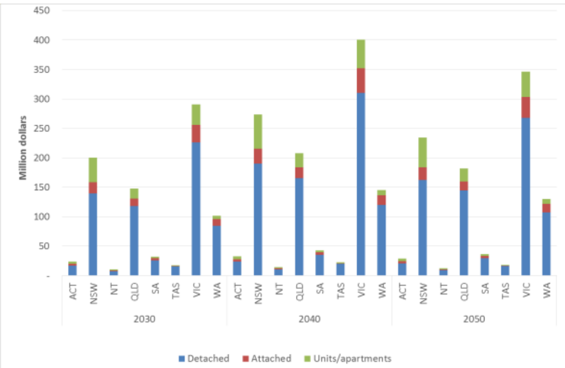


Figure 4-20: Accelerated EE Trajectory, Residential Building Energy Cost Savings by Type, State/Territory (M$), 2030, 2040, 2050

In regard to the Conservative Net trajectory (Figure 4-21), residential energy cost savings peak at around $3.4 billion near the year 2040. The significant increase in energy cost savings compared to the Conservative EE trajectory, reflects the reduced grid electricity costs for Attached and Units/apartments. In regard to Detached, it includes reduced grid electricity costs plus payments to households for surplus energy.

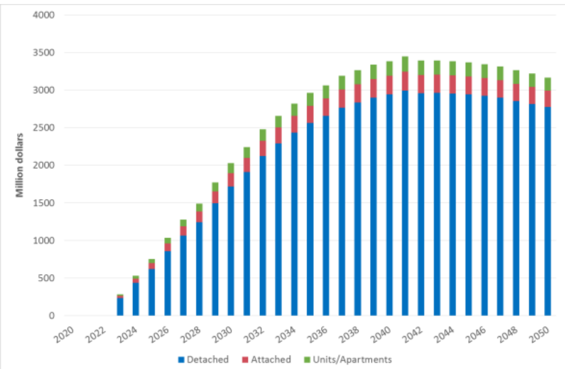


Figure 4-21: Conservative Net Trajectory, Residential Building Energy Cost Savings by Type, Australia (M$), 2023-2050

The energy cost savings show a similar pattern among the states and territories in the Conservative EE trajectory (Figure 4-22), with maximum savings in VIC of around $905 million.

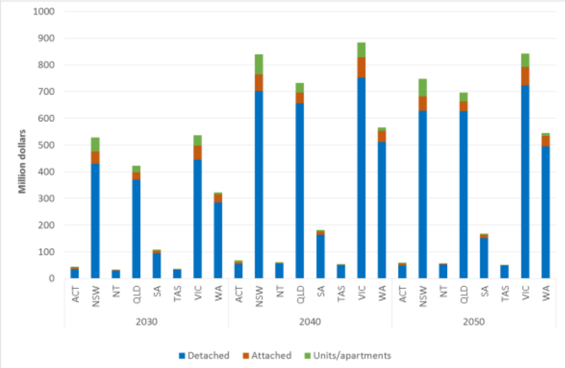


Figure 4-22: Conservative Net Trajectory, Residential Building Energy Cost Savings by Type, State/Territory (M$), 2030, 2040, 2050

For the Accelerated Net trajectory (Figure 4-23), residential energy cost savings peak at around $3.9 billion near the year 2040. The significant increase in energy cost savings compared to the Conservative Net trajectory, reflects the additional energy efficiency improvements and increased solar PV uptake in all building classes.

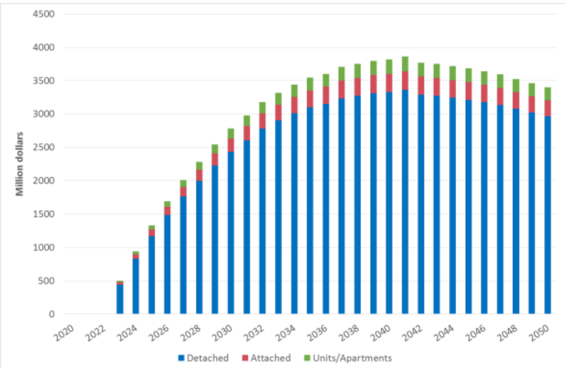


Figure 4-23: Accelerated Net Trajectory, Residential Building Energy Cost Savings by Type, Australia (M$), 2023-2050

The energy cost savings in the Accelerated Net trajectory show a similar pattern among the states and territories to the Conservative EE trajectory (Figure 4-24), with maximum savings in VIC of around $1.05 billion.

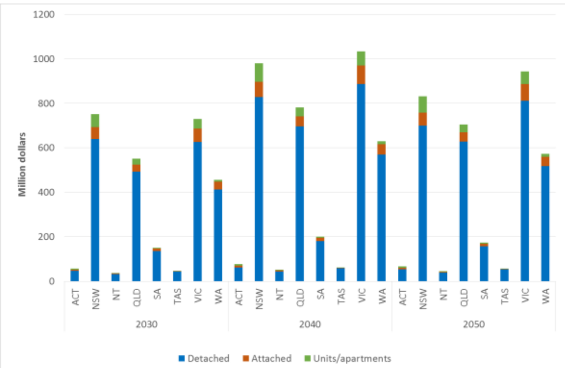


Figure 4-24: Accelerated Net Trajectory, Residential Building Energy Cost Savings by Type, State/Territory (M$), 2030, 2040, 2050

4.3.2 Commercial Sector

The national energy cost savings from the Conservative EE trajectory for the classes of commercial building show that savings are greatest for retail buildings (Figure 4-25).

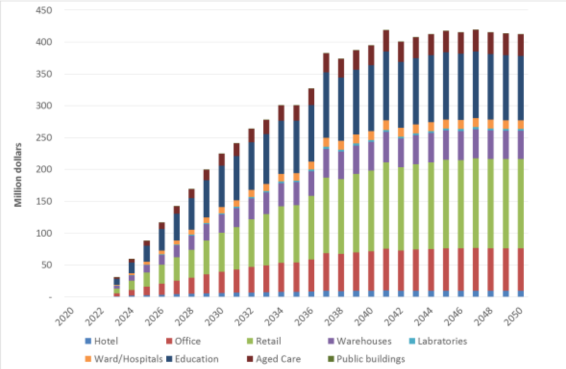


Figure 4-25: Conservative EE Trajectory, Commercial Building Energy Cost Savings by Type, Australia (M$), 2023-2050

Commercial energy cost savings peak at around $420 million near the year 2040. However, compared to the residential sector, the drop off in savings is less pronounced as retail energy prices for commercial end-users maintain small growth rather than flattening out.

Similar to the energy savings by state and territory, the energy cost savings show a similar pattern among the states and territories as the aggregation analysis is using an average national energy price projection.

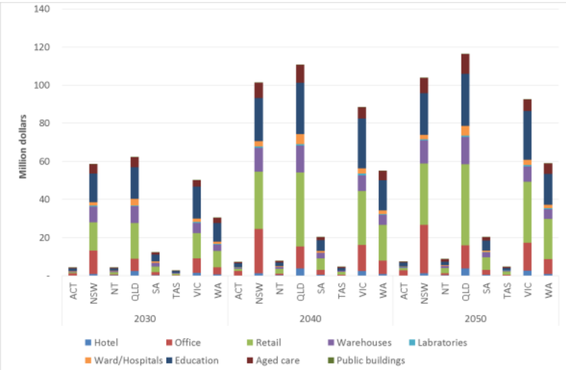


Figure 4-26: Conservative EE Trajectory, Commercial Building Energy Cost Savings by Type, State/Territory (M$), 2030, 2040, 2050

For the Accelerated EE trajectory (Figure 4-27), commercial energy cost savings peak at around $480 million near the year 2040. Similar to the Conservative EE trajectory, the drop off in savings is less pronounced compared to the residential sector as retail energy prices for commercial end-users maintain small growth rather than flattening out.

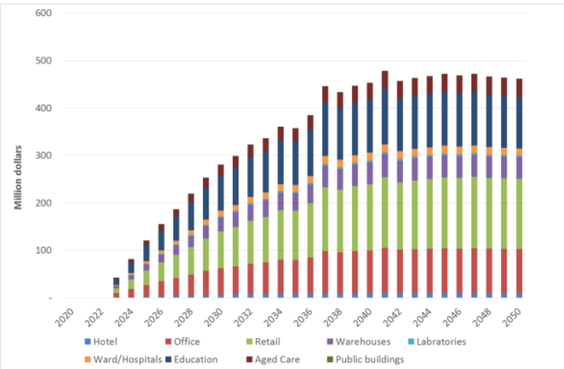


Figure 4-27: Accelerated EE Trajectory, Commercial Building Energy Cost Savings by Type, Australia (M$), 2023-2050

Similar to the energy savings by state and territory, the energy cost savings show a similar pattern among the states and territories, with QLD showing the greatest cost savings (Figure 4-28).

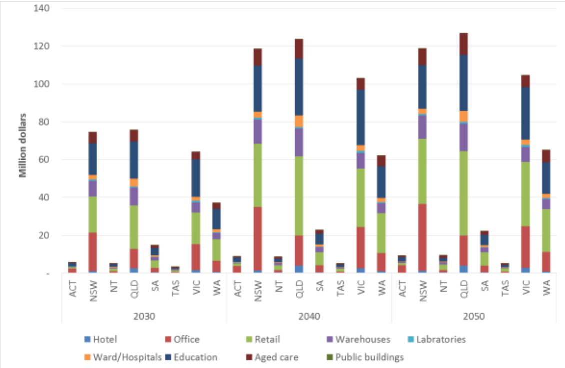


Figure 4-28: Accelerated EE Trajectory, Commercial Building Energy Cost Savings by Type, State/Territory (M$), 2030, 2040, 2050

In regard to the Conservative Net trajectory (Figure 4-29), commercial energy cost savings peak at around $780 million near the year 2040 reflecting significantly reduced grid electricity costs due to the deployment of rooftop solar PV.

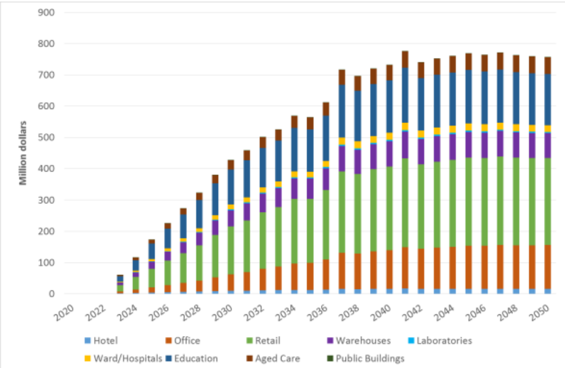


Figure 4-29: Conservative Net Trajectory, Commercial Building Energy Cost Savings by Type, Australia (M$), 2023-2050

The energy cost savings show a similar pattern among the states and territories to the Conservative EE trajectory (Figure 4-30).

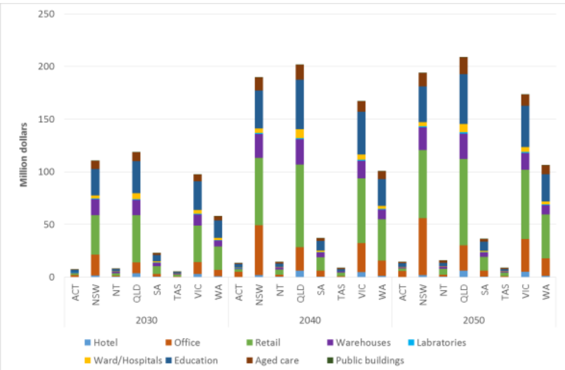


Figure 4-30: Conservative EE Trajectory, Commercial Building Energy Cost Savings by Type, State/Territory (M$), 2030, 2040, 2050

For the Accelerated Net trajectory (Figure 4-31), commercial energy cost savings are marginally higher than the Conservative Net trajectory, and peak at around $830 million near the year 2041 reflecting reduced grid electricity costs from additional energy efficiency and deployment of rooftop solar PV.

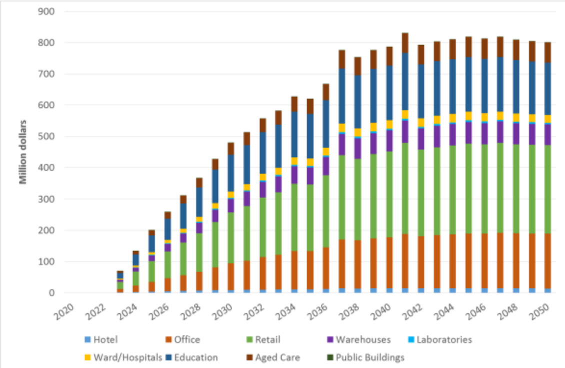


Figure 4-31: Accelerated Net Trajectory, Commercial Building Energy Cost Savings by Type, Australia (M$), 2023-2050

The energy cost savings for the states and territories show a similar pattern to the Conservative Net trajectory (Figure 4-32).

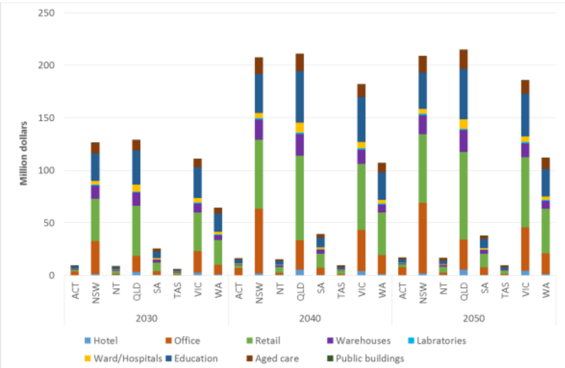


Figure 4-32: Accelerated Net Trajectory, Commercial Building Energy Cost Savings by Type, State/Territory (M$), 2030, 2040, 2050

4.3.3 Cumulative energy cost savings

For the Conservative EE trajectory (Table 4-1), cumulative energy cost savings to 2030 equal around $4.3 billion. For the entire projection period to 2050, cumulative energy cost savings equal around $29.3 billion.

Table 4-1: Conservative EE Trajectory, Cumulative energy cost savings to 2030, 2050 by State/Territory and National (Billion dollars)

	2022-2030		2022-2050	
	Residential	Commercial	Residential	Commercial
ACT	0.10	0.02	0.61	0.15
NSW	0.80	0.27	5.03	2.16
NT	0.04	0.02	0.27	0.16
QLD	0.58	0.28	3.78	2.35
SA	0.13	0.06	0.81	0.43
TAS	0.07	0.01	0.42	0.10
VIC	1.14	0.23	7.25	1.89
WA	0.40	0.14	2.69	1.17
AUS	**3.25**	**1.03**	**20.86**	**8.42**

For the Accelerated EE trajectory (Table 4-2), cumulative energy cost savings to 2030 equal around $5.4 billion. For the entire projection period to 2050, cumulative energy cost savings equal around $34.8 billion.

Table 4-2: Accelerated EE Trajectory, Cumulative energy cost savings to 2030, 2050 by State/Territory and National (Billion dollars)

	2022-2030		2022-2050	
	Residential	Commercial	Residential	Commercial
ACT	0.12	0.03	0.72	0.20

NSW	0.99	0.36	6.00	2.58
NT	0.05	0.02	0.32	0.19
QLD	0.72	0.36	4.52	2.68
SA	0.16	0.07	0.95	0.50
TAS	0.09	0.02	0.50	0.11
VIC	1.43	0.31	8.76	2.24
WA	0.50	0.18	3.16	1.35
AUS	**4.05**	**1.34**	**24.94**	**9.85**

For the Conservative Net trajectory (Table 4-3), cumulative energy cost savings to 2030 equal around $22.3 billion. For the entire projection period to 2050, cumulative energy cost savings equal around $87.9 billion.

Table 4-3: Conservative Net Trajectory, Cumulative energy cost savings to 2030, 2050 by State/Territory and National (Billion dollars)

	2022-2030		2022-2050	
	Residential	Commercial	Residential	Commercial
ACT	0.20	0.04	1.45	0.31
NSW	2.32	0.53	17.77	4.16
NT	0.16	0.04	1.27	0.31
QLD	1.93	0.56	15.46	4.38
SA	0.48	0.11	3.84	0.81
TAS	0.17	0.03	1.19	0.19
VIC	2.57	0.47	19.05	3.69
WA	1.34	0.27	11.83	2.20
AUS	**20.61**	**2.04**	**71.86**	**16.05**

For the Accelerated Net trajectory (Table 4-4), cumulative energy cost savings to 2030 equal around $36.7 billion. For the entire projection period to 2050, cumulative energy cost savings equal around $102.6 billion.

Table 4-4: Accelerated Net Trajectory, Cumulative energy cost savings to 2030, 2050 by State/Territory and National (Billion dollars)

	2022-2030		2022-2050	
	Residential	Commercial	Residential	Commercial
ACT	0.28	0.04	1.72	0.35
NSW	3.67	0.59	21.95	4.47
NT	0.22	0.04	1.19	0.33
QLD	2.86	0.61	17.46	4.56
SA	0.78	0.12	4.54	0.85
TAS	0.25	0.03	1.44	0.20
VIC	3.86	0.52	23.29	3.94
WA	2.16	0.30	13.99	2.32
AUS	**34.72**	**2.25**	**85.58**	**17.02**

4.4 Network Savings

Apart from energy savings from the NCC trajectories, there are expected to be reductions in peak demand which can reduce the need for augmentation of electricity networks compared to the business as usual scenario.

The calculation of avoided summer peak demand derived from the energy savings (Section4.2) relies on the conservation load factor (CLF) methodology (ISF, 2010). The CLF for a specific energy saving technology 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). CLF values of 0.1 and 0.25 were used for residential and commercial electricity savings respectively, meaning that residential savings had proportionally more impact on reducing peak demand than commercial savings. While the peak reduction varies for different building types and locations, these CLF values were selected to best reflect the average equivalent CLF determined in the building-level energy modelling (Sections 2 and 3).

For the Conservative EE trajectory, the sector impact on peak demand reductions (Figure 4-33) increases steadily from the initial change in the NCC, resulting in 5.3 gigawatts (GW) and 1.2 GW of peak demand reduction in 2030 from residential and commercial buildings respectively. This increases to 21.4 GW and 6.9 GW of peak demand reduction in 2050 from residential and commercial buildings respectively.

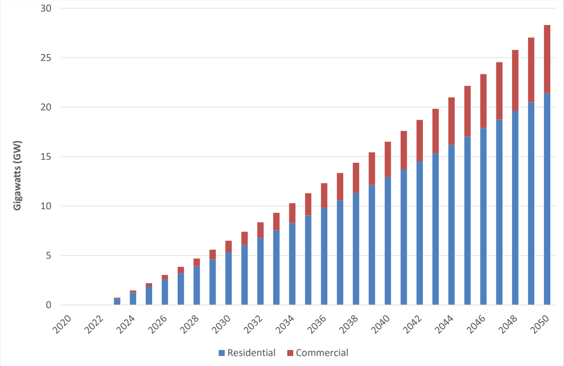


Figure 4-33: Conservative EE Trajectory, Peak Demand Savings by Sector, Australia (GW), 2020-2050

For the Accelerated EE trajectory, the sector impact on peak demand reductions (Figure 4-34) is greater, resulting in 6.5 gigawatts (GW) and 1.4 GW of peak demand reduction in 2030 from residential and commercial buildings respectively. This increases to 25.1 GW and 7.5 GW of peak demand reduction in 2050 from residential and commercial buildings respectively.

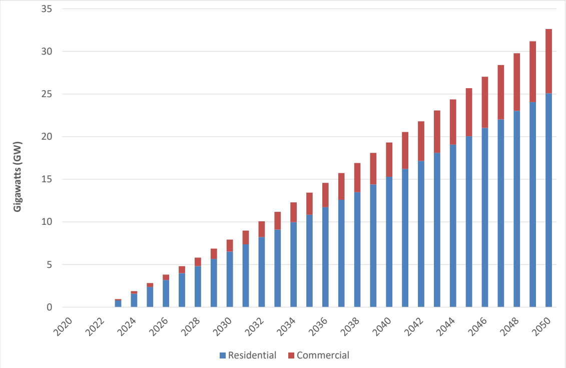


Figure 4-34: Accelerated EE Trajectory, Peak Demand Savings by Sector, Australia (GW), 2020-2050

To estimate potential benefits from deferred network expenditure, these peak demand savings need to be multiplied by an estimate of average $/kW augmentation costs avoided. This data was sourced from the network capital cost assumptions of the Electricity Network Transformation Roadmap (Graham et al., 2015). The annualised avoided capital costs are applied each year to the total projected peak demand savings. Annualised costs vary by state but on average are assumed to be $177/kW currently, declining to around $164/kW by 2050 reflecting recent Australian Energy Regulator (AER) determination decisions and assumed continued productivity improvements.

This approach differs to the network savings calculation in the building-level analysis (Sections 2 and 3, as noted in Appendix A). In the building-level analysis, the $/kW was applied as a once-off capital cost saving, which represents a levelised network augmentation cost saving taking into account savings over the lifetime of the network assets. The $/kW values used in this section are smaller as they represent an annualised equivalent. This is done in order to gain a more granular insight of the savings accrued in each year, so that the cumulative savings accrued by society to 2030 and 2050 can be calculated. The annualised $/kW figures used in this section are equivalent to the once-off capital cost $/kW figure used in Sections 2 and 3 as they are derived from the same reference.

For aggregation purposes, the avoided cost was scaled down 30% in the next five years to recognise that there will be significant existing headroom in many parts of the network and in addition, networks will have already planned some augmentations which will not be effected by the peak demand savings. However, this assumption only has a minor impact on results since estimated peak demand savings are low in the first five years. In the longer term, peak demand savings will be taking place in the context of a network that is also managing a more complex operating regime including the potential for mass electric vehicle adoption, peer to peer energy trading and customers selling the use of their behind the meter devices to provide grid services. No specific adjustments have been made to recognise these more complex long term developments. However, the peak demand savings will assist in providing greater hosting capacity for these potential new network services. .Based on the method outlined above, for the Conservative EE trajectory, the estimated benefit of deferred network investment to 2030 is around $2.3 billion, increasing to $12.6 billion for the entire projection period to 2050 (Table 4-5).

Table 4-5: Conservative EE Trajectory, Network Benefits, by State/Territory and National, 2030, 2050

	2030	**2050**
ACT	0.06	0.34
NSW	0.55	3.06
NT	0.03	0.18
QLD	0.43	2.50
SA	0.09	0.52
TAS	0.05	0.24
VIC	0.75	4.11
WA	0.28	1.64
AUS	2.25	12.59

In relation to the Accelerated EE trajectory (Table 4-6), the estimated benefit of deferred network investment to 2030 is around $2.8 billion, increasing to $15.0 billion for the entire projection period to 2050.

Table 4-6: Accelerated EE Trajectory, Network Benefits, by State/Territory and National, 2030, 2050

	2030	**2050**
ACT	0.08	0.41
NSW	0.69	3.65
NT	0.04	0.21
QLD	0.54	2.95
SA	0.12	0.60
TAS	0.06	0.28
VIC	0.94	4.95
WA	0.35	1.92
AUS	2.81	14.97

Due to the substantial deployment of rooftop solar PV in the Conservative Net and Accelerated Net scenarios, estimated network benefits were not calculated for these scenarios, due to a lack of data on the overall impact of solar PV on reducing peak demand.

The calculated network benefits for both the Conservative and Accelerated EE trajectories are significant but need to be interpreted with caution. Despite factoring down modelled future avoided costs, still, the use of a static CLF over time may overestimate the quantum of peak demand reduction based on the annual electricity savings. There may also be significant variation across spatial areas or mixed precincts that are not captured using this approach, particular for distribution network costs. Other developments in the composition of network spending in the future ('intelligence' of the network and its capacity to deal with complex, 2-way power flows) may limit the network benefits that are realised. More sophisticated analysis to capture these dynamics is beyond the scope of this report.

4.5 Emissions Reductions

Greenhouse gas (GHG) emission savings are categorised according to the classes of buildings outlined in Sections 2 and 3. The GHG emissions savings of buildings are calculated based on the energy savings discussed in Section 4.2 multiplied by the emission intensity of grid electricity (for the electricity savings) and natural gas (for the natural gas savings in some classes of commercial buildings). The assumed GHG emission intensity of grid electricity is drawn from the Roadmap scenario from the *Electricity Network Transformation Roadmap*. This is an aggressive decarbonisation of electricity system, falling from current levels of 0.8 tCO_2-e/MWh to around 0.5 tCO_2-e/MWh by 2030 and zero carbon by 2050. The impact of a slower, 'business-as-usual' grid decarbonisation is discussed in Section 4.5.4.

4.5.1 Residential Sector

Over the first half of the projection period, GHG emissions reduction increased steadily in line with the energy savings discussed in Section 4.2.

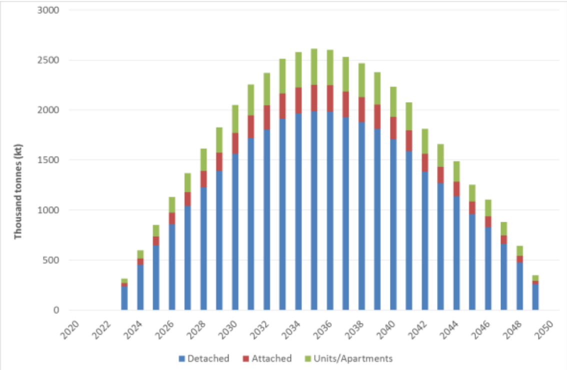


Figure 4-35: Conservative EE Trajectory, Residential Building GHG Emissions Savings by Type, Australia (kt), 2023-2050

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 2035, with the total value being 2600 kilo tonnes. Detached contributes around 2000 kilo tonnes, Units/Apartments contribute around 360 kilo tonnes, and Attached contributes around 265 kilo tonnes.

In 2050, the GHG emission savings for residential buildings become zero due to the decarbonisation of grid electricity by 2050.

Among all the states/territories, VIC contributes the most GHG emission reductions, peaking at around 1 million tonnes, followed by NSW peaking at 650 kilo tonnes and QLD peaking at almost 510 kilo tonnes.

In regard to the Accelerated EE trajectory (Figure 4-36), the peak emission reduction over the projection period occurs in 2035, with the total value being around 3100 kilo tonnes. Detached contributes around 2400 kilo tonnes, Units/Apartments contribute around 360 kilo tonnes, and Attached contributes around 420 kilo tonnes.

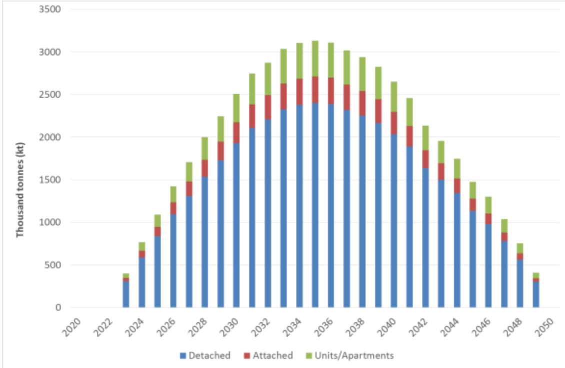


Figure 4-36: Accelerated EE Trajectory, Residential Building GHG Emissions Savings by Type, Australia (kt), 2023-2050

Similar to the Conservative EE trajectory, VIC contributes the most GHG emission reductions, peaking at around 1.2 million tonnes, followed by NSW peaking at 780 kilo tonnes and QLD peaking at almost 610 kilo tonnes.

In regard to the Conservative Net trajectory (Figure 4-37), the peak reduction in national GHG emissions over the projection period occurs in 2037, with the total value being around 24.5 million tonnes. Reflecting the contribution of rooftop solar PV, Detached contributes around 22.4 million tonnes, Units/Apartments contribute around 1.6 million tonnes, and Attached contributes around 0.5 million tonnes.

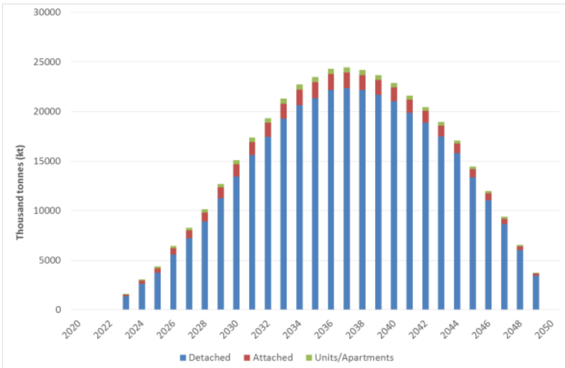


Figure 4-37: Conservative Net Trajectory, Residential Building GHG Emissions Savings by Type, Australia (kt), 2023-2050

Similar to the Conservative EE trajectory, QLD contributes the most GHG emission reductions, peaking at around 7.2 million tonnes, followed by VIC peaking at 7.0 million tonnes, and NSW peaking at 5.2 million tonnes.

For the Accelerated Net trajectory (Figure 4-38), the peak reduction in national GHG emissions over the projection period occurs in 2036, with the total value being around 28.3 million tonnes. Reflecting the contribution of rooftop solar PV, Detached contributes around 26.0 million tonnes, Units/Apartments contribute around 1.7 million tonnes, and Attached contributes around 0.6 million tonnes.

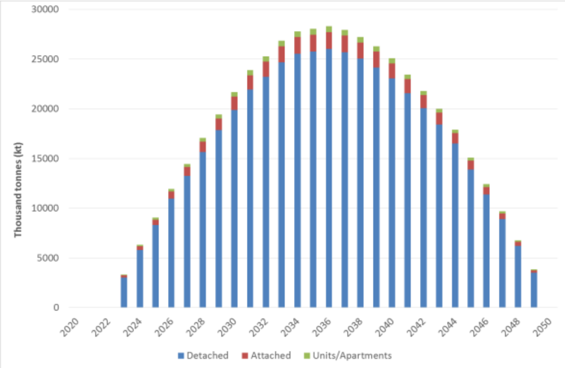


Figure 4-38: Accelerated Net Trajectory, Residential Building GHG Emissions Savings by Type, Australia (kt), 2023-2050

VIC contributes the most GHG emission reductions, peaking at around 8.5 million tonnes, followed by QLD peaking at 7.7 million tonnes, and NSW peaking at 6.6 million tonnes.

4.5.2 Commercial Sector

Similar to the residential sector, over the first half of the projection period, GHG emissions reduction in new commercial buildings increased steadily in line with the energy savings discussed in Section 4.2 (Figure 4-39).

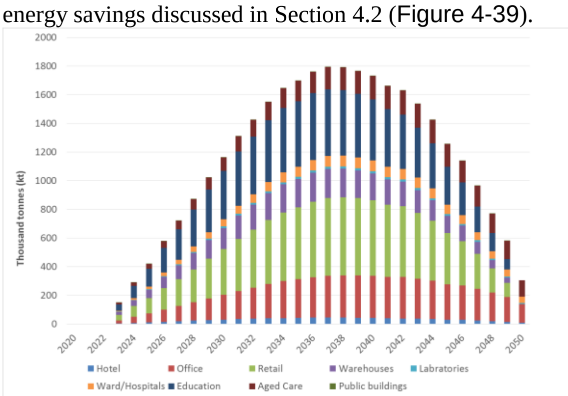


Figure 4-39: Conservative EE Trajectory, Commercial Building GHG Emissions Savings by Type, Australia (kt), 2023-2050

In contrast to residential buildings, annual GHG emission savings do not decline to zero in 2050 reflecting ongoing emission savings from reduced natural gas use in the Conservative EE trajectory.

Among all the states/territories, QLD contributes the most GHG emission reductions, peaking at around 540 kilo tonnes, followed by NSW peaking at 460 kilo tonnes and VIC peaking at almost 430 kilo tonnes. This change in ranking from residential reflects the influence of natural gas GHG emissions in VIC as well as high growth in new builds in QLD.

In regard to the Accelerated EE trajectory (Figure 4-40), annual GHG emission savings peak slightly later than residential (in the year 2037) at around 2100 kilo tonnes. Among all the states/territories, QLD contributes the most GHG emission reductions, peaking at around 620 kilo tonnes, followed by NSW peaking at 560 kilo tonnes and VIC peaking at almost 545 kilo tonnes.

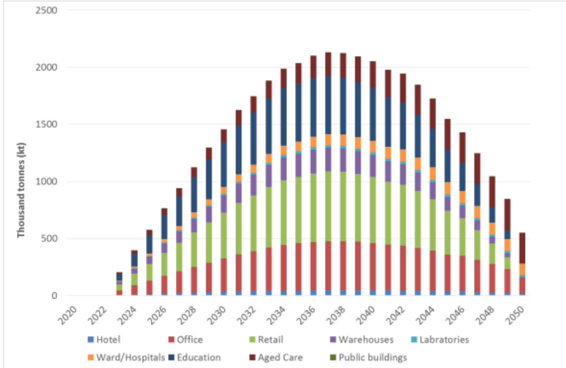


Figure 4-40: Accelerated EE Trajectory, Commercial Building GHG Emissions Savings by Type, Australia (kt), 2023-2050

For the Conservative Net trajectory (Figure 4-41), annual GHG emission savings from commercial buildings peak in the year 2037 at around 3.4 million tonnes. Among all the states/territories, QLD contributes the most GHG emission reductions, peaking at around 1 million tonnes, followed by NSW peaking at 880 kilo tonnes and VIC peaking at almost 875 kilo tonnes.

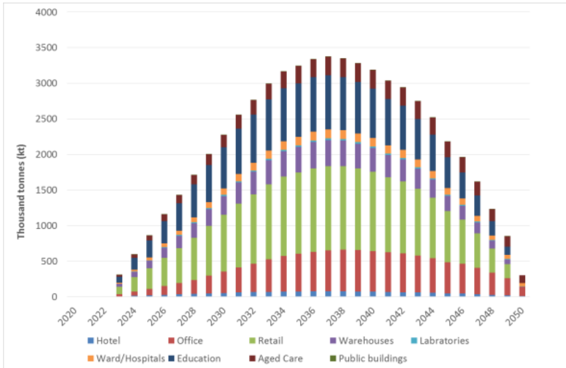


Figure 4-41: Conservative Net Trajectory, Commercial Building GHG Emissions Savings by Type, Australia (kt), 2023-2050

Similarly, in the Accelerated Net trajectory (Figure 4-42), annual GHG emission savings peak in the year 2037 at around 3.6 million tonnes. Among all the states/territories, QLD contributes the most GHG emission reductions, peaking at around 1 million tonnes, followed by NSW peaking at 960 kilo tonnes and VIC peaking at almost 945 kilo tonnes.

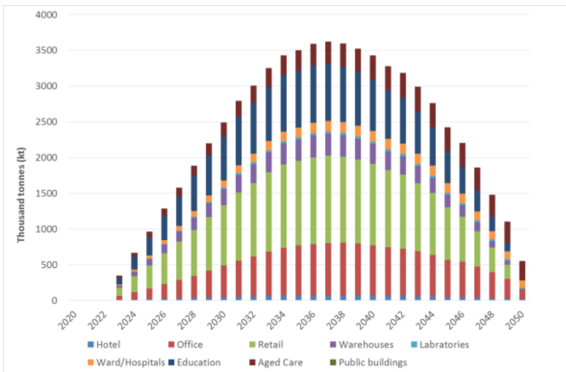


Figure 4-42: Accelerated Net Trajectory, Commercial Building GHG Emissions Savings by Type, Australia (kt), 2023-2050

4.5.3 Cumulative GHG emissions reductions

The cumulative emissions reduction by 2030 and 2050 for residential, commercial and all new buildings under the Conservative EE Trajectory are denoted in Table 4-7 and Table 4-8 respectively. Note that the cumulative value is derived from the summation of each year over the projection period. As observed, the national cumulative GHG emissions reduction is around 15 million tonnes and 78 million tonnes in 2030 and 2050 respectively.

Table 4-7: Conservative EE Trajectory, Cumulative GHG emissions reductions to 2030 by State/Territory and National (Million tonnes)

State/Territory	Residential	Commercial	Total
ACT	0.29	0.10	0.39
NSW	2.42	1.38	3.80
NT	0.12	0.09	0.21
QLD	1.93	1.60	3.53
SA	0.18	0.14	0.32
TAS	0.02	0.01	0.02
VIC	3.51	1.28	4.79
WA	1.05	0.61	1.66
AUS	**9.50**	**5.22**	**14.72**

Table 4-8: Conservative EE Trajectory, Cumulative GHG emissions reductions to 2050 by State/Territory and National (Million tonnes)

State/Territory	Residential	Commercial	Total
ACT	1.36	0.69	2.05
NSW	11.23	8.63	19.86
NT	1.00	1.10	2.10
QLD	9.11	9.56	18.67
SA	1.15	1.18	2.33
TAS	0.17	0.13	0.30
VIC	15.82	7.48	23.30
WA	5.47	4.21	9.69
AUS	**45.31**	**32.98**	**78.29**

Among all the states/territories, VIC contributes the most GHG emission reductions (due to its relatively high grid electricity emissions intensity compared to other states), around 23 million tonnes, followed by NSW at around 20 million tonnes and QLD contributing around 19 million tonnes by 2050.

For the Accelerated EE trajectory (Table 4-9 and Table 4-10), the national cumulative GHG emissions reduction is around 19 million tonnes and 95 million tonnes by 2030 and 2050 respectively. Residential constitutes the majority of GHG emissions savings at around 12 million tonnes in 2030 and over 54 million tonnes by 2050.

Table 4-9: Accelerated EE Trajectory, Cumulative GHG emissions reductions to 2030 by State/Territory and National (Million tonnes)

State/Territory	Residential	Commercial	Total
ACT	0.35	0.14	0.49
NSW	3.00	1.82	4.82
NT	0.15	0.12	0.26
QLD	2.40	2.02	4.42
SA	0.22	0.18	0.40
TAS	0.02	0.02	0.04
VIC	4.37	1.67	6.05
WA	1.29	0.78	2.07
AUS	**11.80**	**6.75**	**18.55**

Table 4-10: Accelerated EE Trajectory, Cumulative GHG emissions reductions to 2050 by State/Territory and National (Million tonnes)

State/Territory	Residential	Commercial	Total
ACT	1.61	0.94	2.55
NSW	13.47	10.78	24.24
NT	1.19	1.28	2.48
QLD	10.95	11.29	22.24
SA	1.36	1.44	2.80
TAS	0.20	0.23	0.44
VIC	19.24	9.62	28.86
WA	6.48	5.10	11.58
AUS	**54.50**	**40.69**	**95.19**

VIC contributes the most GHG emission reductions (due to its relatively high grid electricity emissions intensity compared to other states), around 29 million tonnes, followed by NSW at around 24 million tonnes and QLD contributing around 22 million tonnes by 2050.

In regard to the Conservative Net trajectory (Table 4-11 and Table 4-12), the national cumulative GHG emissions reduction is around 70 million tonnes and 470 million tonnes by 2030 and 2050 respectively. There is a significant increase in the share of GHG abatement from Residential buildings, reflecting export of surplus electricity to the grid.

Table 4-11: Conservative Net Trajectory, Cumulative GHG emissions reductions to 2030 by State/Territory and National (Million tonnes)

State/Territory	Residential	Commercial	Total
ACT	1.32	0.19	1.50
NSW	13.55	2.71	16.26
NT	0.87	0.18	1.05
QLD	18.01	3.16	21.17
SA	1.47	0.27	1.73

TAS	0.08	0.01	0.09
VIC	16.83	2.61	19.44
WA	8.25	1.21	9.46
AUS	**60.37**	**10.35**	**70.72**

Table 4-12: Conservative Net Trajectory, Cumulative GHG emissions reductions to 2050 by State/Territory and National (Million tonnes)

State/Territory	Residential	Commercial	Total
ACT	7.89	1.24	9.13
NSW	88.09	16.03	104.12
NT	12.95	2.06	15.00
QLD	119.09	17.70	136.79
SA	14.11	2.09	16.20
TAS	1.15	0.20	1.35
VIC	101.44	14.04	115.47
WA	63.46	7.71	71.17
AUS	**408.18**	**61.06**	**469.24**

QLD contributes the most GHG emission reductions (due to its superior solar output and load growth compared to other states) at around 137 million tonnes, followed by VIC at around 115 million tonnes and NSW contributing around 104 million tonnes by 2050.

For the Accelerated Net trajectory (Table 4-13 and Table 4-14), the national cumulative GHG emissions reduction is around 112 million tonnes and 565 million tonnes by 2030 and 2050 respectively, with Residential constituting over 498 million tonnes, and commercial around 67 million tonnes by 2050.

Table 4-13: Accelerated Net Trajectory, Cumulative GHG emissions reductions to 2030 by State/Territory and National (Million tonnes)

State/Territory	Residential	Commercial	Total
ACT	1.99	0.22	2.21
NSW	24.08	3.04	27.12
NT	1.21	0.20	1.40
QLD	28.33	3.42	31.75
SA	2.57	0.29	2.86
TAS	0.12	0.02	0.15
VIC	27.73	2.89	30.62
WA	14.61	1.33	15.93
AUS	**100.64**	**11.41**	**112.04**

Table 4-14: Accelerated Net Trajectory, Cumulative GHG emissions reductions to 2050 by State/Territory and National (Million tonnes)

State/Territory	Residential	Commercial	Total
ACT	9.65	1.49	11.13
NSW	114.42	17.76	132.18
NT	10.64	2.17	12.81
QLD	136.95	18.84	155.79
SA	16.81	2.29	19.10
TAS	1.37	0.30	1.67
VIC	130.23	15.76	145.99
WA	78.11	8.40	86.51
AUS	**498.19**	**67.00**	**565.19**

Similar to the Conservative Net trajectory, QLD contributes the most GHG emission reductions at around 156 million tonnes, followed by VIC at around 146 million tonnes and NSW contributing around 132 million tonnes by 2050.

4.5.4 Alternative trajectory GHG emissions reductions

In the event of slower, 'business-as-usual' grid decarbonisation, the cumulative tonnes of GHG emission savings to 2030 and 2050 under the Conservative EE trajectory scenario would be lower as shown in Table 4-15 and Table 4-16 respectively. 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. The national values are close to 21 million tonnes and 148 million tonnes based on this lower emissions reduction trajectory by 2030 and 2050 respectively.

Table 4-15: Conservative EE trajectory, Cumulative GHG emissions reductions using the Alternative, Lower Ambition Emissions Trajectory to 2030 by State/Territory and National (Million tonnes)

State/Territory	Residential	Commercial	Total
ACT	0.41	0.13	0.55
NSW	3.46	1.95	5.41
NT	0.17	0.13	0.30
QLD	2.77	2.30	5.07
SA	0.26	0.20	0.46
TAS	0.02	0.01	0.03
VIC	5.39	1.81	7.20
WA	1.50	0.87	2.37
AUS	**13.99**	**7.41**	**21.40**

Table 4-16: Conservative EE trajectory, Cumulative GHG emissions reductions using the Alternative, Lower Ambition Emissions Trajectory to 2050 by State/Territory and National (Million tonnes)

State/Territory	Residential	Commercial	Total
ACT	2.68	1.20	3.88
NSW	22.04	16.54	38.58
NT	2.32	2.59	4.92

QLD	16.96	17.92	34.88
SA	2.48	2.43	4.91
TAS	0.40	0.23	0.63
VIC	29.26	13.03	42.29
WA	9.94	7.44	17.38
AUS	**86.07**	**61.39**	**147.46**

4.6 Lifecycle costs and benefits

Similar to the building level analysis, aggregated costs and benefits of the NCC trajectories can be calculated assuming energy cost savings persist beyond the end of the projection period at 2050. Congruent with Sections 2 and 3, these benefits are assumed to persist over a forty-year life (although beyond 2050, energy prices are assumed to be constant).

These lifecycle (or present value) costs and benefits for the Conservative EE trajectory are presented below for new builds that are built over the period 2022-2030 and 2022-2050 for residential (Figure 4-43) and commercial buildings (Figure 4-44) respectively. The energy bill savings here differ from those presented in Section 4.3, as this section calculates energy bill savings over the 40-year life of the buildings, while Section 4.3 summarised only the bill savings accrued to 2030 and 2050. Similarly, the network savings here differ from those presented in Section 4.4, as this section assumes savings accrue over a 30-year network asset life, whereas Section 4.4 summarised only the bill savings accrued to 2030 and 2050.

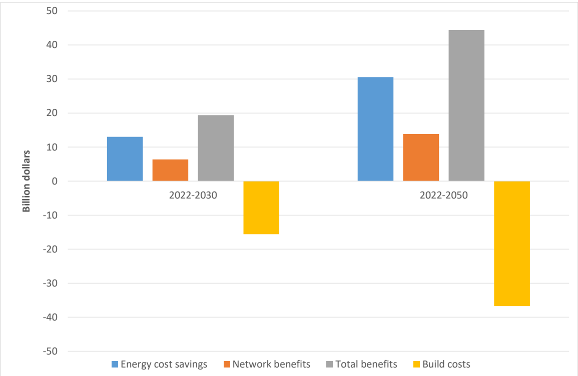


Figure 4-43: Conservative EE Trajectory, Costs and Benefits by type ($B), Residential Buildings, selected periods

For residential buildings built over the period 2022- 2030, total benefits of $19.4 billion which consists of avoided energy costs ($13 billion) and deferred network augmentation costs ($6.4 billion) exceeds the $15.6 billion in additional capital costs of new builds. For residential buildings built over the period 2022- 2050, total benefits of $44.4 billion which consists of avoided energy costs ($30.6 billion) and deferred network augmentation costs ($13.9 billion) exceeds the $36.7 billion in additional capital costs of new builds.

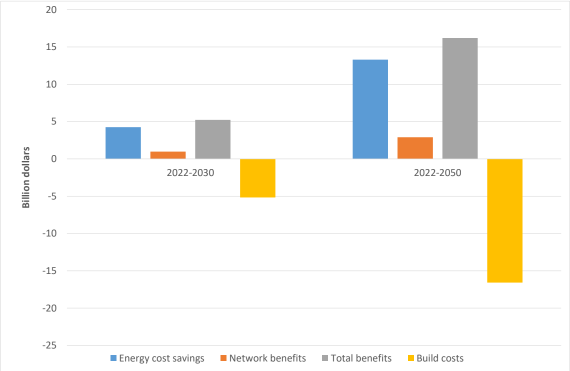


Figure 4-44: Conservative EE Trajectory, Costs and Benefits by type ($B), Commercial Buildings, selected periods

For commercial buildings built over the period 2022- 2030, total benefits of $5.2 billion which consists of avoided energy costs ($4.3 billion) and deferred network augmentation costs ($1 billion) matches (slightly exceeds before rounding) the $5.2 billion in additional capital costs of new builds. For commercial buildings built over the period 2022- 2050, total benefits of $16.2 billion which consists of avoided energy costs ($13.3 billion) and deferred network augmentation costs ($2.9 billion) also more or less balance out the $16.6 billion in additional capital costs of new builds.

When residential and commercial buildings built in the period 2022-2050 are considered together, the total benefits of $60.6 billion which consists of avoided energy costs ($43.9 billion) and deferred network augmentation costs ($16.8 billion) exceeds the $53.3 billion in additional capital costs of new builds.

The value assumed for the CLF impacts on the project network benefits. To test the sensitivity of the results, the lifecycle costs and benefits were determined using more conservative CLF values of 0.2 for residential and 0.4 for commercial (i.e. such that the peak reduction benefit is reduced by around 40-50 per cent). These CLF values reflect the fact that the entire peak reduction benefit from all buildings might not be realised if the peak reductions across different buildings occur at different times. As shown in the following table, even these conservative CLF values result in the societal benefits more or less balancing out the costs.

Table 4-17: Conservative EE Trajectory – Costs and Benefits for varying CLF assumptions

	CLF equivalent to building energy modelling (0.1 for residential, 0.25 for commercial)		Conservative CLF (0.2 for residential, 0.4 for commercial)	
	Buildings built 2022-2030	Buildings built 2022-2050	Buildings built 2022-2030	Buildings built 2022-2050
Avoided energy costs ($B)	17.3	43.9	17.3	43.9
Deferred network costs ($B)	7.3	16.8	3.8	8.7
Additional capital costs ($B)	20.8	53.3	20.8	53.3
Benefit-cost ratio	1.18	1.14	1.01	0.99

4.7 Cost of delay

The analysis in previous sections assumes changes to the NCC commence in 2022. In this section, we focus on the energy bill savings lost, the benefit of avoided capital expenditure, the cost of incurred network costs, and GHG emission reduction savings lost owing to a delay in the implementation of the NCC trajectory until 2025 over the projection period. The lost electricity savings from delaying the code change to 2025 are the energy savings that do not occur in the years 2023 through to 2037. Once the last code changes in 2037, the electricity savings for all new builds 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.

The costs and benefits from a delay in the NCC trajectory for the Conservative EE trajectory are presented below.

In regard to lost energy bill savings (Table 4-18), these increase from around $2.6 billion in 2030 to just under $7.1 billion by 2050.

Table 4-18: Cost of delay (lost energy bill savings, $B) at national and state/territory level, 2030, 2050

	2030	**2050**
ACT	0.07	0.18
NSW	0.65	1.77
NT	0.04	0.10
QLD	0.52	1.45
SA	0.11	0.31
TAS	0.05	0.14
VIC	0.83	2.23
WA	0.33	0.90
AUS	**2.61**	**7.09**

Another cost of delay is additional expenditure on network augmentation as peak demand is higher than it otherwise would have been. Similar to the calculation of network savings in Section 4.4, the lost electricity savings from the delay are calculated and then the additional peak demand is derived using the CLF methodology. The additional incurred network augmentation costs (Table 4-19) from the delay increase from around $0.7 billion in 2030 to $1.7 billion by 2050.

Table 4-19: Cost of delay (network costs, $B) at national and state/territory level, 2030, 2050

	2030	**2050**
ACT	0.02	0.05
NSW	0.18	0.43
NT	0.01	0.02
QLD	0.14	0.34
SA	0.03	0.07
TAS	0.02	0.04
VIC	0.24	0.56
WA	0.09	0.22
AUS	0.72	1.72

In terms of increased GHG emissions from the delay (Table 4-20), cumulative GHG emissions increase from around 9 million tonnes in 2030 to just under 22 million tonnes by 2050.

Table 4-20: Cost of delay (lost cumulative GHG emission savings, Mt) at national and state/territory level, 2030, 2050

	2030	2050
ACT	0.24	0.55
NSW	2.34	5.59
NT	0.13	0.44
QLD	2.10	5.15
SA	0.19	0.59
TAS	0.01	0.06
VIC	3.03	6.98
WA	0.99	2.58
AUS	**9.04**	**21.94**

Appendix A - Economic Analysis Assumptions

A.1 Energy Costs

The national electricity and gas prices are derived from previous work by CSIRO completed during the Electricity Network Transformation Roadmap – ENTR.[16] 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 electricity prices.
- For the electricity sector to achieve net zero emissions by 2050, an implicit carbon price series was used in addition to the base electricity pricing. Assumed to commence in 2020, the carbon price increases from around $30/tCO2-e to around $190/tCO2-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 (tCO2-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 for grid emissions intensity.

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. The calculated price paths are shown in Figure 45.

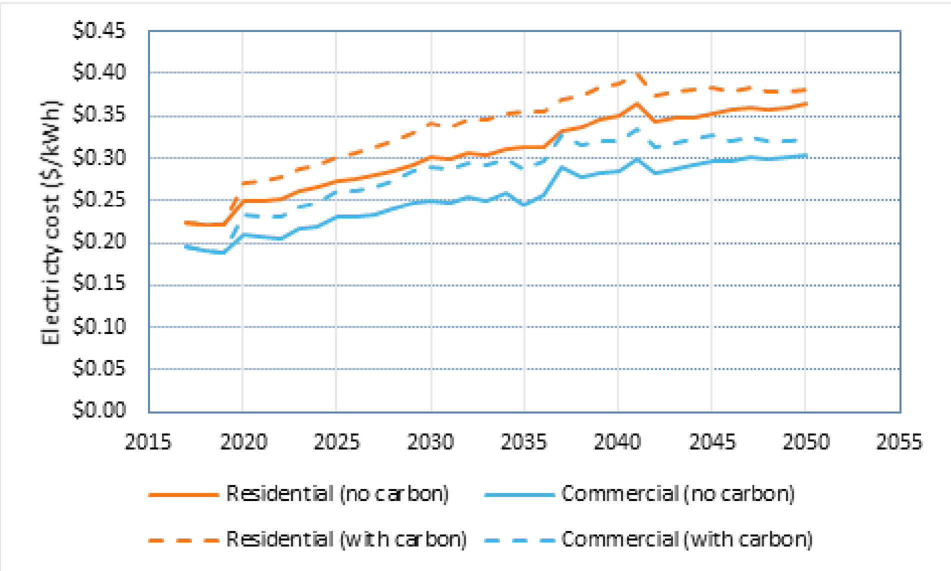


Figure 45: Calculated price paths for electricity.

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

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.

A.1.1 Discussion – Energy Costs

We used 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 the network.[17,18] If network businesses imagined their revenues could not fall when their product is over-priced, then they are being reminded otherwise at present.[19] 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.[20]

A.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:[21]

"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 46. 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

[17] 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
[18] 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
[19] Han, E. 2014, 'Australian Energy Regulator clamps down on network charges', Sydney Morning Herald, 27 November.
[20] Houston Kemp, Residential Building Regulatory Impact Statement Methodology, April 2017, pp 14 – 15.
[21] 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.

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.

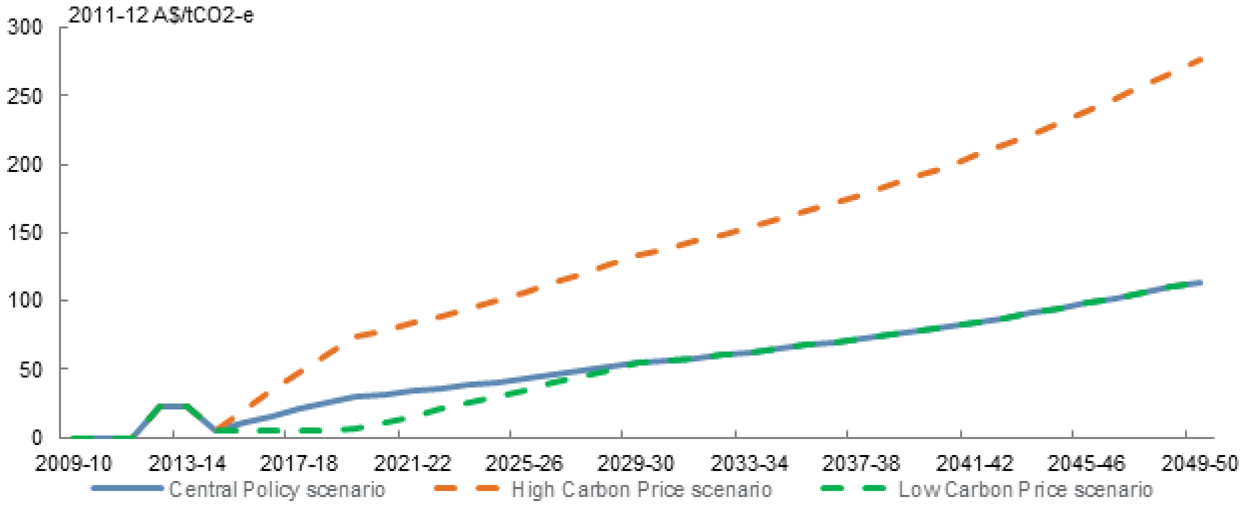


Figure 46: Shadow carbon price projections – ACIL Allen. The carbon price used for this study runs from $30/t in 2020 to $190/t in 2050, making it an intermediate case between the central and high price scenarios.

A.2 Economic Methodology

The benefit cost methodology used for the baseline economic scenario is consistent with the Australian Government's Best Practice Regulation guidelines[22] and Guidance Note on Cost-Benefit Analysis.[23] 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.

A.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.

A.2.2 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.

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

A.2.3 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.

A.2.4 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.

A.2.5 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/m² to build to 6 Star rather than 5 Star in 2010, then it would cost an additional $15/m² 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.[24] 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.

A.3 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. 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 is the common practice and the default discount rate of 7% was chosen to maximise the perceived credibility and impact of this project.

A.4 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[25]

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.

A.5 Other Costs and Benefits Included

A.5.1 Costs and Benefits Included

For this analysis, the only additional cost/benefit considered is the change in size of air-conditioning plant.[26]

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 (kWth). 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.

[24] Houston Kemp, Residential Buildings Regulatory Impact Statement Methodology, April 2017, pp iv - v.
[25] Rawlinson's Australian Construction Handbook, Rawlinsons Publishing, Edition 35, 2017.
[26] This is in addition to the avoided network augmentation costs discussed in the Energy Costs section.

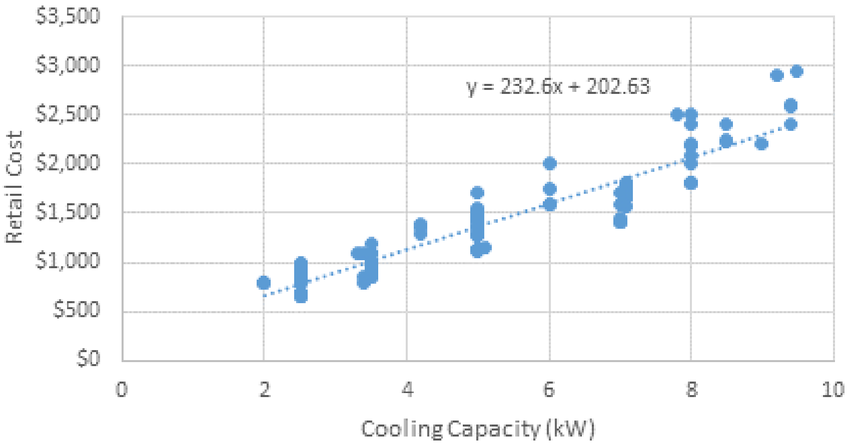


Figure 47: Cost of air-conditioning systems.[27]

No allowance has been made for differences in installation costs, which are considered to be relatively insensitive to capacity. Based on this we have allowed for an incremental air-conditioning cost of $230/kWth. 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.

A.5.2 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:[28]

- 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

[27] Cooling and heating capacities for air-conditioners are directly proportional.
[28] 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.[29]

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'.[30] 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.

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

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

Appendix B - Residential Methodology Details

B.1 Infiltration Rates

B.1.1 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"[31].

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 the CSIRO 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.

B.1.2 Method

In order to achieve the targeted infiltration rate in the base case models, the following procedure was undertaken.

1. The infiltration rate $\overline{\mathrm{ACH}}_{\mathrm{archetype}}$ of the AccuRate Sustainability archetype base case model was calculated using the information provided in Chen's documentation *Infiltration Calculations in AccuRate V2.0.2.13* [32]:

   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 $ACH_{zone} = A+B\upsilon$, 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 Sustainability 'Scratch' file.

   b. υ is dependent on the wind speed derived from the AccuRate Sustainability 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 and Detached archetypes, was taken as 2.4 m while it was taken as the mid-height of the zone above the ground for the Apartment archetype (4.35 m) due to this archetype being higher than 9 m.

   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 $ACH_{zone} = A+B\upsilon$, 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 $ACH_{50} \approx 20 \times ACH$ [33]. It should be

[31] Ambrose MD and Syme M (2015). House Energy Efficiency Inspections Project – Final Report. CSIRO,
[32] Australia. Chen, D. (2013). Infiltration Calculations in AccuRate V2.0.2.13.
[33] Sherman, M. H. (1987). Estimation of infiltration from leakage and climate indicators. Energy and Buildings, 10(1), 81–86. https://doi.org/10.1016/0378-7788(87)90008-9

noted that despite the fact that this correlation is widely accepted[34,35], 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 Sustainability 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.

B.1.3 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 B.1.2.

Note that the Apartment and the Attached Townhouse each had two exhaust fans, while the Detached House had six 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.

[34] CIBSE. (2000). CIBSE TM²3 Testing Buildings for Air Leakage.
[35] Egan, A. M. (2011). Air tightness of Australian offices buildings: reality versus typical assumptions used in energy performance simulation. Proceedings of Building Simulation, 14–16.

Table 4-21 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		
Climate Zone 2	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%
Climate Zone 5	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%
Climate Zone 6	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%

B.2 Apartment Archetype

B.2.1 Form Details

The apartment building modelled was based on the details provided by Isaacs[36] (2007, pp. 17-18). The apartment on the corner of the first floor was selected as the representative archetype, refer to Figure 48. 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 49 with 73 m² of total net conditioned floor area[37]. A 3D model of the apartment building showing approximate room layout is presented in Figure 48.

Figure 48: Schematic of the Apartment building (Isaacs 2007, p. 17)

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

Figure 49: Floor plan of the Apartment building (Isaacs 2007, p.17)

B.2.2 Construction Details

The main construction details used for the apartment are summarised in Table 4-22.

Table 4-22: 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 50Pa**, 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.

B.2.3 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 default/pre-set occupancy profile, internal loads (such as lighting) and HVAC schedule assumptions provided by AccuRate Sustainability were employed in the modelling. 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[38]. The details are provided in Delsante[39]. AccuRate Sustainability default heating temperature setpoint values were employed for the heating conditions.

B.3 Attached House

B.3.1 Form Details

The attached house modelled was also selected from the Isaacs's (p. 16) report[40]. The house selected is shown in Figure 50. The net floor area of the house was 128 m², which falls within the size distribution of the most frequent floor areas, i.e. 100-150 m² for a double-storey attached house. Refer to Figure 52 for more details. A 3D model of the attached house showing room layout is presented in Figure 2 and Figure 64.

Figure 50: Façade of the attached house (Isaacs 2007, p.16)

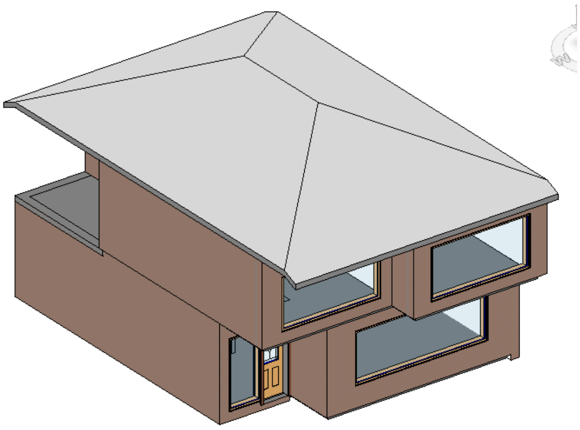


Figure 64: Attached, single storey, archetype adjusted physical geometry (courtesy of S. Beazley)

[38] 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.
[39] Delsante, A. (2005). Is the new Generation of Building Energy Rating Software up to the Task? - A Review of AccuRate, (September), 11–15.
[40] Isaacs, T (2007), Development of housing stock model to predict heating and cooling energy use in Victoria.

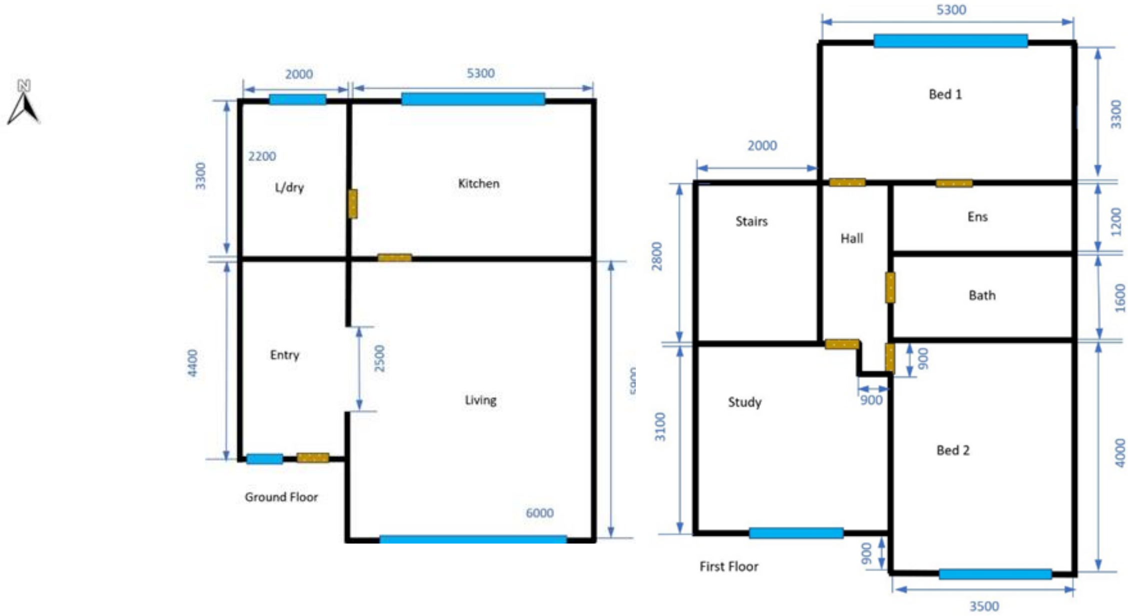


Figure 52: Floor plan of the ground and first floor of the attached house

B.3.2 Construction Details

The construction details of the attached house are specified in Table 4-23. 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 4-23: Construction specifications for the attached archetype

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, p.10) 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.

B.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 default/pre-set occupancy profile, internal loads (such as lighting) and HVAC schedule assumptions provided by AccuRate Sustainability were employed in the modelling. Domestic hot water was considered separately. The HVAC system modelled and its operation were similar to those for apartment buildings.

B.4 Detached house

B.4.1 Form Details

The detached house selected was based on the archetype developed by Isaacs (2007, p. 12) report as shown in Figure 66. The model has been slightly revised, as shown in Figure 1, with a total floor area of 188 m², as per medium detached dwelling analysed in the Pitt & Sherry[41] report, and the dimensions are specified in Figure 68.

Figure 66 3D sketch of the detached house (Isaacs 2007, p. 12)

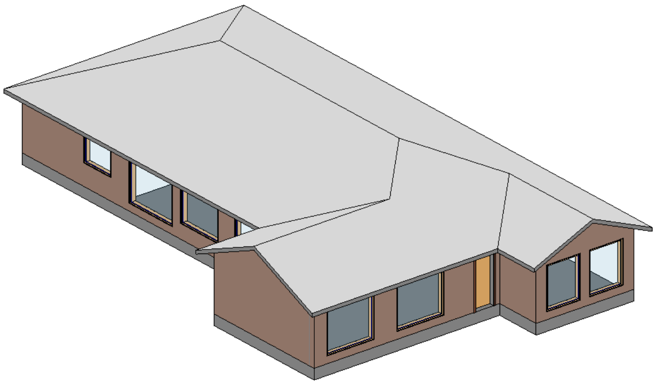


Figure 67 Detached, single storey, archetype adjusted physical geometry (courtesy of S. Beazley)

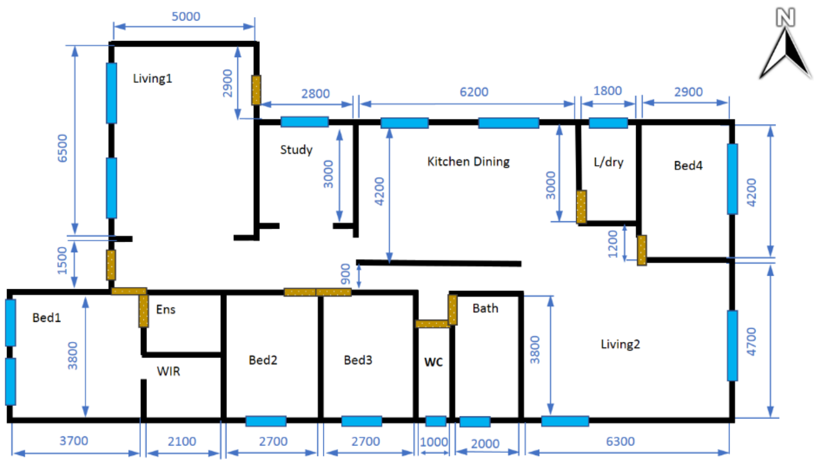


Figure 68 Dimensions of the detached house (Isaacs 2007, p. 12)

B.4.2 Construction Details

[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.

The construction details are specified in Table 4-24. 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 4-24 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

B.4.3 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 default/pre-set occupancy profile, internal loads (such as lighting) and HVAC schedule assumptions provided by AccuRate Sustainability were employed in the modelling. Domestic hot water was considered separately. The HVAC system modelled and its operation were similar to those for apartment buildings.

B.5 Residential Base Case

The objective of this work was to determine the glazing to be used in the 2016 multi-dimensional baseline models ('2016 6-Star Compliant Glazing') and the multi-dimensional increased stringency models ('Increased Performance Glazing'), and define the method to subsequently apply the 'Increased Performance Glazing' to the multi-dimensional analysis. At the highest level, the glazing models will represent:

- '2016 6-Star Compliant Glazing' – Glazing that meets the 2016 NCC requirements with typical WWRs
- 'Increased Performance Glazing' – Glazing that meets the proposed 2019 NCC requirements with typical WWRs

In establishing the new base case, the project was not attempting to:

- Develop a least cost baseline model with realistic glazing dimensions for each archetype which is both optimised and compliant as per how a practitioner might;
- Create modelling results which can be directly compared to a NatHERS Star rating (as discussed above, our models have an adjusted infiltration rate representing 'as built' status as opposed to what would ordinarily be used in a compliance calculation); and
- Create modelling results which can be directly compared to previously presented 'Baseline I' and 'Baseline II' results from the project's Interim Report (this would require a re-calculation of those results to align with the above mentioned adjustments).

[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.

The first step in the process was to define initial archetype glazing, which was not itself be used in any of the scenarios, but is used to generate the '2016 6-Star Compliant Glazing' and 'Increased Performance Glazing'.

For the three archetypes define models that meet the following criteria:

- Include relevant corrections from the Tony Isaacs Consulting (TIC) peer review and TAG suggestions;
- WWRs reasonably represent data presented by the CSIRO;
- Ventilation requirements – size of openable sash of windows to be 5% of floor area, complying with minimum NCC 2016 requirements. UOW archetypes models used in previous work have a defined openable sash of all windows at 50% of total window gross (frame and glass) area;
- Natural lighting requirements – size of aggregate light transmitting area of windows to be 10% of habitable floor area, complying with NCC 2016 minimum requirements. To determine the aggregate light transmitting area of the windows, the proportion of frame area is removed from the total window area. EA and TIC have indicated that the visible light transmittance of window types, previously included in modelling calculations, does not need to be factored into the aggregate light transmitting area as it is not strictly required by the Code; and
- For simplicity of analysis, ensure that ventilation and daylight requirements are met irrespective of the range frame percentages present amongst the glazing types in Table 2-2: (and reproduced in Table 4-25). Note that visible light transmittance for the various glazing types will not be considered when calculating natural lighting requirements as it is not strictly required by the Code (as advised by EA and TIC).

The method to establish multi-dimensional '2016 6-Star Compliant Glazing' base case model can be found in Section 0 of Appendix B - Residential Methodology Details.

B.6 Glazing Analysis

B.6.1 Introduction

Glazing has an extremely important influence on the energy efficiency and thermal comfort performance of any building, in large part due to the major heat exchange processes associated with windows via radiation, conduction and convection. In residential buildings, the choice of optimal glazing types, and associated inside and external shading elements, is complex since the effects of glazing on overall building performance are strongly linked to the geometric design of the building, window-to-wall ratio (WWR), climate zone, glazing and framing characteristics, etc.

The following sections of this report describe how the NCC Trajectories project addressed the issue of proposed increases in energy efficiency stringencies for glazing in Residential Buildings using the similar principles to those adopted for the analysis of Commercial Buildings.

B.6.2 Overview of the Methodology

The overall objective of the work was to develop a comprehensive and rational determination of increased glazing performance stringencies, or Improved Glazing Performance targets.

Informed by the fundamental principles of building physics, a rational and straightforward approach to this issue was adopted whereby any external wall of a residential building that includes one or more glazing elements is considered to be a composite wall/glazing system characterized by two fundamental parameters that: 1) determine the transmission of thermal energy via conduction through the window/wall composite structure, and 2) govern the transmission of radiative thermal energy through the non-opaque surfaces/apertures of the structure.

1. The area-weighted thermal transmittance, U_{total}, of the wall/glazing component, where: $U_{total} = U_{window} \times WWR + U_{wall} \times (1 – WWR)$
2. The total wall solar heat gain coefficient (SHGC), i.e. SHGCxWWR.

As set out below, the key steps in the overall process of determining the proposed Improved Glazing Performance targets (or stringencies) were as follows.

a) Determine the appropriate base case window sizes and window-to-wall ratios for all archetypes based on current NCC daylighting requirements and data gathered on current industry practice.

b) Determine the relationship between the thermal energy required to maintain comfortable conditions in a dwelling as a function of glazing type and window-to-wall ratios. Changes in annual heating and cooling thermal energy required as a function of changes to glazing characteristics are dependent on a great many individual parameters (e.g. climate zone, type of building archetype, orientation, WWR, window and wall thermal characteristics, etc.). These results are integrated and simplified through the use of the U_{total}/WWRxSHGC approach.

c) Bring construction cost data together with the energy requirements from a) to determine the minimum requirements for future glazing energy efficiency stringencies – the new Improved Glazing Performance targets. As in the present DtS glazing energy performance requirements of the NCC 2016, the new Improved Glazing Performance targets will be dependent not only on the characteristics of the glazing, but also the wider design of the building, climate, orientation, etc.

B.6.2.1 Glazing Energy Analysis Methodology

The baseline window and wall characteristics for the three residential archetype buildings were chosen after in-depth consultation with numerous stakeholders, including the Technical Advisory Group.

The minimum window-to-wall ratio (WWR_{min}) of each archetype was determined based on the following considerations:

a. National Construction Code (2016) requires a that the minimum natural light transmitting area, i.e. glass area excluding the framing, has to be at least 10% of the floor area of the room.
b. In cases where the room does not have a window/glazed panel, natural light is permitted to come from an adjoining room. In this instance the total light transmitting area should be a minimum of 10% of the combined floor area of both rooms.

Windows complying with the WWR_{min} requirement were then chosen for each archetype and the lowest performance glass (i.e. Glass 1 in Table 4-25). The window/glass type was then varied by selecting appropriate window characteristics from the AccuRate software window library, so as to effectively change the window U-value and solar heat gain coefficient (SHGC). The glass types used in this analysis are summarised in Table 4-25.

B.6.2.2 Effects of Glazing Orientation and External Shading

The impact of glazing in a building is very strongly dependent on the orientation of the façade in which the glazing is located. Thus, to accurately determine the impact on the thermal energy requirements of the building of changing the glazing characteristics as a function of façade orientation, the glazing type and the window-to-wall ratio (WWR) changes were only imposed on a single façade of each archetype. This 'principal façade' was taken to be the one with the most significant/largest glazing area. The location of the principal facades for each archetype are shown in Figure 70 (see blue arrows). Therefore, only the glazing characteristics and WWR on this particular façade were modified and the properties of the windows on the other façades were held constant at the base case values.

The external shading of windows in the residential archetype buildings in the present work was significantly more geometrically complex than for the commercial office building archetypes, particularly in respect of elements such as eaves and balconies. The influence of external shading on the solar gains through a given window can be significant. In the NCC2016 this is dealt with through the shading factor, P/H (shading projection, P, and window height, H) which is used to calculate the winter and summer glazing 'exposure factors' (see Figure 69) for each window/facade.

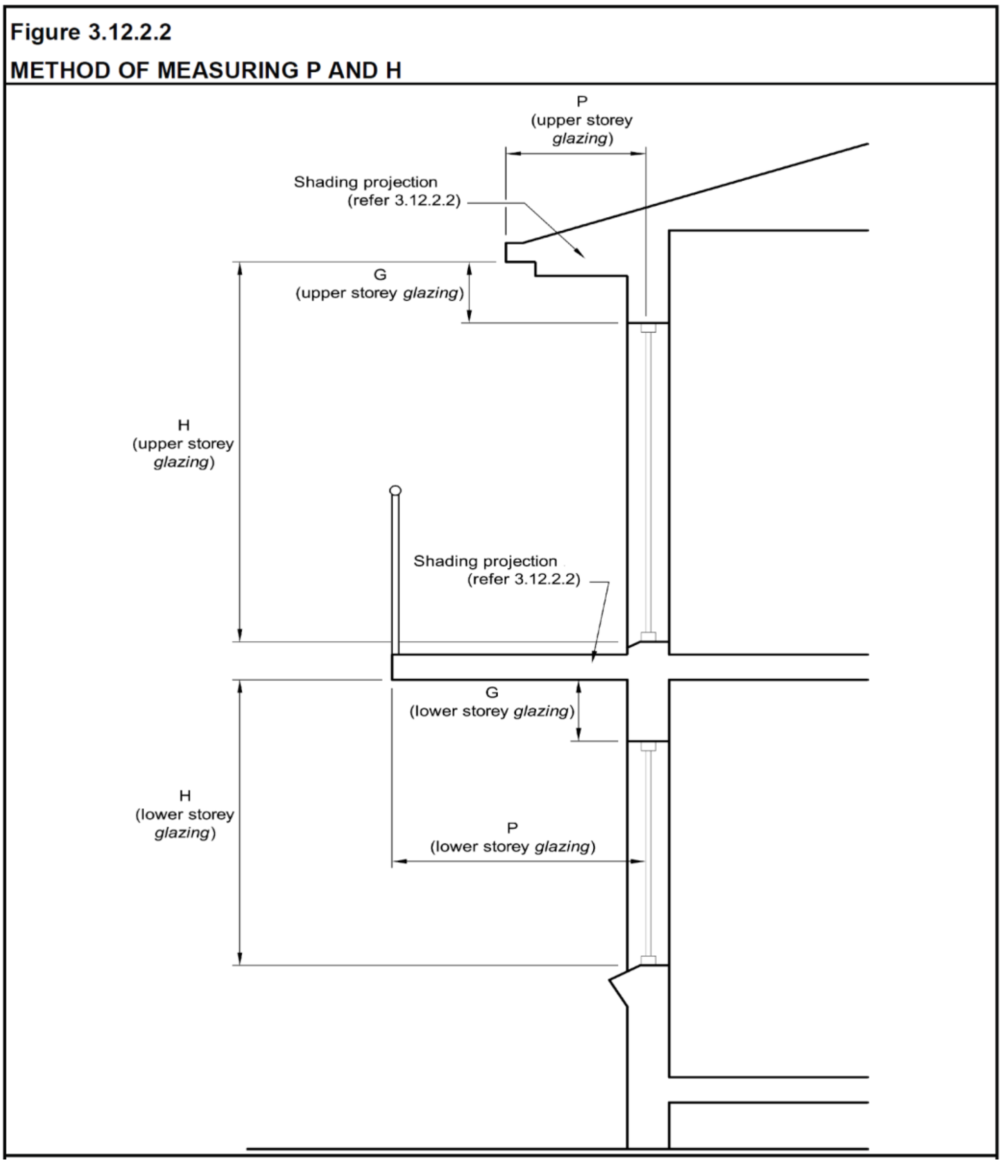


Figure 69: Method of determining the shading factor for a given window (NCC2016, 3.12.2.2)

To eliminate any confounding effects from changes to the 'shading factor' when adjusting WWRs, the heights and sill-heights of all windows and glass doors were therefore maintained at the maximum WWR values for each of the archetypes, i.e. window-to-wall ratios were varied by changing only the width of glazed elements (window and doors) in the principal facade.

To establish the proposed new, Improved Glazing Performance targets a reasonably wide a range of WWRs were examined for each archetype. For each archetype, climate zone (CZ), and principal façade orientation three WWR cases were modelled:

a) WWR_{min} – the window dimensions being determined from: i) the 10% window-to-floor-area requirement, and ii) the use of Glass 1.

b) A mid-range window-to-wall ratio of WWR_{min}+10%, where for example, if the base case WWR_{min}=8%, then (WWR_{min}+10%)=18%.

c) A high WWR scenario of WWR_{min}+20%, representing large glazing areas at the high end of current practice. It should be noted that window-to-wall ratios somewhat lower WWR_{min}+20% were modelled for a variety of geometrical reasons (e.g. for CZ2, CZ5 and CZ6 values of WWR_{min}+~15% were used).

Table 4-26 presents the matrix of options used in this analysis. All the windows in the building were first set to the lowest performance window (Glass 1 Table 4-25) and with WWR_{min}.

Thereafter, as with the base case glazing, the different types of glass were tested in the principal façade while holding the other façade glazing constant, i.e. Glass 1 and WWR_{min}. Each glass type was evaluated for the principal façade facing in the four cardinal directions. After this, the same process was repeated for WWR_{min}+10% and WWR_{min}+15% for CZ2, CZ5 and CZ6 or WWR_{min}+20% for CZ7.

Overall the glazing analysis involved a very significant effort to develop hundreds of Accurate simulations of the residential building archetypes across the 4 climate zones and with a wide range of glazing types, window-to-wall ratios, and window configurations, i.e. simulations were needed for 3 archetypes x 4 climate zones x 6 glass types x 4 orientations x 3 WWRs, etc.

Table 4-25: Window types used in the glazing analysis.

Type	U-value (W/m^2K)	SHGC	VT	Frame ratio (%)	Description	Cost for windows ($/m²)	Cost for doors ($/m²)
Glass 1	6.7	0.7	0.9	24	Al frame, Single glazing (SG) clear glass	246.92	422.26
Glass 2	4.6	0.46	0.61	19	Composite frame, SG Low solar gain and low-e	430.09	679.27
Glass 3	4.3	0.53	0.75	24	Al frame, double glazing (DG), air fill, glass: High solar gain low-e - Clear	416.33	558.59
Glass 4	2.3	0.25	0.45	20	uPVC frame DG, air fill, glass: Low solar gain low-e - Clear	458.27	457.99
Glass 5	2.9	0.51	0.75	24	Al frame, DG, Argon fill, glass: High solar gain low-E - Clear	675.95	973.00
Glass 6	2.6	0.53	0.82	35	Timber frame, DG, Argon fill, glass: Clear - Clear	317.71	272.83

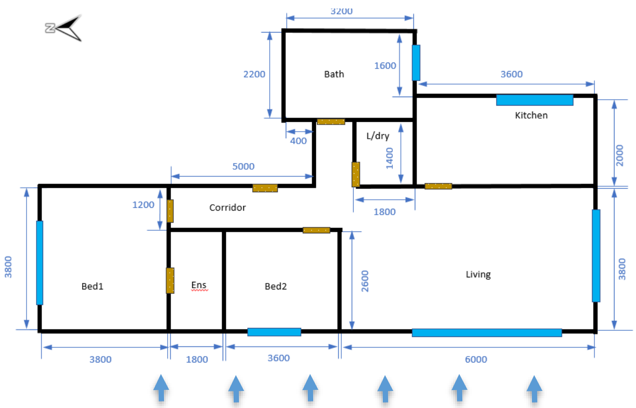
Table 4-26: Matrix of options for the glazing analysis.

Scenario	Glass 1	Glass 2	Glass 3	Glass 4	Glass 5	Glass 6
Base case (WWR_{min})	AF	PF	PF	PF	PF	PF
Base case WWR_{min}+10%	AF	PF	PF	PF	PF	PF
Base case WWR_{min}+~15% (CZ2, CZ5, CZ6)	AF	PF	PF	PF	PF	PF
Base case WWR_{min}+20% (CZ7)	AF	PF	PF	PF	PF	PF

AF: all facades: PF: principal façade.

The increased stringency levels for the glazing were then chosen so as to give a range of improved glazing/wall performance scenarios between the current baseline and what was considered to be achievable in the short to medium term. The AccuRate simulations then provided the annual heating, cooling and total heating and cooling thermal energy requirements as a function of the different climates, orientations, SHGCxWWR, U-values, WWR, etc.

All building performance simulations were carried out using the AccuRate software package v2.3.3.13, and AccuBatch v2.3.0.0 was utilized as far as possible to maximise the efficiency of running multiple versions of the archetypes.



a) Apartment

b) Attached (terrace townhouse)

c) Detached house

Figure 70 Principal façade and reference orientation (north = 0°) and location of 'principal façade' (blue arrows) used for glazing analysis simulations for: a) apartment, b) attached, and c) detached archetypes.

B.6.3 Glazing Analysis Energy Results

The key outputs required for the Benefit Cost Analysis resulting from changes in glazing on each archetype, as determined from the AccuRate energy simulations, were:

i) changes in the annual energy requirements of the HVAC system and

ii) peak electrical loads.

In-depth details of these results are presented at the end of this Appendix. Some sample results for particular archetypes and climate zones are presented below to provide the reader with an appreciation of the influence of glazing on building performance in terms of annual heating and cooling energy requirements and the peak electrical heating/cooling loads.

Table 4-27 Example of changes in annual total (heating and cooling) thermal energy required as a function of glazing characteristics on the principal façade of the Apartment archetype.

Climate Zone	Building Orient'n	Principal Façade Orient'n	Base Case (Heating & Cooling) MJ/m² Glass 1 WWRmin	Energy Savings (Heating/Cooling) MJ/m² Glass 1 WWRmin+10%	Glass 1 WWRmin+15%*	Glass 2 WWRmin	Glass 2 WWRmin+10%	Glass 2 WWRmin+15%*	Glass 3 WWRmin	Glass 3 WWRmin+10%	Glass 3 WWRmin+15%*	Glass 4 WWRmin	Glass 4 WWRmin+10%	Glass 4 WWRmin+15%*
2	0	West	61.7	-15.5	-25.7	-1.2	-19.0	-30.4	0.4	-12.4	-21.6	0.6	-9.1	-17.3
2	90	North	58.1	-1.2	-3.1	1.6	-0.8	-4.2	2.1	1.8	-0.6	4.5	2.2	-0.4
2	180	East	51.7	-8.1	-14.1	1.0	-9.6	-16.8	1.7	-5.2	-10.6	2.7	-3.4	-7.1
2	270	South	61.4	-4.8	-8.0	0.0	-5.2	-8.7	1.9	-1.6	-3.9	2.0	-1.1	-3.7
5	0	West	57.0	-4.6	-11.2	1.1	-7.1	-16.3	1.9	-1.8	-7.0	0.5	-1.8	-6.0
5	90	North	46.8	-2.1	-5.4	0.9	-2.7	-6.6	1.5	0.2	-2.1	0.9	-0.6	-1.8
5	180	East	48.6	-6.7	-12.1	0.0	-8.6	-15.3	1.7	-4.2	-8.4	1.4	-2.4	-5.6
5	270	South	60.1	-5.1	-7.3	-0.7	-5.2	-7.6	1.7	-0.3	-1.3	0.7	-1.8	-3.4
6	0	West	141.6	-15.7	-25.8	-1.5	-21.0	-33.2	5.3	-5.2	-12.9	—	—	—
6	90	North	123.6	-7.1	-14.9	-0.6	-11.0	-20.8	5.0	2.7	-2.5	—	—	—
6	180	East	133.0	-14.4	-23.7	-0.9	-17.1	-27.8	5.7	-3.0	-8.9	—	—	—
6	270	South	150.3	-17.2	-26.4	-1.1	-19.4	-29.7	6.4	-3.5	-9.3	—	—	—
7	0	West	140.4	-27.2	-63.6	1.2	-18.1	-45.7	5.6	-8.9	-31.3	—	—	—
7	90	North	125.3	-19.0	-43.4	-0.6	-12.9	-31.8	3.7	-3.5	-17.4	—	—	—
7	180	East	137.7	-22.8	-51.4	1.5	-13.6	-35.0	5.5	-3.8	-19.7	—	—	—
7	270	South	155.2	-23.7	-50.6	3.0	-14.9	-34.9	7.4	-4.1	-17.3	—	—	—

Table 4-28 Example of changes in the peak heating electrical power required for heating as a function of glazing characteristics on the principal façade of the Apartment archetype.

Climate Zone	Building Orient'n	Principal Façade Orient'n	Base Case (Heating) kW Glass 1 WWRmin	Peak Electrical HVAC Power Savings (kW) Glass 1 WWRmin+10%	Glass 1 WWRmin+12%	Glass 2 WWRmin	Glass 2 WWRmin+10%	Glass 2 WWRmin+12%	Glass 3 WWRmin	Glass 3 WWRmin+10%	Glass 3 WWRmin+12%	Glass 4 WWRmin	Glass 4 WWRmin+10%	Glass 4 WWRmin+12%*
2	0	South	0.98	-0.06	-0.07	0.01	-0.04	-0.05	0.08	0.04	0.03	0.08	0.05	0.05
2	90	West	0.91	-0.05	-0.06	0.00	-0.06	-0.09	0.07	0.04	0.03	0.06	0.02	0.02
2	180	North	0.81	0.07	0.08	0.06	0.11	0.10	0.07	0.15	0.17	0.02	0.10	0.12
2	270	East	0.71	0.01	0.00	0.02	-0.04	-0.05	0.09	0.08	0.07	0.06	0.02	0.01
5	0	South	1.00	-0.08	-0.09	0.00	-0.08	-0.09	0.09	0.04	0.03	0.10	0.04	0.03
5	90	West	1.05	-0.07	-0.09	0.00	-0.07	-0.09	0.09	0.04	0.03	0.09	0.04	0.03
5	180	North	0.99	-0.05	-0.07	0.00	-0.07	-0.08	0.09	0.07	0.06	0.06	0.03	0.02
5	270	East	1.06	-0.07	-0.09	0.00	-0.07	-0.08	0.09	0.04	0.03	0.09	0.04	0.03
6	0	South	1.76	-0.10	-0.12	0.00	-0.10	-0.13	0.10	0.03	0.01	—	—	—
6	90	West	1.82	-0.10	-0.11	-0.01	-0.10	-0.12	0.10	0.03	0.02	—	—	—
6	180	North	1.76	-0.08	-0.09	-0.01	-0.09	-0.11	0.10	0.05	0.05	—	—	—
6	270	East	1.82	-0.10	-0.12	0.00	-0.10	-0.12	0.10	0.03	0.01	—	—	—
7	0	South	2.28	-0.12	-0.24	0.08	0.00	-0.09	0.12	0.06	-0.02	—	—	—
7	90	West	2.30	-0.11	-0.22	0.08	-0.01	-0.09	0.11	0.06	-0.01	—	—	—
7	180	North	2.26	-0.09	-0.17	0.06	-0.01	-0.06	0.09	0.06	0.02	—	—	—
7	270	East	2.27	-0.08	-0.16	0.07	0.01	-0.04	0.11	0.07	0.03	—	—	—

A comprehensive presentation of all the key energy simulation results may be found at the end of this Appendix.

B.6.3.1 Energy Simulation Results for the Apartment Archetype

The western façade of the apartment archetype was selected as the principal façade (for a northerly building orientation of 0 degrees), with a principal facade WWR_{min}=0.09 as the base case for CZ2, CZ5 and CZ6, and WWR_{min}= 0.07 for CZ7. Window sizes were then determined for the other scenarios, and resultant matrix of WWR values and total window areas (for the principal façade) employed for each scenario for every climate zone is presented in Table 4-29.

Table 4-29 Apartment glazing analysis parameter matrix.

Scenario	CZ	Principal façade WWR Glass 1	Glass 2	Glass 3	Glass 4	Glass 5	Glass 6	Principal façade window area (m²) Glass 1	Glass 2	Glass 3	Glass 4	Glass 5	Glass 6
Base case (WWR_{min})	2,5,6	0.09	0.12	0.1	0.16	0.1	0.11	3.6	4.9	4.3	6.8	4.3	4.6
Base case WWR_{min}+10%	2,5,6	0.19	0.26	0.22	0.35	0.22	0.24	7.7	10.6	9.2	14.6	9.2	9.8
Base case WWR_{min}+15%	2,5,6	0.24	0.33	0.28	0.45	0.28	0.3	9.7	13.4	11.7	18.4	11.7	12.5
Base case (WWR_{min})	7	0.07	0.07	0.07	0.07	0.07	0.07	2.7	2.7	2.7	2.7	2.7	3.0
Base case WWR_{min}+10%	7	0.17	0.17	0.17	0.17	0.17	0.17	6.8	6.8	6.8	6.8	6.8	7.1

Base case WWR_{min}+20%	7	0.27	0.27	0.27	0.27	0.27	0.27	10.9	10.9	10.9	10.9	10.9	11.2

The figure below, and the comprehensive set of graphs provided at the end of this report, present the results for thermal energy required by the dwellings (annual heating, annual cooling and annual heating and cooling combined for the whole apartment) as a function of: SHGCxWWR; window type and the direction faced by the principal façade concerned on which these changes were made.

Typically, the total energy consumption decreased with decreasing SHGCxWWR for all four climates irrespective of the apartment orientation and glass type. Looking at heating and cooling consumption separately, each climate zone behaved differently for the heating. The two climate zones with the largest heating demand, i.e. CZ7 in all orientations and CZ6 with the principal façade facing east, south and west, show an increasing trend as SHGCxWWR increases. This is largely because the heat losses due to a larger glazing area outweigh the increased winter solar heat gains, and more heating is needed.

As expected, the trends for windows of different U-values converged as SHGCxWWR approaches zero, since the limit of SHGCxWWR→0 represents a wall with no window, where $U_{total}=U_{wall}$.

A representative example of the thermal energy requirements for one particular climate zone and one orientation of the principal façade are shown in Figure 71.

Apartment - Climate Zone 2

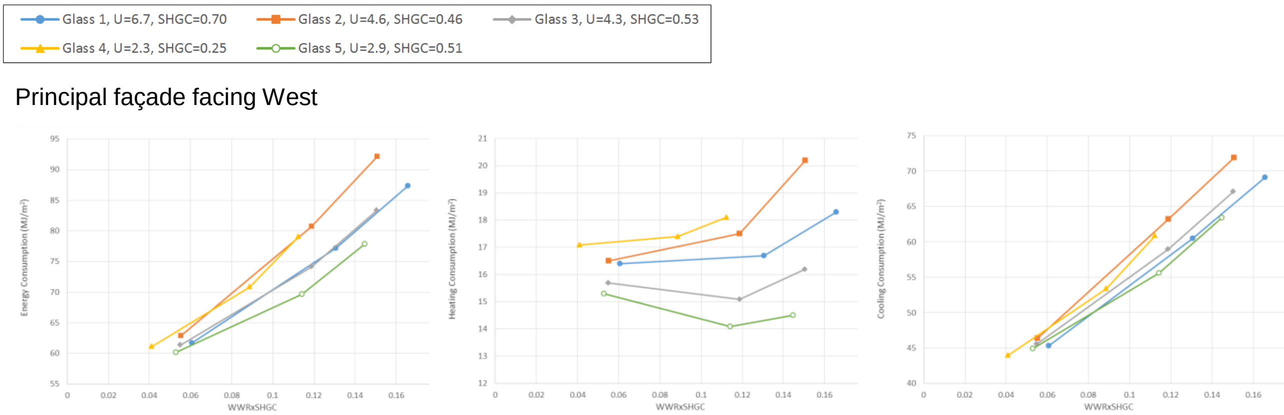


Figure 71 Example graphs for the Apartment archetype annual thermal energy required (total, heating and cooling) vs SHGCxWWR for a Climate Zone 2 and principal façade facing West.

All the energy results from the more than 800 simulations/models undertaken for the residential glazing analysis are provided at the end of this Appendix.

B.6.3.2 Results for Attached Archetype

The southern façade of the attached archetype was selected as the principal façade (for a northerly building orientation of 0 degrees). The principal façade WWR_{min} of the attached house with the base case window Glass 1 was 0.31 (CZ2, CZ5 and CZ6). The resultant matrix with WWRs and principal façade window areas for each scenario is presented in Table 4-30. A particular example of the thermal energy requirements (heating, cooling and heating and cooling combined) versus SHGCxWWR and glass types for Climate Zone 7 with the principal façade facing West are shown in Figure 72.

The results for all climate zones and orientations are provided at the end of this Appendix. It may be seen from these figures that the total heating and cooling energy requirements of the attached house typically increased with increasing SHGCxWWR and U-values for the four orientations and four climate zones. For the same SHGCxWWR and glass type, the Attached archetype required the most heating and cooling energy in Climate Zone 7, followed by Climate Zone 6, Climate Zone 2 and Climate Zone 5.

Table 4-30 Attached archetype glazing analysis matrix

Scenario	CZ	Principal façade WWR						Principal façade window area (m²)					
		Glass 1	Glass 2	Glass 3	Glass 4	Glass 5	Glass 6	Glass 1	Glass 2	Glass 3	Glass 4	Glass 5	Glass 6
Base case (WWR_{min})	2,5,6	0.31	0.43	0.37	0.59	0.37	0.4	10.8	15.0	13.0	20.5	13.0	13.9
Base case WWR_{min}+10%	2,5,6	0.41	0.57	0.49	0.78	0.49	0.52	14.3	19.8	17.2	27.2	17.2	18.4
Base case WWR_{min}+15%	2,5,6	0.43	0.59	0.51	0.81	0.51	0.55	15.0	20.8	18.0	28.5	18.0	19.3
Base case (WWR_{min})	7	0.21	0.20	0.21	0.20	0.21	0.25	7.4	7.1	7.4	7.1	7.4	8.7
Base case WWR_{min}+10%	7	0.31	0.30	0.31	0.30	0.31	0.35	10.9	10.7	10.9	10.7	10.9	12.7
Base case WWR_{min}+20%	7	0.41	0.40	0.41	0.40	0.41	0.45	14.4	14.1	14.4	14.1	14.4	15.7

A representative example of the thermal energy requirements one particular climate zone and one orientation of the principal façade are shown in below.

Attached - Climate Zone 7

Principal façade facing West

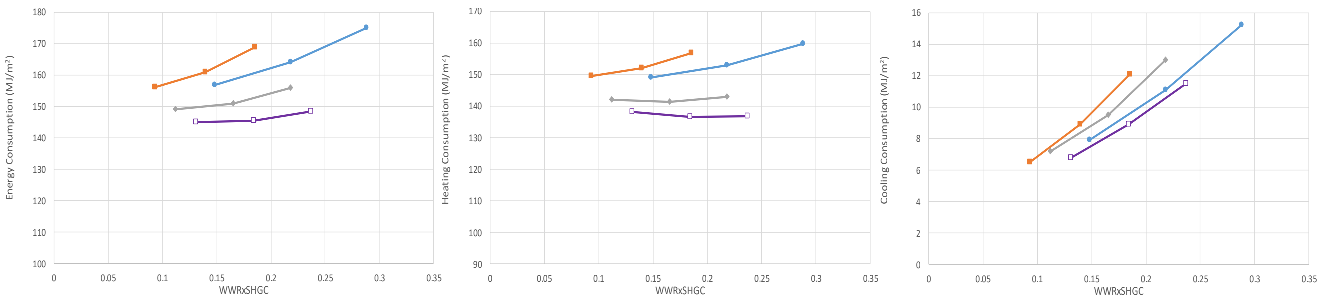


Figure 72: Example graphs for the attached archetype annual thermal energy required (total, heating and cooling) vs SHGCxWWR for a particular climate zone and principal façade orientation

All the energy results from the more than 800 simulations/models undertaken for the residential glazing analysis are provided at the end of this Appendix.

B.6.3.3 Results for Detached Archetype

The analysis for the detached house was focussed on the south façade of the baseline house model. The resultant matrix with WWR and total window area for each scenario is presented in Table 4-31**.** A particular example of the thermal energy requirements (heating, cooling and heating and cooling combined) versus SHGCxWWR and glass types for Climate Zone 5 with the principal façade facing West are shown in Figure 73.

The trends in the annual heating and cooling requirements of the detached archetype was qualitatively similar to that of the attached house across the four orientations and three climate zones.

Table 4-31: Details of the glazing options for the detached house

Scenario	CZ	Principal façade WWR						Principal façade window area (m²)					
		Glass 1	Glass 2	Glass 3	Glass 4	Glass 5	Glass 6	Glass 1	Glass 2	Glass 3	Glass 4	Glass 5	Glass 6
Base case (WWR_{min})	2,5,6	0.12	0.16	0.14	0.22	0.14	0.15	5.8	8.0	6.9	11.0	6.9	7.4
Base case WWR_{min}+10%	2,5,6	0.22	0.30	0.26	0.41	0.26	0.28	10.7	14.8	12.8	20.3	12.8	13.7
Base case WWR_{min}+15%	2,5,6	0.27	0.37	0.32	0.51	0.32	0.34	13.2	18.2	15.8	25.0	15.8	16.9
Base case (WWR_{min})	7	0.09	0.09	0.09	0.09	0.09	0.11	5.2	4.9	5.2	4.9	5.2	6.1
Base case WWR_{min}+10%	7	0.19	0.19	0.19	0.19	0.19	0.21	10.8	10.5	10.8	10.5	10.8	11.6
Base case WWR_{min}+20%	7	0.29	0.29	0.29	0.29	0.29	0.31	16.3	16.0	16.3	16	16.3	17.2

Detached - Climate Zone 5

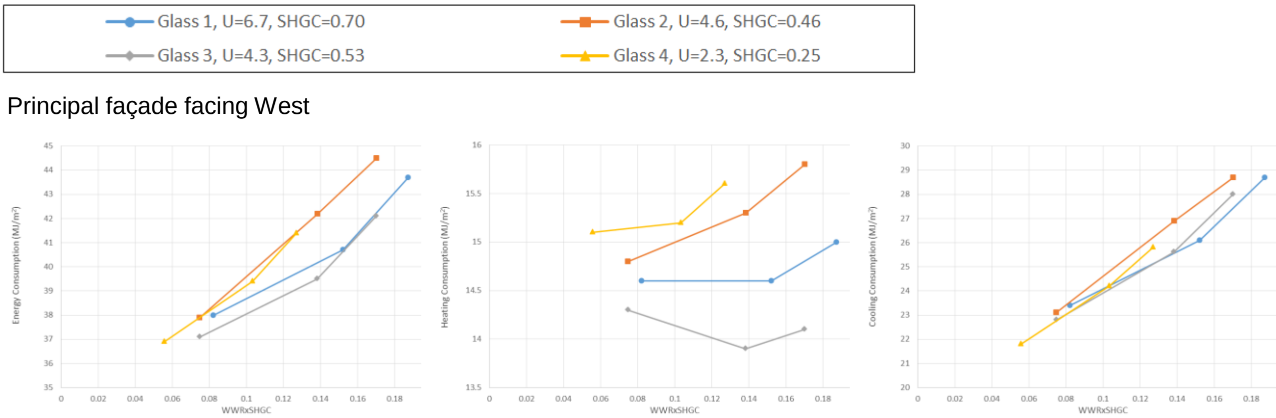


Figure 73 Example graphs for the detached archetype annual thermal energy required (total, heating and cooling) vs SHGCxWWR for a particular climate zone and principal façade orientation

All the energy results from the more than 800 simulations/models undertaken for the residential glazing analysis are provided at the end of this Appendix.

B.6.4 Glazing BCA and Determination of the Improved Performance Glazing Targets

The geometries of all the windows in the very many AccuRate models of the archetypes energy described in the previous section were then used to determine the capital costs of the glazing in each case. The performance of the scenarios compared with the base case is shown in Figure 74 below.

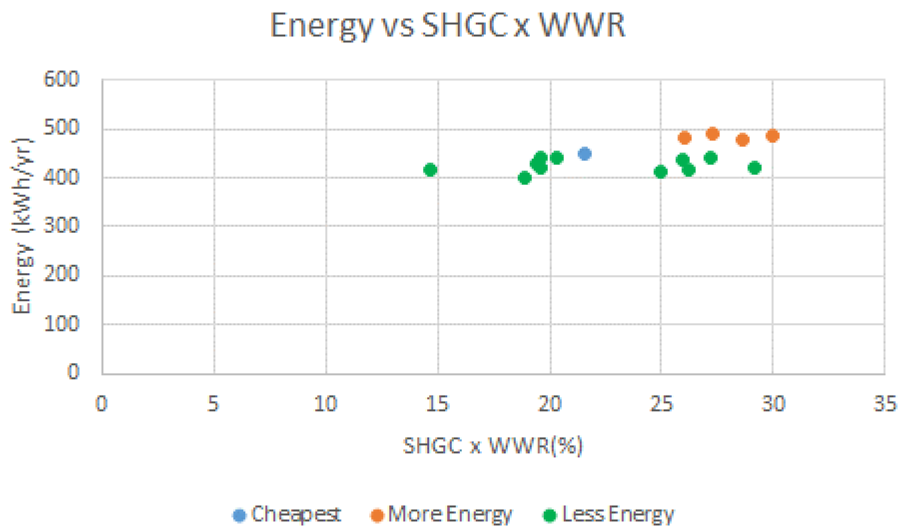


Figure 74: Example Energy vs SHGC x WWR plot showing the relative position of the cheapest option for Attached Climate Zone 2 North.

The scenarios that performed better than the base case scenario were then characterised by plotting them on a U_{total} (wall + window) value versus SHGC x WWR graph as shown in Figure 75 below. Using this relationship, the upper bound values of both U-total and SHGC x WWR to ensure energy compliance were determined, which represented the Improved Performance Glazing targets. Glazing that did not meet both these requirements would be deemed to be 'energy non-compliant' with respect to these targets. This process was then repeated across each orientation. The Improved Performance Glazing targets are provided in Table 4-32 below.

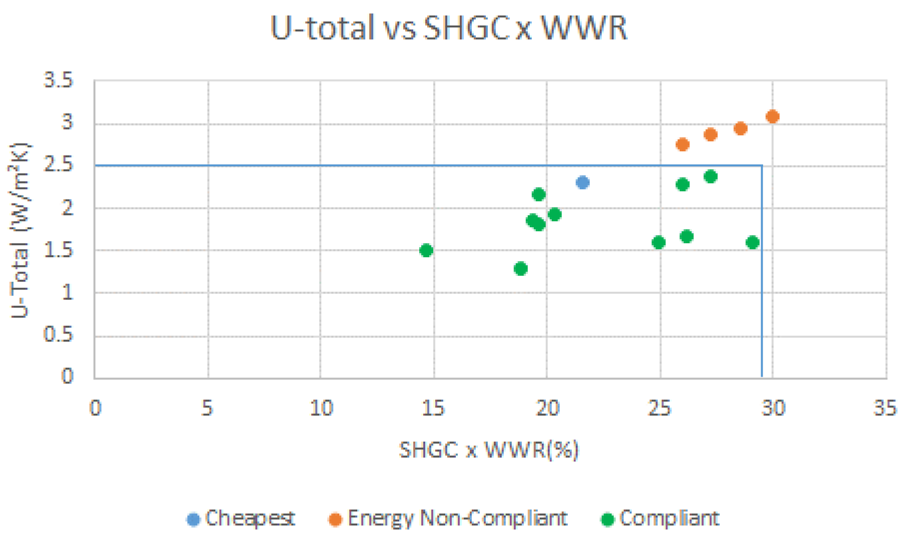


Figure 75: Example U_{total} vs SHGC x WWR plot for Attached archetype in Climate Zone 2 North facing condition.

Table 4-32: Proposed 'Improved Performance Glazing' targets.

Attached			Detached			Apartment		
CZ2			CZ2			CZ2		
Orientation	SHGC*WWR	U_{tot}	Orientation	SHGC*WWR	U_{tot}	Orientation	SHGC*WWR	U_{tot}
N	0.29	2.3	N	0.14	1.1	N	0.06	0.75
E	0.25	2.3	E	0.08	1.1	E	0.06	0.75
S	0.29	2.3	S	0.17	1.1	S	0.06	0.75
W	0.26	2.3	W	0.14	1.1	W	0.06	0.75
CZ5			CZ5			CZ5		
Orientation	SHGC*WWR	U_{tot}	Orientation	SHGC*WWR	U_{tot}	Orientation	SHGC*WWR	U_{tot}
N	0.29	2.3	N	0.08	1.1	N	0.06	0.75

E	0.29	2.3	E	0.08	1.1	E	0.06	0.75
S	0.29	2.3	S	0.18	1.1	S	0.06	0.75
W	0.29	2.3	W	0.1	1.1	W	0.06	0.75
CZ6			CZ6			CZ6		
Orientation	SHGC*WWR	U_{tot}	Orientation	SHGC*WWR	U_{tot}	Orientation	SHGC*WWR	U_{tot}
N	0.29	1.5	N	0.18	1.1	N	0.06	0.75
E	0.29	1.5	E	0.18	1.1	E	0.06	0.75
S	0.29	1.5	S	0.18	1.1	S	0.06	0.75
W	0.29	1.5	W	0.18	1.1	W	0.06	0.75
CZ7			CZ7			CZ7		
Orientation	SHGC*WWR	Utot	Orientation	SHGC*WWR	Utot	Orientation	SHGC*WWR	Utot
N	0.29	1.5	N	0.15	1.1	N	0.06	0.75
E	0.29	1.5	E	0.15	1.1	E	0.06	0.75
S	0.29	1.5	S	0.15	1.1	S	0.06	0.75
W	0.29	1.5	W	0.15	1.1	W	0.06	0.75

It should be noted that should this approach be adopted to the minimum performance specifications of glazing in the future, then further research/modelling may be required to determine the sensitivity of the targets given in Table 4-32 to building design parameters such as shading factor, etc.

B.6.5 Determination of Glazing Base Case Models for Multi-Dimensional Energy Analyses

B.6.5.1 Objective

The objectives of this part of the work was to:

1. Determine the glazing to be used in the 2016 multi-dimensional baseline AccuRate Sustainability models ('2016 6-Star Compliant Glazing') of the three archetypes, and to
2. Determine the glazing to be included in the multi-dimensional increased stringency archetypes ('Improved Performance Glazing') as determined from the 'Improved Performance Glazing' targets shown in Table 4-32 which were selected on a climate zone/archetype basis and used across all future time steps.

B.6.5.2 Selection of Archetype Glazing Dimensions

The first step in the process was to define the baseline glazing types in the various archetypes, which were then used to generate the '2016 6-Star Compliant Glazing' and the proposed 'Improved Performance Glazing' targets.

To do this, AccuRate models for the three archetypes/climate zones were defined that met the following criteria:

- WWRs were chosen to align with certification data for recent building approvals as provided by CSIRO, and shown in Table 4-34 and Table 4-35.
- Ventilation requirements – sizes of the openable areas of windows were chosen to meet the 5% of floor area NCC 2016 requirements, and the openable areas of each window was set to be 50% of that window's total gross (frame plus glass) area;
- Natural lighting requirements – size of aggregate light transmitting area of windows to be 10% of habitable floor area, complying with NCC 2016 minimum requirements.

B.6.5.3 Method to Establish Multi-Dimensional '2016 6-Star Compliant Glazing' Baseline Models

The process to determine glazing for the Multi-Dimensional '2016 6-Star Compliant Glazing' Baseline Models was as follows.

1. Set building fabric to 2016 compliance: Apply NCC2016 DtS compliance to all parameters of the Baseline Archetypes other than glazing.

2. Select the glazing type (same for all facades) to ensure that 6-Star performance is achieved in at least one orientation, and determine the two 'primary orientations' (with the highest and lowest energy consumption) for each archetype:

   For each NCC2016 DtS compliant archetype baseline model (from Step 1):

   a. Determine the minimum window-to-wall ratio (WWR) which satisfies the ventilation and daylighting requirement of the Code. Add the appropriate increase in WWR (10% for Class 1 and 20% for Class 2) to establish 'reasonably sized' windows based on WWR data provided by CSIRO for new builds (Table 4-34 and Table 4-35). Ensure that the air movement requirements for Class 1 buildings are met.

b. For each façade, beginning with the lowest cost glazing (Glass 1) from Table 4-33, and applying this glass type to all facades, test the NatHERS rating (default infiltration) for the building in all four cardinal orientations.
c. If the building achieves NatHERS 6 Star rating in at least one orientation, no further adjustment to glazing is required, otherwise select the next cheapest glass type from Table 4-33, applying this glass type to all facades, and repeat until the 6 Star requirement is met for at least one orientation.
d. Select the 'best' and 'worst' energy performing orientations for the relevant archetypes and climate zone. These are to be used as the NCC2016 DtS compliant archetype primary orientations.

3. Select the cheapest glazing type on a façade-by-façade basis that results in NCC2016 6-Star dwelling compliance for the two principal orientations:

   (this is to ensure that the dwellings are NCC2016 6-Star compliant using default infiltration, but the Multi-D base case employed a more realistic as-built 15ACH@50Pa air tightness)

   For each NCC2016 DtS compliant building archetype primary orientation baseline model (from Steps 1 and 2), determine the lowest cost glazing from Table 4-33 that ensures that the primary orientation of the relevant archetype achieves a NatHERS 6 Star rating (using Accurate default infiltration settings, which was approximately equivalent to 6ACH@50Pa for these archetypes), for each climate zone. The following process was used:

   a. For each façade, select the lowest cost glazing.
   b. Test the NatHERS rating (default infiltration) for the building, and check whether the glazing satisfies the NCC Volume 2 Glazing Calculator.
   c. If it achieves 6 Stars, no further adjustment required.
   d. If it does not achieve 6 Stars, sequentially replace the glazing on each façade with the next cheapest glazing from Table 4-33, starting with the most marginal facade based on the Glazing Calculator results.
   e. If one or more single façade upgrade achieves 6 Stars (default infiltration), select the façade with the lowest glazing area upgrade that achieves 6 Stars and stop.
   f. If no single façade upgrade achieves 6 Stars, test combinations of 2, 3 and ultimately 4 façade upgrades using this next cheapest glazing and similarly select the lowest area façade upgrade that achieves 6 Stars and stop.
   g. If no combination of single façade upgrades at this level achieves 6 Stars, return to d. using all facades at the new glazing levels and testing the third cheapest glazing (and so on).
   h. Repeat until the building achieves 6 Stars.

Table 4-33: List of AccuRate glass types (from default glazing library) used for the Multi-Dimensional 2016 6-Star Compliant Glazing analysis

Glass Name	U	SHGC	VT	Frame
Glass 1	6.7	0.7	0.9	0.24
Glass 2	4.6	0.46	0.61	0.19
Glass 3	4.3	0.53	0.75	0.24
Glass 4	2.3	0.25	0.45	0.2
Glass 5	2.9	0.51	0.75	0.24
Glass 6	2.6	0.53	0.82	0.35

Table 4-34: Typical WWR percentages for Class 1 and Class 2 buildings for the indicated states and territories [data provided by CSIRO]

Archetype	Orientation	WWR % from HStar Data Base			
		QLD	NSW	VIC	ACT
Detached and Attached Archetypes (Class 1)	Average WWR % across 4 orientations	19.0	20.7	20.0	19.4
Apartment Archetype (Class 2)	Average WWR % across 4 orientations	24.3	33.1	47.4	32.9

Table 4-35: Typical WWR percentages for Class 1 and Class 2 buildings for the indicated states and territories representing CZ2, CZ5, CZ6 and CZ7 by orientation [data provided by CSIRO]

Class	Orientation	ACT	NSW	QLD	Vic
Detached and Attached Archetypes (Class 1)	N	29.9%	23.2%	20.2%	21.6%
	NE	22.8%	22.4%	20.6%	20.8%
	E	16.0%	20.6%	19.0%	19.4%
	SE	14.8%	20.1%	19.6%	19.1%
	S	18.4%	19.1%	18.4%	19.8%

Class	Orientation	ACT	NSW	QLD	Vic
	SW	14.8%	19.5%	18.4%	19.3%
	W	14.0%	19.9%	17.3%	19.1%
	NW	23.2%	21.3%	19.4%	20.7%
Apartment Archetype (Class 2)	N	49.1%	39.2%	26.2%	45.7%
	NE	22.9%	37.4%	30.5%	48.0%
	E	24.0%	35.0%	25.1%	56.3%
	SE	30.8%	27.3%	22.1%	8.6%
	S	43.4%	26.8%	21.0%	42.0%
	SW	8.8%	27.6%	23.7%	56.1%
	W	43.1%	33.2%	22.8%	45.8%
	NW	34.9%	37.4%	24.7%	51.6%

B.6.5.4 Apply the 'Improved Performance Glazing' targets to the archetype models developed in Section B.6.5.3 above

a. Determine the glass types to be used in the multi-dimensional models with 'Improved Performance Glazing' based on the 'Improved Performance Glazing' targets in Table 4-32. These values represent the performance of earlier archetype models which utilised the smallest, cheapest window that can comply with the ventilation and natural lighting requirements of the NCC 2016. The values specified are target maximum values for U_{TOT} and $SHGC \times WWR$ (which are a function of building orientation). Please note the definition $U_{TOT} = U_w WWR + U_{wall}(1\text{-}WWR)$; where U_{wall} is the U-value of the opaque (non-glazed) area of a given façade/wall. Note that this U_{wall} was kept constant, i.e. the same as the baseline models with '2016 6-Star Compliant Glazing'.
b. For each façade the cheapest glazing that achieves the $SHGC \times WWR$ requirement of the Improved Performance Glazing was determined.
c. If that façade also met the U-value requirement with this glazing, no further adjustment required. If it did not, then the cheapest glazing with an identical or lower SHGC and a U-value that enables the U-value requirement to be met was selected.

Single-dimensional (1-D) Analysis of Impact of Glazing Upgrade

A single-dimensional analysis was carried out to determine the impact of upgrading glazing alone (no other building element upgrades) from '2016 6-Star Compliant Glazing' to 'Improved Performance Glazing' (as shown in Table 4-36) as part of the multi-dimensional modelling baseline selection.

Table 4-36 Thermal and electrical loads for the residential archetypes in the two primary orientations for CZ2, CZ5, CZ6 and CZ7

Archetype	CZ	Azimuth	2016 6-Star Compliant Glazing			Improved Performance Glazing		
			$Load_{th}$ (MJ/m²/year)	$Load_{el}$ (kWh/m²/year)	Star Rating	$Load_{th}$ (MJ/m²/year)	$Load_{el}$ (kWh/m²/year)	Star Rating
Apartment	2	180°	58.5	5.42	5.1	42.5	3.94	6.4
		90°	57.5	5.32	5.1	42	3.89	6.4
	5	270°	57	5.28	4.8	42.6	3.94	5.9
		90°	53.6	4.96	5	36.2	3.35	6.6
	6	90°	176.2	16.31	4.7	119	11.02	6.1
		270°	175.5	16.25	4.7	136	12.59	5.7
	7	90°	213.2	19.74	5.3	138.9	12.86	6.8
		270°	226.8	21.00	5.8	164.2	15.20	6.3
Attached	2	180°	41.6	3.85	6.6	36.4	3.39	7.2
		270°	61.2	5.67	5	62.9	5.74	4.9
	5	180°	29.9	2.77	7.4	25.9	2.40	7.9
		270°	49.4	4.57	5.4	43.1	3.99	6.1
	6	180°	110	10.19	6.5	102.5	9.49	6.7
		270°	133.8	12.39	5.9	120.8	11.19	6.2
	7	180°	143.4	13.28	6.8	140.6	13.02	6.9
		270°	172.4	15.96	6.2	154.2	14.28	6.6
Detached	2	0°	54.9	5.08	5.1	42.3	3.92	6.2
		180°	52.3	4.84	5.3	52.3	4.84	5.3

Archetype	CZ	Azimuth	2016 6-Star Compliant Glazing			Improved Performance Glazing		
			Load$_{th}$ (MJ/m²/ year)	Load$_{el}$ (kWh/m²/year)	Star Rating	Load$_{th}$ (MJ/m²/ year)	Load$_{el}$ (kWh/m²/year)	Star Rating
	5	90°	50	4.63	5.1	37.6	3.48	6.3
		180°	51.9	4.81	4.9	40	3.70	6
	6	90°	147.7	13.68	5.2	123.5	11.44	5.9
		270°	152.6	14.13	5.1	126	11.67	5.8
	7	90°	204.8	18.96	5.3	176.3	16.32	5.9
		270°	210.5	19.49	5.2	179.3	16.60	5.8

'2016 6-Star Compliant Glazing' model results presented higher energy consumption than the 'Improved Performance Glazing' model in all cases (refer to Table 4-36).

B.6.5.5 Multi-D Analysis with '2016 6-Star Compliant Glazing' Baseline Models and 'Improved Performance Glazing'

Apply the balance of measures (increased air tightness, PV, ceiling fans, roof insulation, lighting, roller shutters, and domestic hot water) to the 'Improved Performance Glazing' model to formulate the

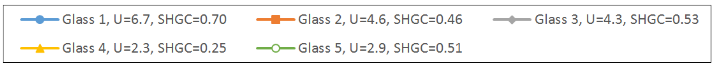
- Economic Scenario, and
- High Impact Scenario

For each archetype in each climate zone.

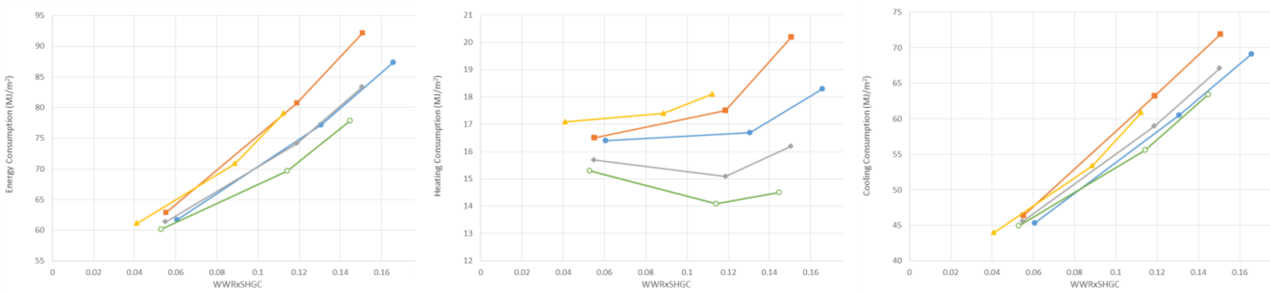
Heating and cooling (annual energy and peak power) and equivalent Star rating results for each archetype, orientation and climate zone for the multi-dimensional analyses were then determined using the models developed as above.

B.6.6 All Annual Thermal Energy Requirement Results Developed for the Residential Glazing Analysis.

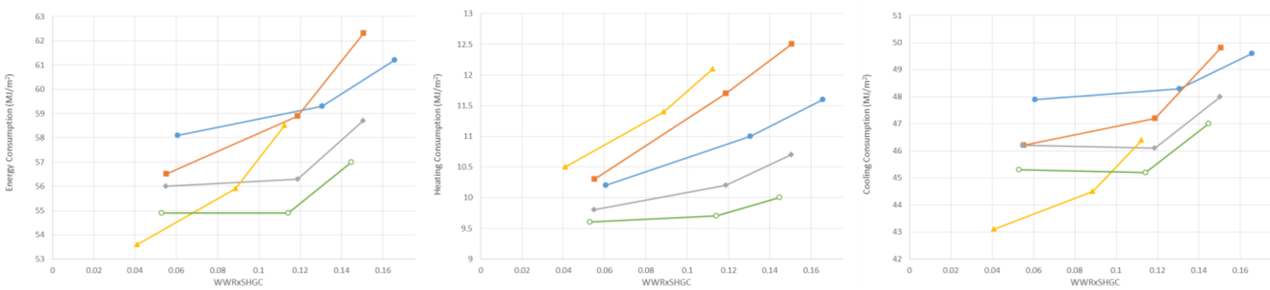
Apartment - Climate Zone 2



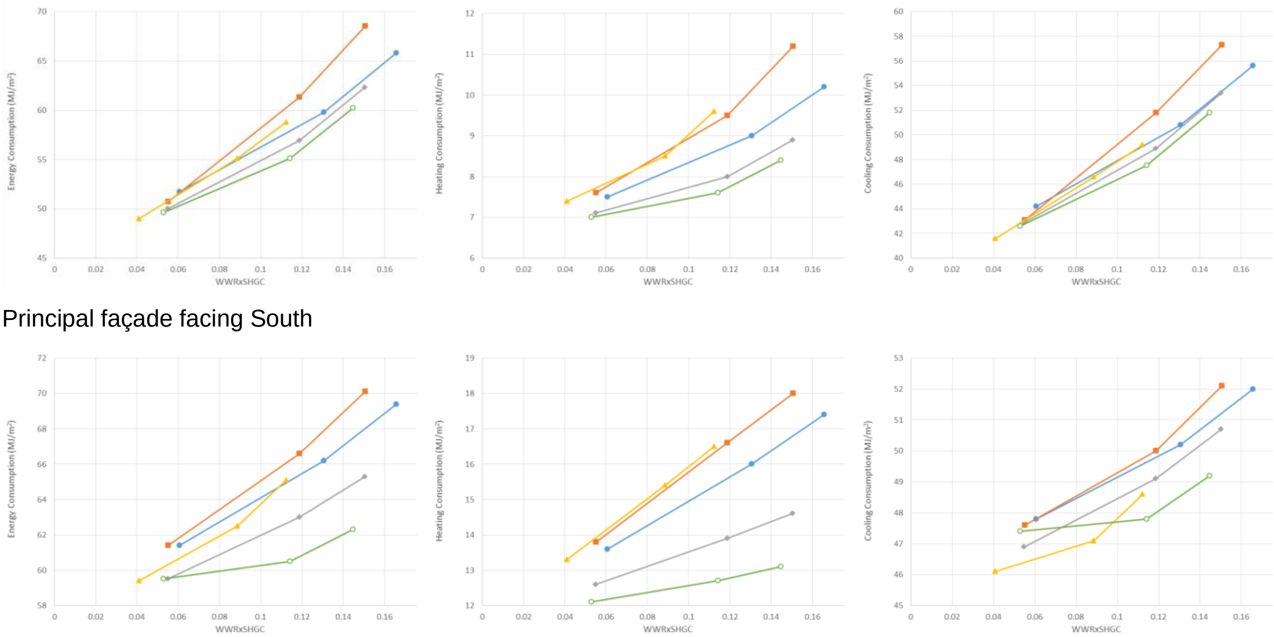
Principal façade facing West



Principal façade facing North



Principal façade facing East



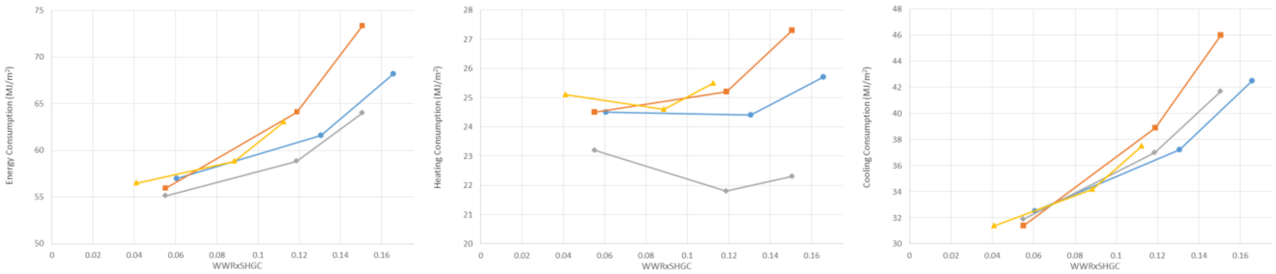
a) Total Energy b) Heating Energy c) Cooling Energy

Figure 76 Apartment archetype annual thermal energy required (total, heating and cooling) vs SHGCxWWR and window type for Climate Zone 2

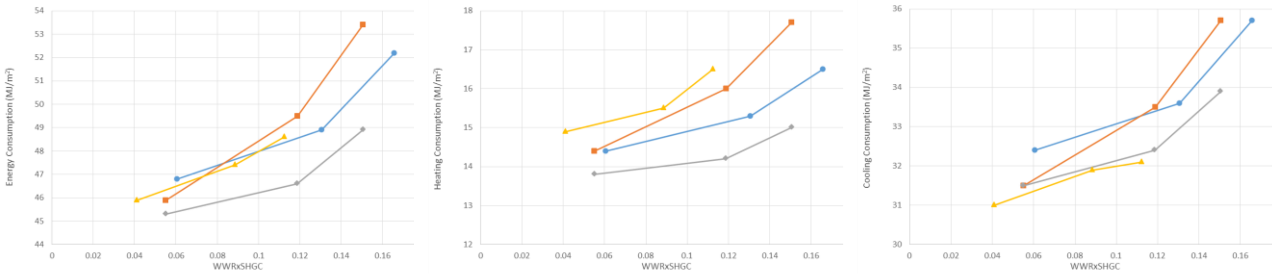
Apartment - Climate Zone 5

Glass 1, U=6.7, SHGC=0.70 — Glass 2, U=4.6, SHGC=0.46
Glass 3, U=4.3, SHGC=0.53 — Glass 4, U=2.3, SHGC=0.25

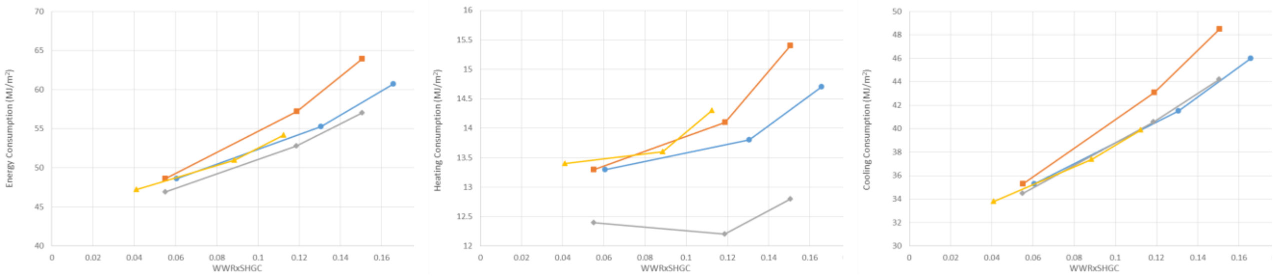
Principal façade facing West



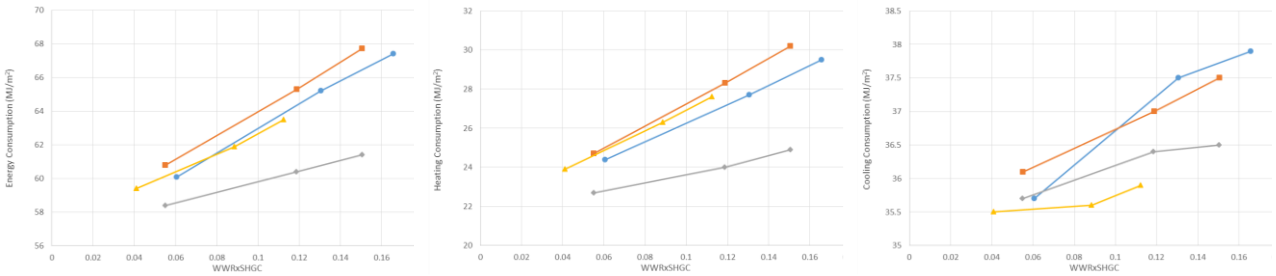
Principal façade facing North



Principal façade facing East



Principal façade facing South

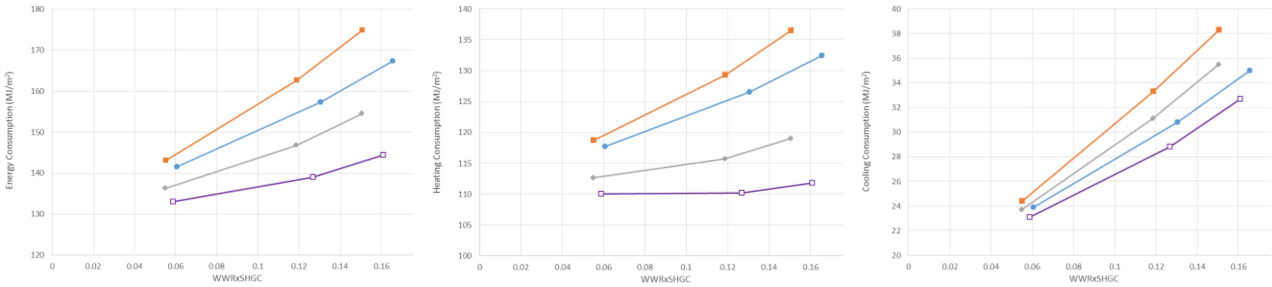


a) Total Energy b) Heating Energy c) Cooling Energy

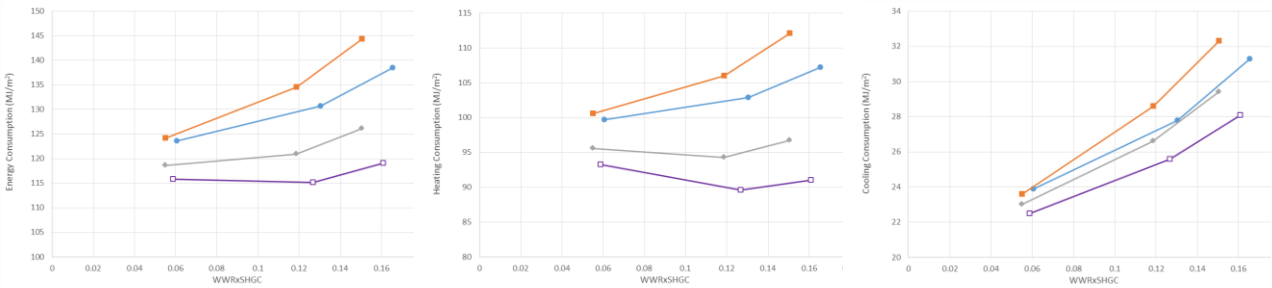
Figure 77 Apartment archetype annual thermal energy required (total, heating and cooling) vs SHGCxWWR and window type for Climate Zone 5

Apartment - Climate Zone 6

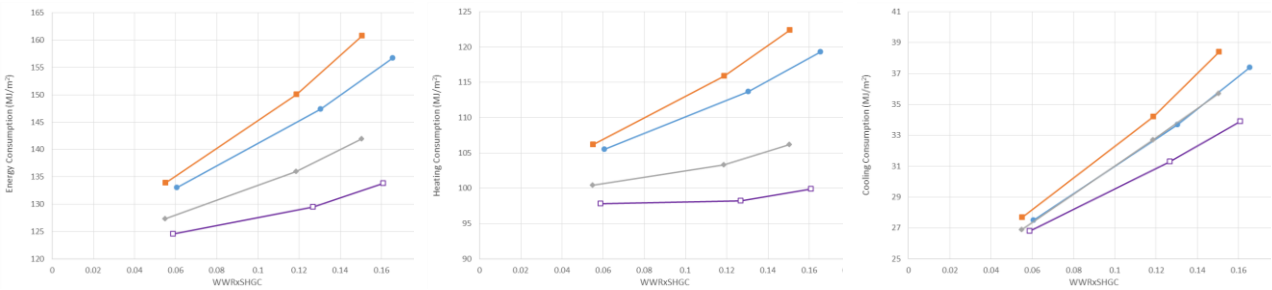
Principal façade facing West



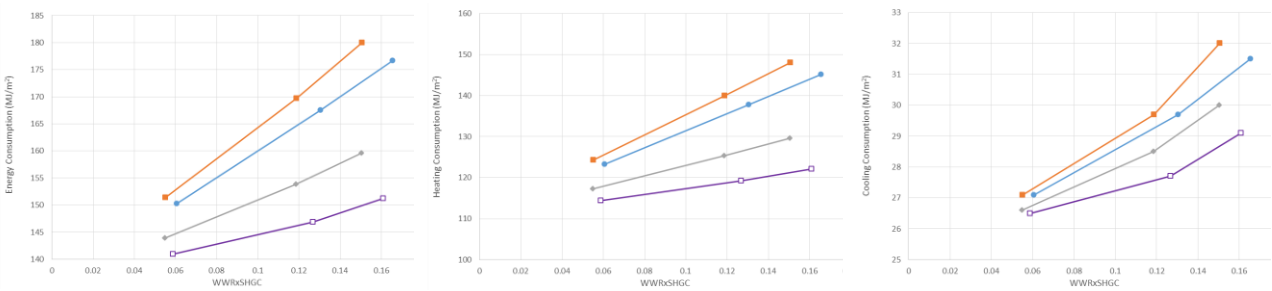
Principal façade facing North



Principal façade facing East



Principal façade facing South



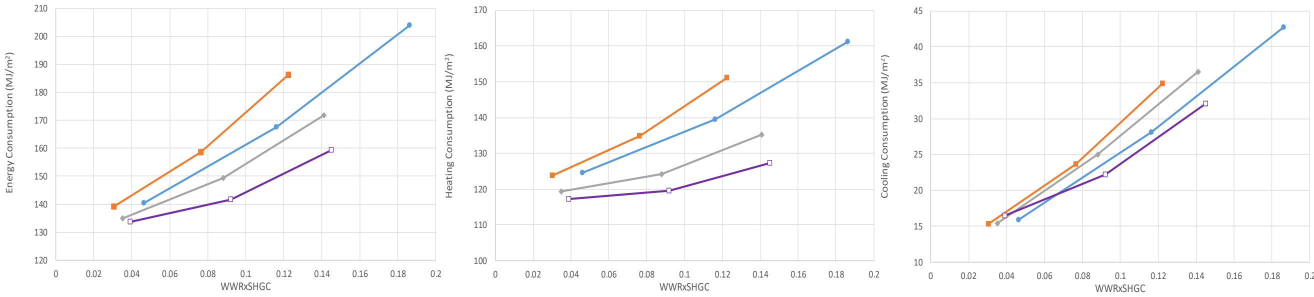
a) Total Energy b) Heating Energy c) Cooling Energy

Figure 78 Apartment archetype annual thermal energy required (total, heating and cooling) vs SHGCxWWR and window type for Climate Zone 6

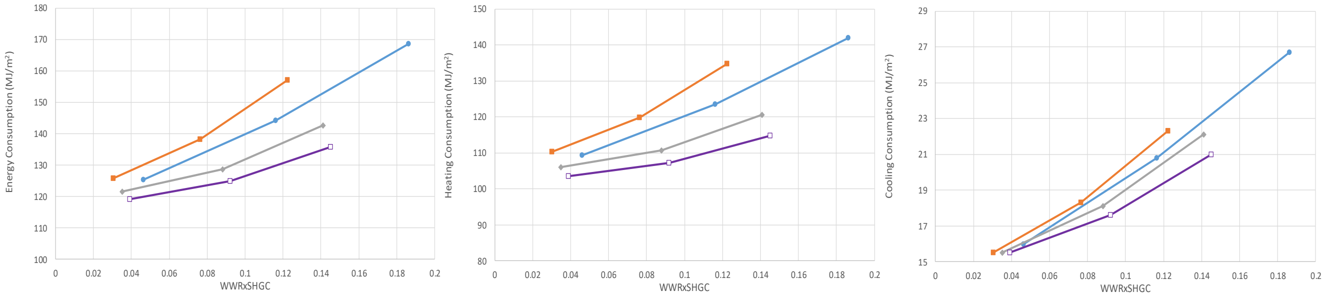
Apartment - Climate Zone 7

Glass 1, U=6.7, SHGC=0.70 | Glass 2, U=4.6, SHGC=0.46
Glass 3, U=4.3, SHGC=0.53 | Glass 6, U=2.6, SHGC=0.53

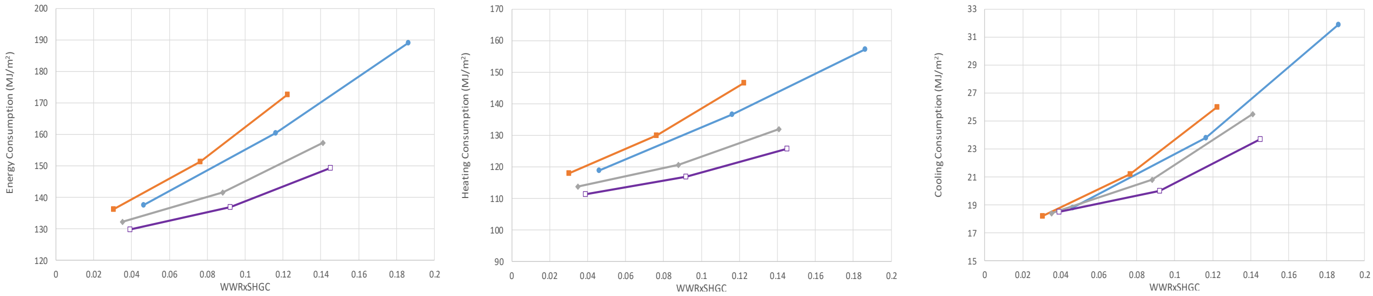
Principal façade facing West



Principal façade facing North



Principal façade facing East



Principal façade facing East

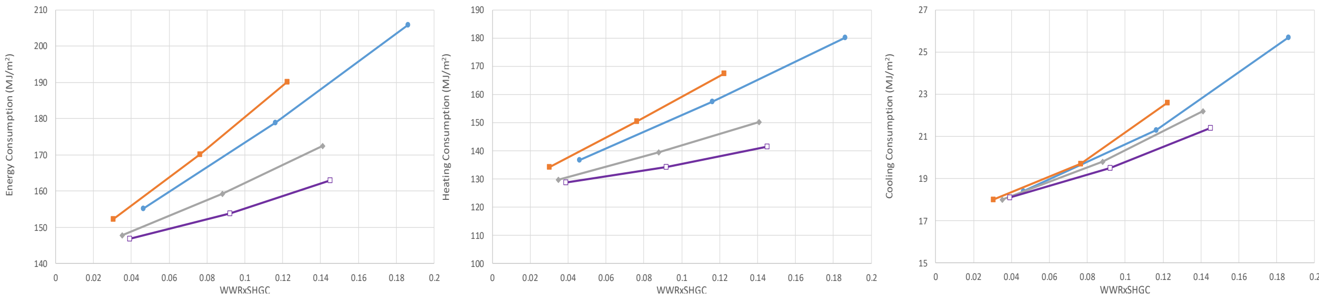


Figure 79 Apartment archetype annual thermal energy required (total, heating and cooling) vs SHGCxWWR and window type for Climate Zone 7

Attached - Climate Zone 2

Figure 80 Attached archetype annual thermal energy required (total, heating and cooling) vs SHGCxWWR and window type for Climate Zone 2

Attached - Climate Zone 5

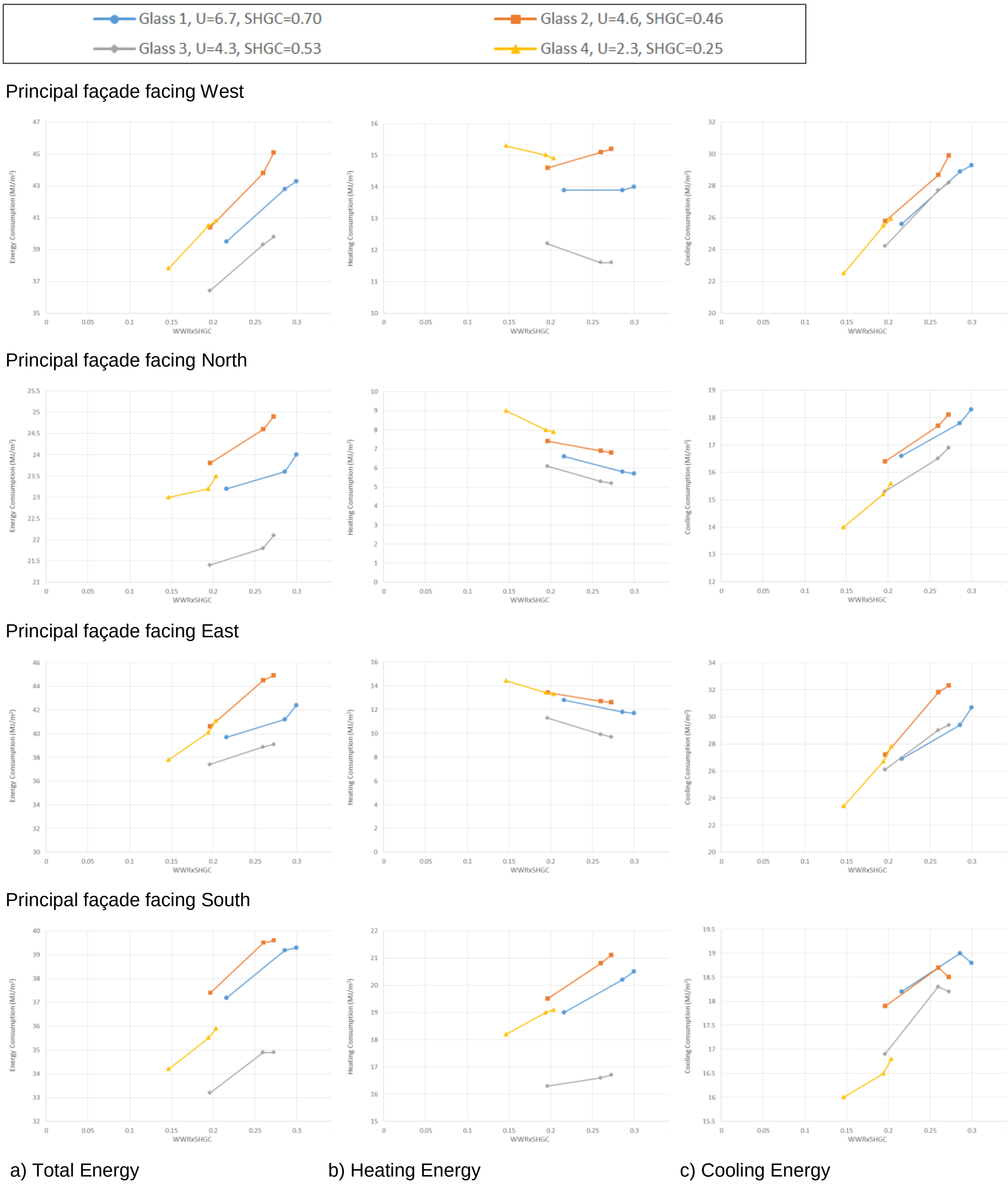


Figure 81 Attached archetype annual thermal energy required (total, heating and cooling) vs SHGCxWWR and window type for Climate Zone 5

Attached - Climate Zone 6

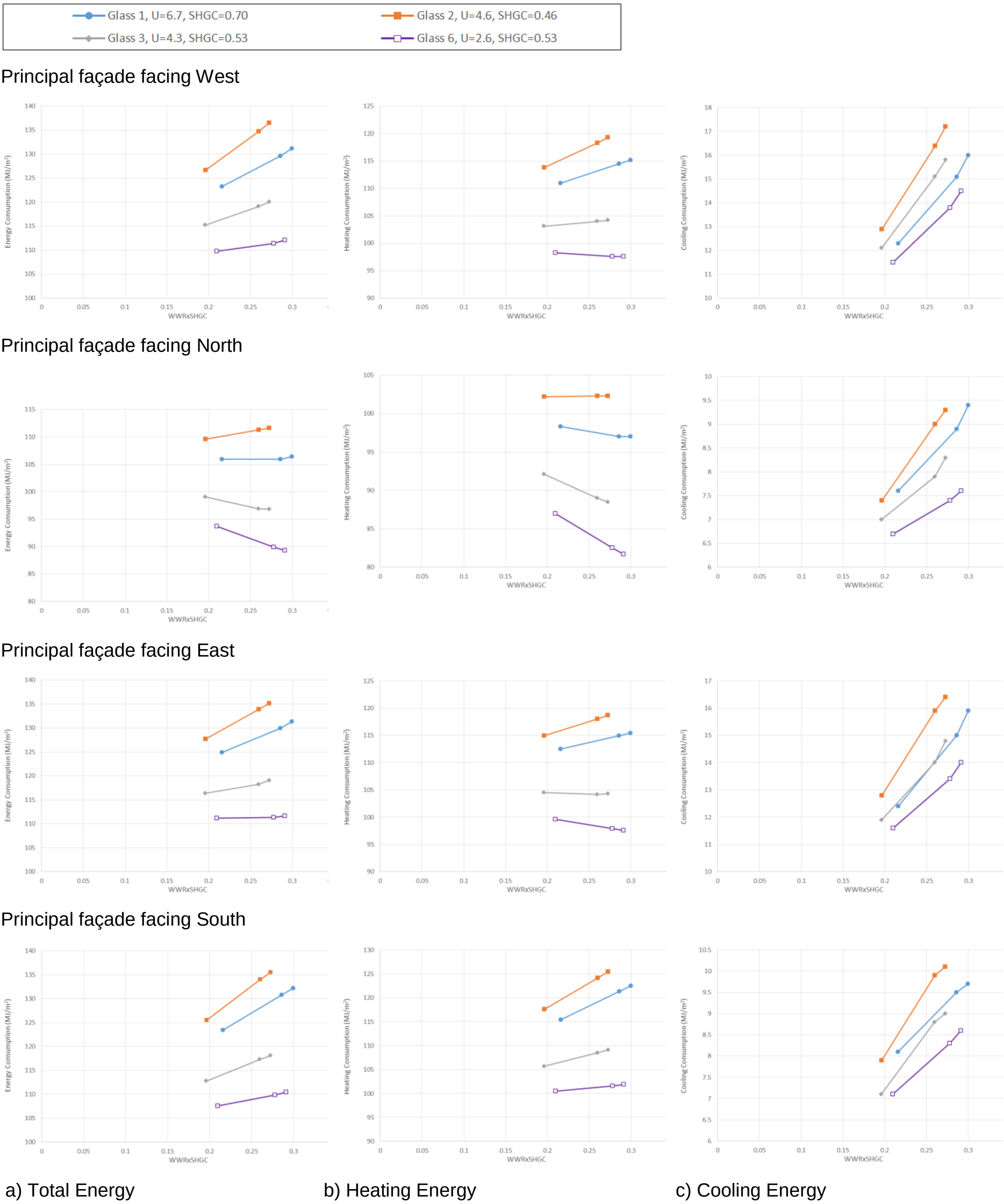
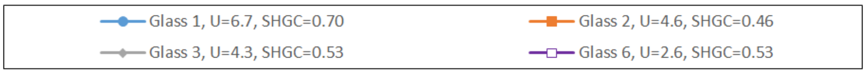
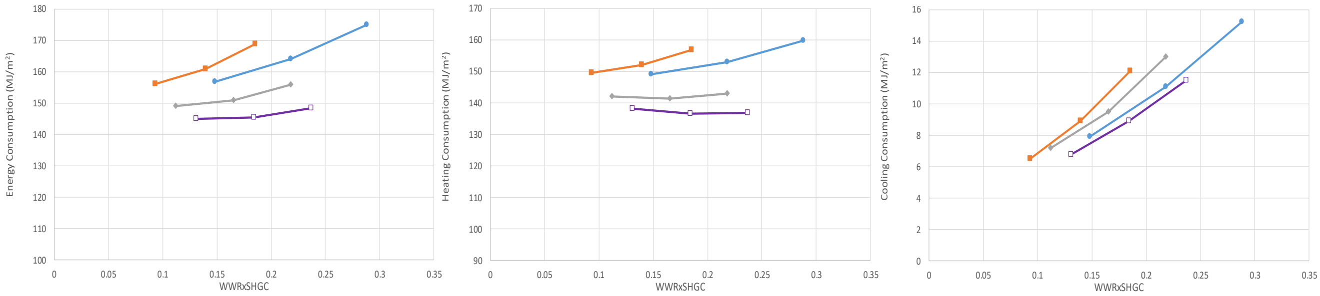


Figure 82 Attached archetype annual thermal energy required (total, heating and cooling) vs SHGCxWWR and window type for Climate Zone 6

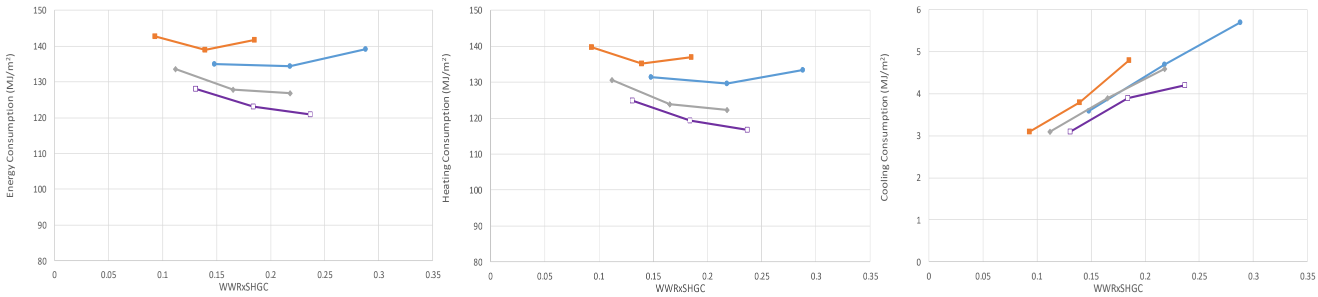
Attached - Climate Zone 7



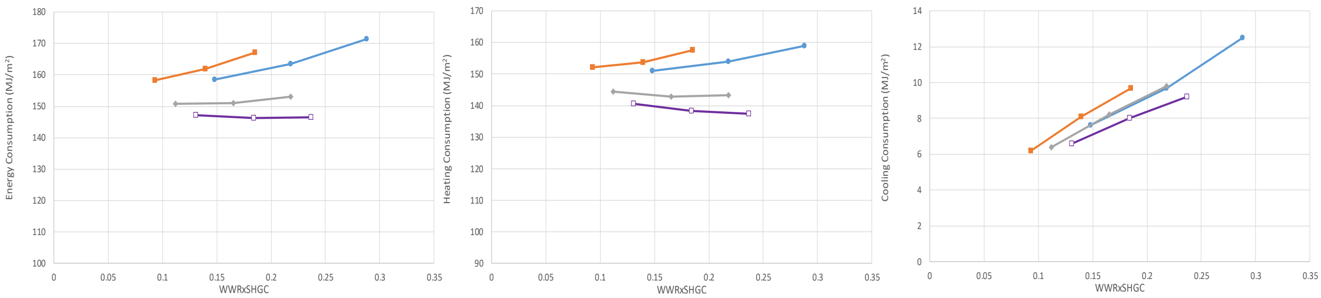
Principal façade facing West



Principal façade facing North



Principal façade facing East



Principal façade facing South

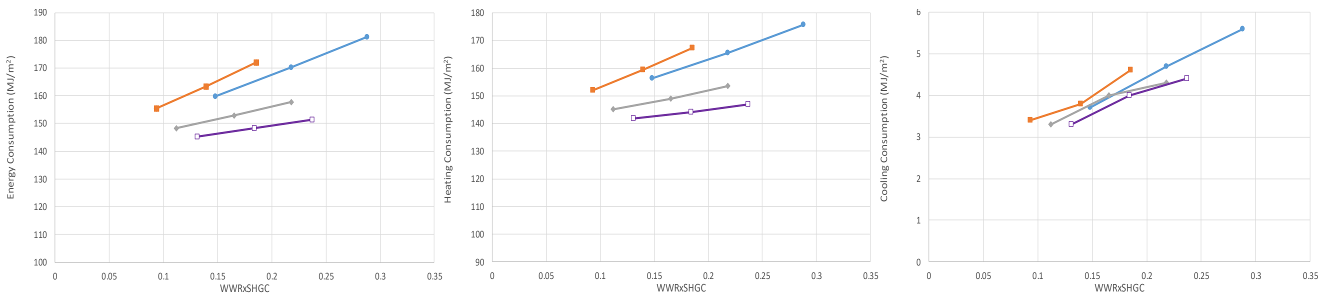
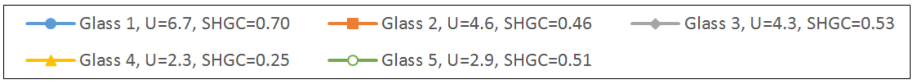
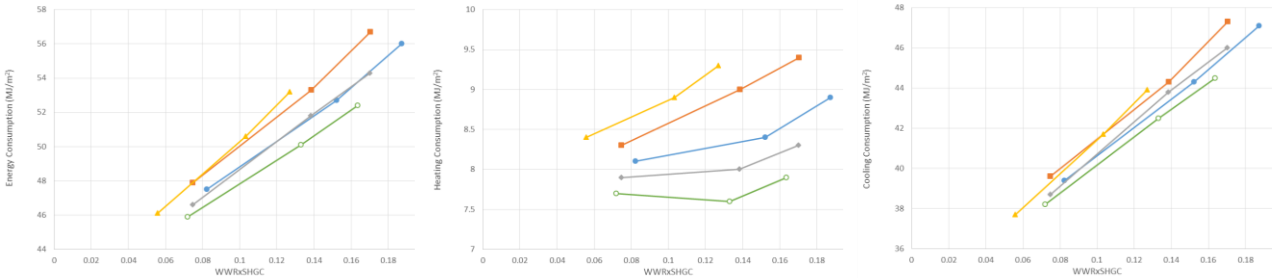


Figure 83 Attached archetype annual thermal energy required (total, heating and cooling) vs SHGCxWWR and window type for Climate Zone 7.

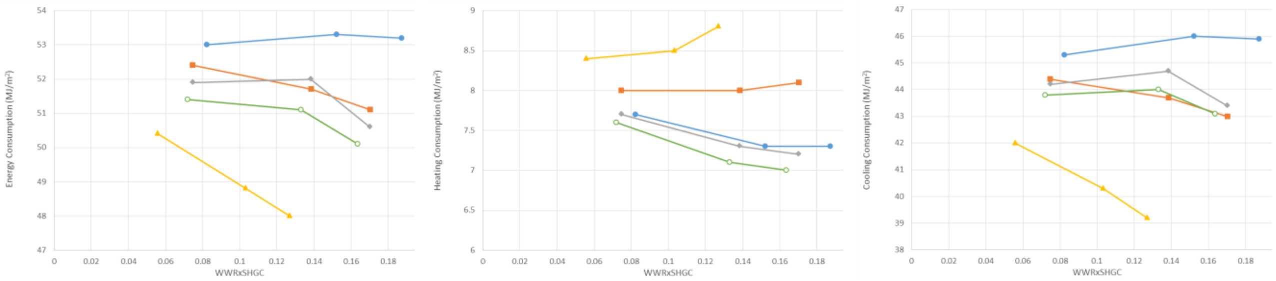
Detached - Climate Zone 2



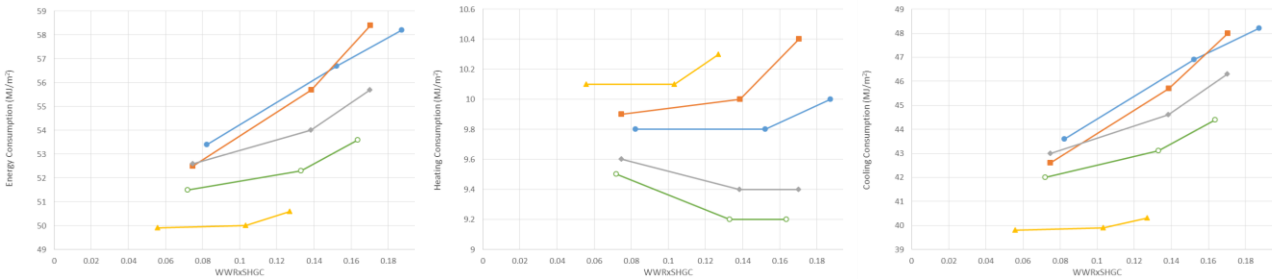
Principal façade facing West



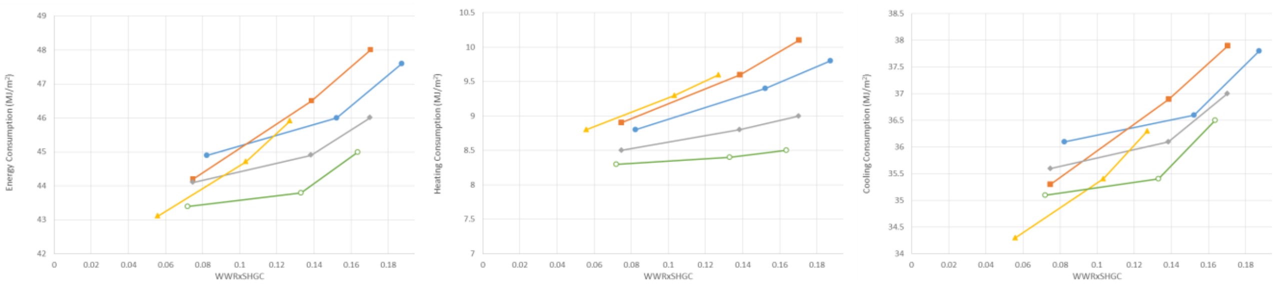
Principal façade facing North



Principal façade facing East



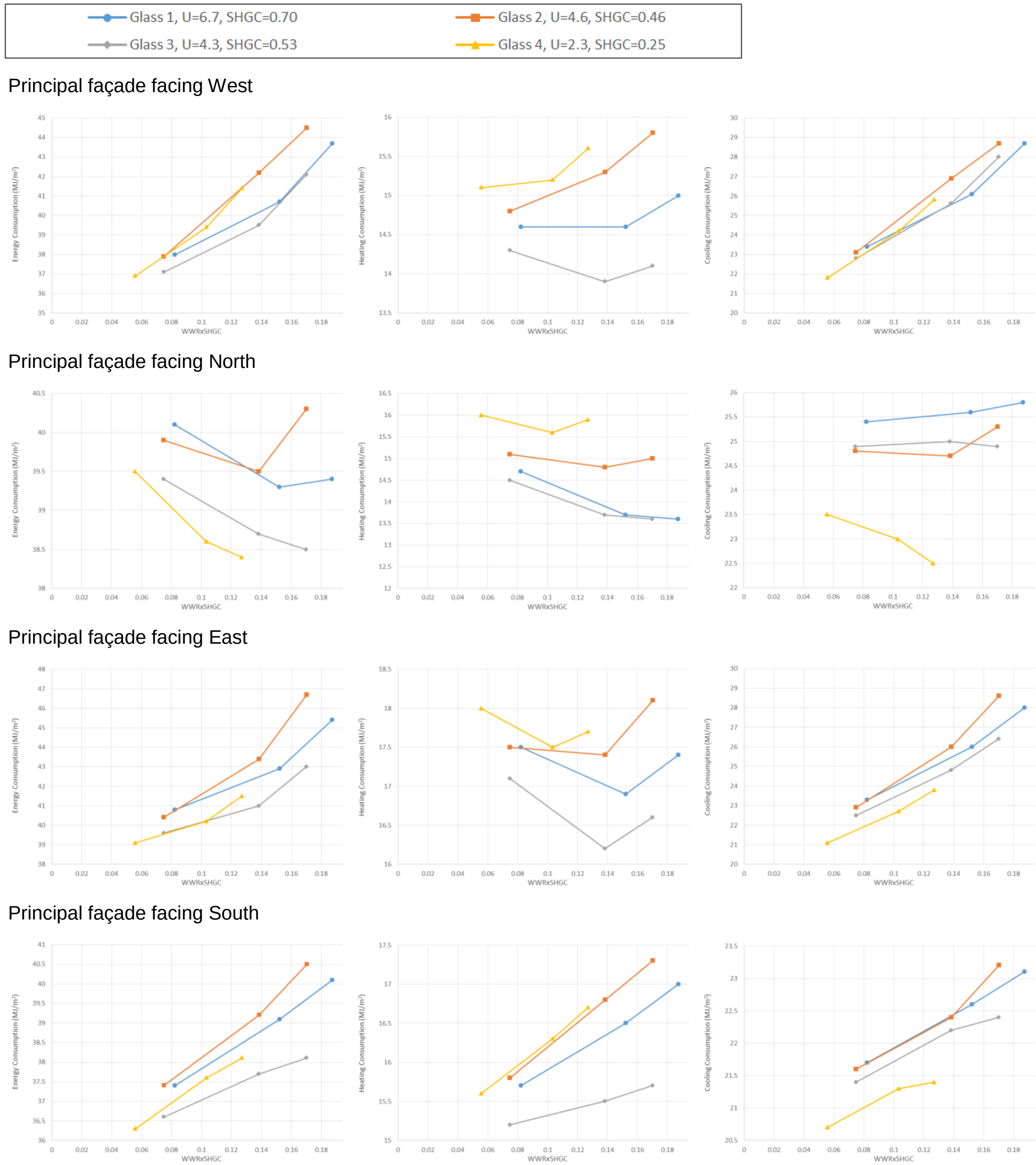
Principal façade facing South



a) Total Energy　　b) Heating Energy　　c) Cooling Energy

Figure 84 Detached archetype annual thermal energy required (total, heating and cooling) vs SHGCxWWR and window type for Climate Zone 2

Detached - Climate Zone 5



a) Total Energy b) Heating Energy c) Cooling Energy

Figure 85 Detached archetype annual thermal energy required (total, heating and cooling) vs SHGCxWWR and window type for Climate Zone 5

Detached - Climate Zone 6

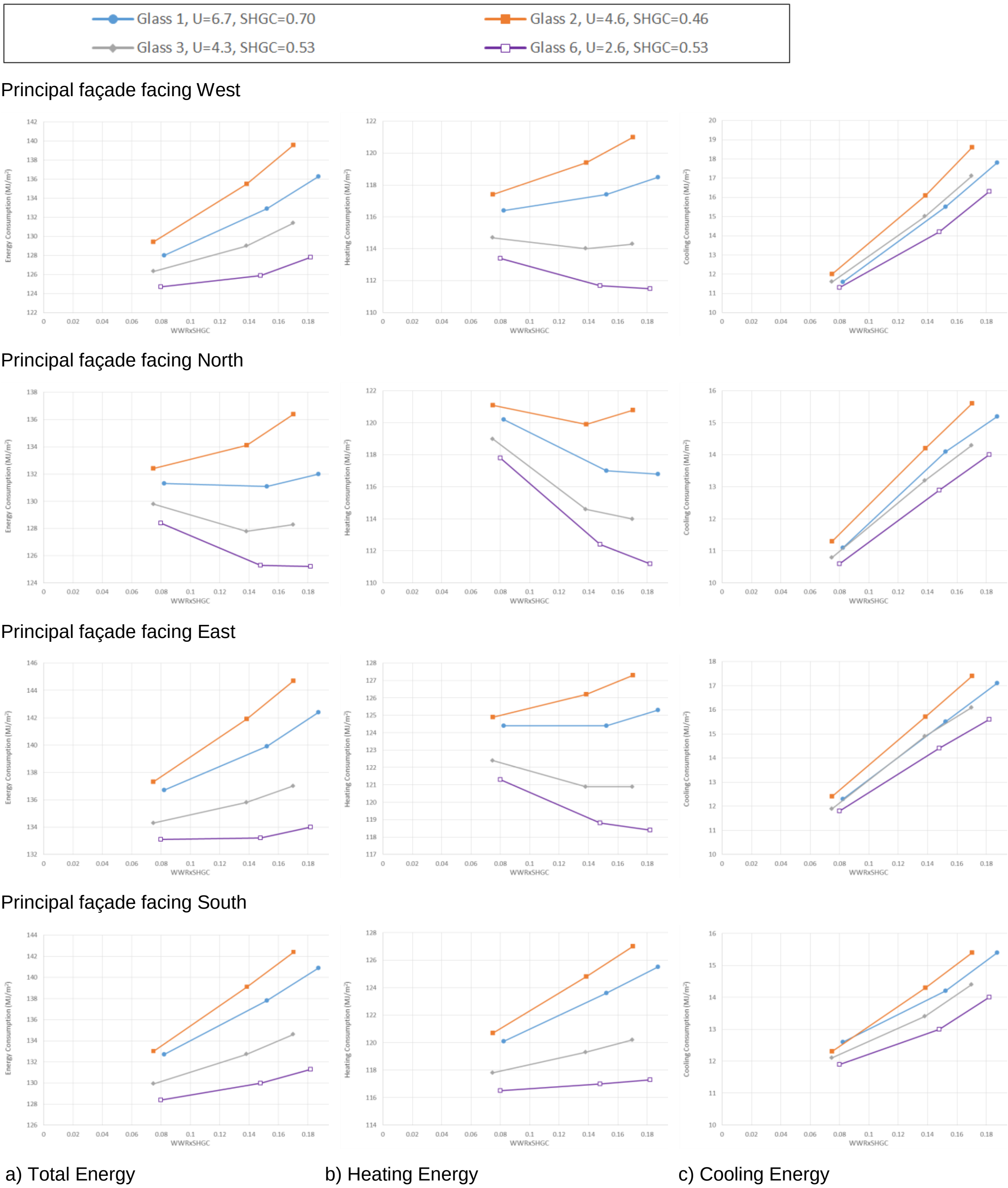
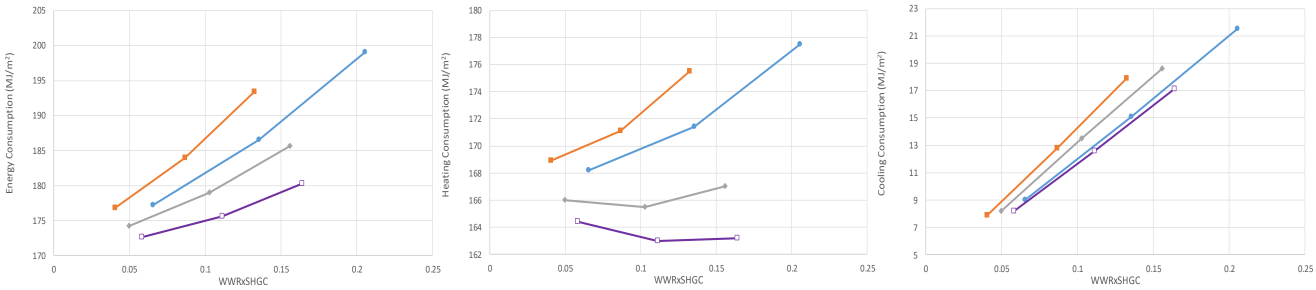


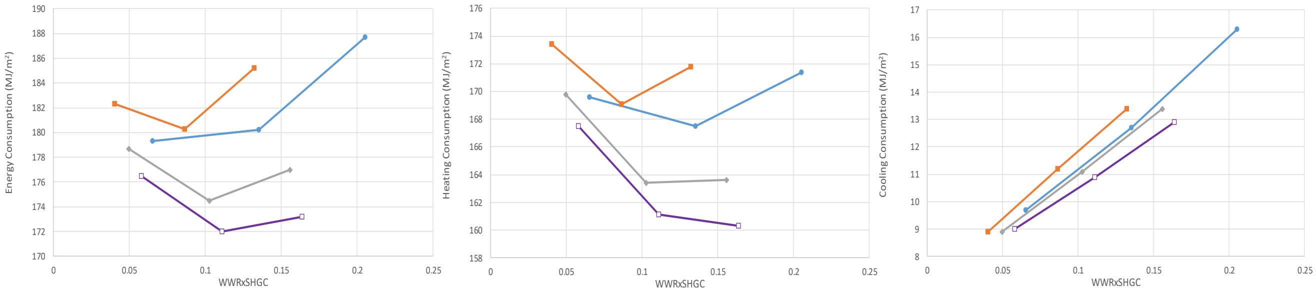
Figure 86 Detached archetype annual thermal energy required (total, heating and cooling) vs SHGCxWWR and window type for Climate Zone 6

Detached - Climate Zone 7

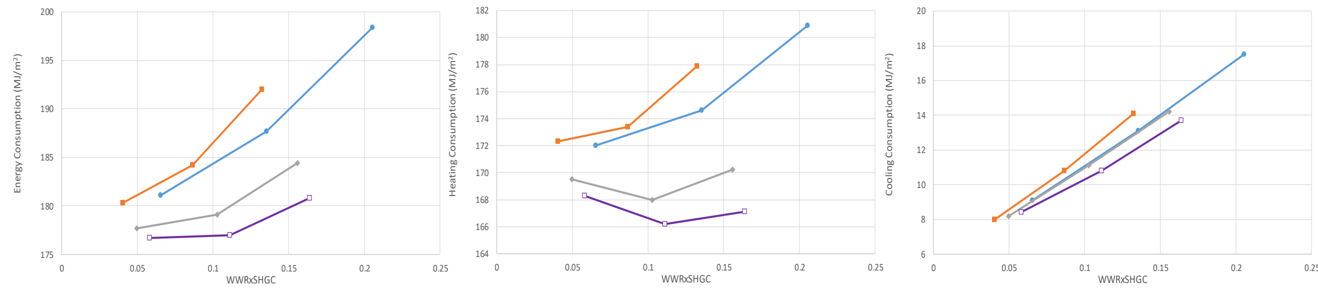
Principal façade facing West



Principal façade facing North



Principal façade facing East



Principal façade facing South

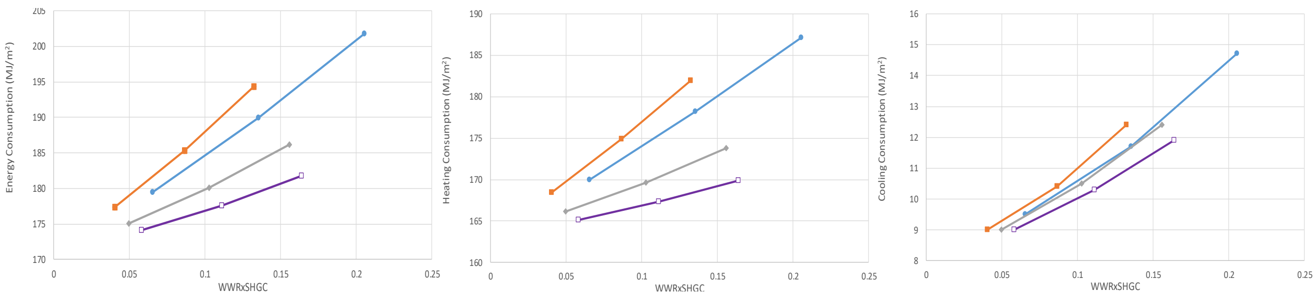


Figure 87 Detached archetype annual thermal energy required (total, heating and cooling) vs SHGCxWWR and window type for Climate Zone 7

B.7 Residential Plug-in Appliance Loads

The objective of the additional plug-in appliance analysis was to determine an appropriate amount of additional electrical load beyond domestic hot water, lighting, and existing heating and cooling figures, to be included in the 'Net Energy Trajectories'. This component of electrical load was added, for each building type, to the aforementioned electrical loads and compared to the appropriate amount of PV generation (refer to below Solar Photovoltaic Analysis), in order to determine if the increased stringency archetypes modelled are achieving net zero energy status.

The AccuRate Sustainability software uses the NatHERS protocol to establish an estimate of nominal heating and cooling contribution attributed to appliances within a building. Figures from DEWHA (DEWHA 2008) and Department of Industry and Science (DIS 2015) suggest that appliance loads are a significant proportion of household energy use within the residential sector. Therefore additional plug appliance load beyond that already allowed for in the heating and cooling figures from AccuRate Sustainability need to be considered for Net Energy Trajectories.

The additional plug appliance loads were determined separately to the building heating and cooling model, currently developed in AccuRate Sustainability. Thus, the additional heating and cooling impact of these devices was not considered in the heating and cooling figures. Where relevant the additional plug appliance loads were correlated to occupancy as defined in the NatHERS protocol. No allowance was made for adapting or adjusting occupancy to particular archetypes, occupant behaviour, climate zones, etc., and no analysis was completed to establish the nominal impact of Minimum Energy Performance Standards and technology improvements for plug appliance loads in this stage of the project.

The individual appliance power and usage were based on the default energy ratings in AusZEH (Australian Zero Emission Home Design Tool), using the methodology outlined by Ren et al[44], and suggested by CSIRO as aligning with data from the DEWHA 2008 report[45] (later updated for the DIS in 2015[46]).

For the NCC Trajectory project the apartment and attached archetypes were assumed to have an occupancy of 3 persons, and for the detached archetype, 5 persons. As appliance technologies and associated occupant use will change throughout the trajectory period, the individual appliances listed in the tables below are not meant to replicate exactly current or future household appliances, but to provide a reasonable level of overall plug-in appliance load annual energy demand.

Table 4-37 Three occupant (apartment and attached archetype) nominal plug-in appliance load

Plug-In Appliance	Annual energy use	Apartment annual energy use[47]	Attached annual energy use[48]
Television	416.3 kWh/year	5.45 kWh/m^2/year	3.10 kWh/m^2/year
DVD	15.9 kWh/year	0.21 kWh/m^2/year	0.12 kWh/m^2/year
Computer	119.6 kWh/year	1.57 kWh/m^2/year	0.89 kWh/m^2/year
Electric Stove	427.1 kWh/year	5.59 kWh/m^2/year	3.18 kWh/m^2/year
Electric Oven	240.9 kWh/year	3.15 kWh/m^2/year	1.79 kWh/m^2/year
Fridge/freezer	613.2 kWh/year	8.02 kWh/m^2/year	4.56 kWh/m^2/year
Microwave	88.6 kWh/year	1.15 kWh/m^2/year	0.66 kWh/m^2/year
Dishwasher	306.3 kWh/year	4.01 kWh/m^2/year	2.28 kWh/m^2/year
Clothes Washer	124.8 kWh/year	1.64 kWh/m^2/year	0.93 kWh/m^2/year
Small allowance for other appliances	950 kWh/year	12.44 kWh/m^2/year	7.06 kWh/m^2/year
Total appliance load	**3,303 kWh/year**	**43.22 kWh/m^2/year**	**24.56 kWh/m^2/year**

Table 4-38 Five occupant (detached archetype) nominal plug-in appliance load

Plug-In Appliance	Annual energy use	Detached annual energy use[49]
Television	416.3 kWh/year	2.20 kWh/m^2/year
DVD	15.9 kWh/year	0.08 kWh/m^2/year
Computer	119.6 kWh/year	0.63 kWh/m^2/year
Electric Stove	711.8 kWh/year	3.76 kWh/m^2/year
Electric Oven	401.5 kWh/year	2.12 kWh/m^2/year
Fridge/freezer	1022.0 kWh/year	5.40 kWh/m^2/year
Microwave	88.6 kWh/year	0.47 kWh/m^2/year
Dishwasher	306.3 kWh/year	1.62 kWh/m^2/year
Clothes Washer	124.8 kWh/year	0.66 kWh/m^2/year
Small allowance for other appliances	950 kWh/year	5.02 kWh/m^2/year
Total appliance load	**4,157 kWh/year**	**21.95 kWh/m^2/year**

It is noted that the above plug-in appliance figures are considerably high when compared to the NatHERS base case of approximately 1,807 kWh/year already included in the AccuRate Sustainability heating and cooling load (no area adjustment applied).

44 Ren et al, "AusZEH Design: Software for low emission and zero-emission house design in Australia", Proc. of Building Simulation, November 2011
45 Energy Efficient Strategies, "Energy Use in the Australian Residential Sector 1986-2020", Prepared for Department of the Environment, Water, Heritage and the Arts, 2008
46 Energy Consult, "Residential Energy Baseline Study: Australia", Prepared for Department of Industry and Science on behalf of the trans-Tasman Equipment Energy Efficiency (E3) Program, August 2015
47 Apartment area used 76.42m²
48 Attached area used 134.50
49 Detached house area used 189.39m²

B.8 Residential Domestic Hot Water Loads

Domestic hot water is a significant use of energy 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 the residential study, only electric options were 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.

The available electric DHW technologies have been characterised in Table 4-39, noting the Efficiency/Coefficient of Performance (COP) is the number of units of hot water produced per unit of input energy, 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 4-39 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 was beyond the scope of this study (for the residential analysis) 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 elected not to analyse DHW for apartments, and instead extrapolated the results for the other archetypes to the apartment case.

Assuming a townhouse occupancy of 3 persons (also used for the apartment archetype) 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.

From Whaley et al[50], 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 litres 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.

Using these assumptions the calculated energy use figures are as shown in Table 4-40 and Table 4-41. These DHW figures were used for both the conservative and accelerated technology energy efficiency trajectory scenarios for the multi-dimensional analysis and applied to the overall household energy using varying levels of COP (base case COP = 3, maximum conservative trajectory scenario COP = 4.5, maximum accelerated technology COP = 5)

[50] David Whaley, Raymond Liddle, Lachlan Mudge, Ellise Harmer, Prof Wasim Saman, "Residential Water Heater Baseline Data Study - Final Report", Report completed by UniSA Barbara Hardy Institute for Department for Manufacturing, Innovation, Trade, Resources and Energy (DMITRE), 2014

Table 4-40 DHW energy use calculations for the residential townhouse (and apartment) based on occupancy of 3 persons

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 4-41 DHW calculations for the residential detached house based on occupancy of 5 persons

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.

B.9 Lighting

Lighting design for each of the archetypes assumed that CFL technology was used in the base case scenarios, and that LED technologies were used in the improved design factors. The improved design factors were applied incrementally for the conservative and accelerated technology energy efficiency trajectory scenarios by adjusting the lighting energy density (W/m²) for each improvement (or anticipated improvement) in lighting technology, e.g. adjusting from CFL technology to advanced LED technology. Table 4-42 to Table 4-44 present the base case lighting energy results for the residential archetypes. The energy density of lighting is varied in increments down to 3 W/m² (advanced LED technology) for the multi-dimensional trajectory analysis.

Table 4-42 Base case (CFL) lighting energy results for the residential apartment

Apartment Archetype (CFL)	Room area	Total installed lighting (based on EA design)	NatHERS based average daily hours of lamp use (hours)	Lighting energy use (kWh/year)	Lighting energy use (kWh/m²/year)
Bed1	14.4 m²	35 W	1.5	19.16	0.25
Ensuite	4.7 m²	37 W	2	27.01	0.35
Bed2	9.4 m²	35 W	1.5	19.16	0.25
Living	22.2 m²	78 W	3	85.41	1.12
Bathroom	7.0 m²	50 W	2	36.50	0.48
Laundry	2.5 m²	13 W	1.5	7.12	0.09
Kitchen	7.2 m²	39 W	4	56.94	0.75
Bedroom Hall	7.0 m²	39 W	1.5	21.35	0.28
Entry Hall	2.0 m²	13 W	1.5	7.12	0.09
Total	76.42 m²	339 W	-	279.77	3.66

Table 4-43 Base case lighting results for the residential attached house

Attached Archetype (CFL)	Room area	Total installed lighting (based on EA design)	NatHERS based average daily hours of lamp use (hours)	Lighting energy use (kWh/year)	Lighting energy use (kWh/m²/year)
First Floor					
Bathroom	5.6 m²	32 W	2	23.36	0.17
Bed1	17.5 m²	64 W	1.5	35.04	0.26
Bed2	14.0 m²	44 W	1.5	24.09	0.18
Ensuite	4.2 m²	32 W	2	23.36	0.17
Study	11.0 m²	52 W	1.5	28.47	0.21
Hallway	5.8 m²	60 W	1.5	32.85	0.24
Ground Floor					0.00
Kitchen	17.5 m²	120 W	4	175.20	1.30
Landing*	6.6 m²	12 W	1.5	6.57	0.05
Laundry	6.6 m²	40 W	1.5	21.90	0.16
Living	31.3 m²	120 W	3	131.40	0.98
Steps	5.6 m²	24 W	1.5	13.14	0.10
Entry	8.8 m²	44 W	1.5	24.09	0.18
Total	134.50 m²	644 W	-	539.47	4.01

Table 4-44 Base case lighting results for the residential detached house

Detached Archetype (CFL)	Room area	Total installed lighting (based on EA design)	NatHERS based average daily hours of lamp use (hours)	Lighting energy use (kWh/year)	Lighting energy use (kWh/m²/year)
Front Living	32.5 m²	160 W	3	175.20	0.93
Study	8.9 m²	32 W	1.5	17.52	0.09
Living/Kitchen	25.3 m²	120 W	4	175.20	0.93
Laundry	5.4 m²	20 W	1.5	10.95	0.06
Bedroom4	12.2 m²	32 W	1.5	17.52	0.09
Hall	19.2 m²	120 W	1.5	65.70	0.35
Bedroom1	14.1 m²	44 W	1.5	24.09	0.13
Ensuite	3.9 m²	32 W	2	23.36	0.12
WIR	3.9 m²	20 W	1.5	10.95	0.06
Bedroom²	10.3 m²	32 W	1.5	17.52	0.09
Bedroom3	10.3 m²	32 W	1.5	17.52	0.09
WC	2.7 m²	20 W	2	14.60	0.08
Bathroom	7.6 m²	32 W	2	23.36	0.12
Rear Living	33.1 m²	140 W	3	153.30	0.81
Total	189.39 m²	836 W	-	746.79	3.94

Appendix C - Residential Energy Modelling Details

C.1 Single-Dimensional Energy Results

The following tables summarise the detailed energy analysis results for the three residential archetypes under Climate Zones 2, 5, 6 and 7. 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 Base 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 Base Case.

The Base Case models for Climate Zone 7 differ slightly from the Base Case models used in Climate Zones 2, 5 and 6 for the single-dimensional results due to being completed in the latter stages of the project and incorporating further Technical Advisory Group feedback requiring minor adjustments to the archetype models (e.g. adjusted zoning in the AccuRate Sustainability software, and modified window to wall ratios to match CSIRO provided data). The Base Case models for the single-dimensional results also differ from the Base Case models for the multidimensional work for similar reasons, and thus some care and knowledge is required to make any direct comparisons between the various stages of modelling.

Glazing adjustments are excluded from design parameter changes in the single-dimensional results as glazing was treated separately within the Glazing Analysis (refer to Section B.6 and of this report).

Slab edge insulation results for the single-dimensional analysis have been reported separately as these models were simulated using a modified (improved) Chenath engine within the AccuRate Sustainability software which better replicated the effects of slab edge insulation.

The external shading (roller shutters and eaves) results are presented as being applied on a per façade basis (maximum level only) to align with the costing that was completed by Energy Action.

C.1.1 Climate Zone 2 Single-Dimension Energy Results

Table 4-45 Energy analysis results for the Apartment Archetype for Climate Zone 2

Orientation	Design parameters		Base 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 west													5.1	-0.7	0.2
		Eave extension north													2.4	-0.9	0
		Eave extension east													6.4	-0.2	0.4
		Roller shutters west				9.2	-0.1	0.5									
		Roller shutters north				2.2	-0.1	0									
		Roller shutters east				5.2	-0.1	0.3									
	Thermal mass					8.8	0.8	0.5	4.7	1.1	0.3	12.3	1.3	0.9			
90º	External wall	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
		Surface colour				0.4	-0.3	0	0.8	-0.8	0	0.7	-1	-0.1			

Orientation	Design parameters		Base 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				0.3	6.2	0.6									
	External shading	Eave extension west													5.7	-0.4	0.4
		Eave extension north													4.1	-0.5	0.3
		Eave extension east													3.9	-0.4	0.3
		Roller shutters west				7.7	0	0.8									
		Roller shutters north				4.1	0	0.4									
		Roller shutters east				5.9	0	0.6									
	Thermal mass					5.3	2.5	0.8	3	2.8	0.6	7.2	3.9	1.2			
180º	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 west													2.9	-0.1	0.3
		Eave extension north													1.3	-2.8	-0.1
		Eave extension east													2.5	-0.9	0.1
		Roller shutters west				4.1	0	0.4									
		Roller shutters north				1.6	-0.1	0.1									
		Roller shutters east				3.1	0	0.3									
	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 west													1.3	0	0.1
		Eave extension north													1.8	0.3	0.2
		Eave extension east													2.7	-1.4	0.1
		Roller shutters west				2.2	0.5	0.3									
		Roller shutters north				1.7	0.5	0.2									
		Roller shutters east				3.4	0.5	0.3									
	Thermal mass					6.9	0.3	0.7	2.4	0.7	0.3	7.7	0.4	0.8			

Table 4-46 Energy analysis results for the Attached Archetype for Climate Zone 2

Orientation	Design parameters		Base 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			

Orientation	Design parameters		Base 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	
		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	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 west															
		Eave extension north													-0.7	-0.6	-0.1
		Eave extension east															
		Roller shutters west															
		Roller shutters north				1.1	0	0.1									
		Roller shutters east															
	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
	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	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									
	External shading	Eave extension west													3.7	-0.3	0.2
		Eave extension north															
		Eave extension east													3.5	0	0.2
		Roller shutters west				13.4	-0.1	0.8									
		Roller shutters north															
		Roller shutters east				5.3	0.1	0.3									
	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			

Orientation	Design parameters		Base 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	
		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
	Floor	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 west															
		Eave extension north													-0.6	-0.3	-0.1
		Eave extension east															
		Roller shutters west															
		Roller shutters north				1.4	0	0.1									
		Roller shutters east															
	Thermal mass					0.4	-0.3	0	-2.3	0.6	-0.2	-1.5	1	-0.1			
270º	External wall	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
		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	Under Slab Insulation				-3.3	-0.3	-0.2							-4.1	-0.3	-0.2
	Ventilation	Ceiling fan				23.2	-0.2	1.6									
	Infiltration	Improve workmanship				9.4	3.9	0.8									
	External shading	Eave extension west													2.6	0	0.2
		Eave extension north															
		Eave extension east													5	-0.1	0.3
		Roller shutters west				5.2	-0.1	0.1									
		Roller shutters north															
		Roller shutters east				8.5	-0.1	0.5									
	Thermal mass					0.9	0.5	0.1	1.1	0.5	0.1	2.4	0.8	0.2			

Table 4-47 Energy analysis results for the Detached Archetype for Climate Zone 2

Orientation	Design parameters		Base Case Load (MJ/m²/year)		Equivalent Star rating	Level 1 Change Saving (MJ/m²/year)		Rating Change	Level 2 Change Saving (MJ/m²/year)		Rating Change	Level 3 Change Saving (MJ/m²/year)		Rating Change	Maximum 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	Under Slab Insulation				-20	-9.7	-1.2	-23.6	-11.5	-1.5	-24.9	-12.2	-1.5	-26	-12.5	-1.5
	Ventilation	Ceiling fan				16.5	-0.5	1.1									
	Infiltration	Improve workmanship				8.1	4.6	0.9									
	External shading	Eave extension west													1.1	-0.4	0
		Eave extension north													2.9	-1.2	0.1
		Eave extension east													2.8	-0.4	0.2
		Roller shutters west				6.7	-0.2	0.4									
		Roller shutters north				2.2	-0.2	0.1									
		Roller shutters east				3.6	-0.2	0.2									
	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						
	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	Under Slab Insulation				-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 west													1.40	-0.40	0.0
		Eave extension north													1.00	-0.80	0.0
		Eave extension east													5.40	-0.80	0.2

Orientation	Design parameters		Base Case Load (MJ/m²/year)		Base Case 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	
		Roller shutters west				4.80	-0.20	0.20									
		Roller shutters north				0.30	-0.20	0.00									
		Roller shutters east				5.60	-0.20	0.30									
	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
	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	Under Slab Insulation				-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 west													1.80	-0.40	0.1
		Eave extension north													1.10	-1.00	0.1
		Eave extension east													9.80	-1.00	0.5
		Roller shutters west				6.80	-0.20	0.30									
		Roller shutters north				0.70	-0.20	0.10									
		Roller shutters east				5.80	-0.20	-3.80									
	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	Under Slab Insulation				-23.1	-8.9	-1.1	-26.8	-10.7	-1.2	-28.5	-11.4	-1.3	-28.9	-11.7	-1.3
	Ventilation	Ceiling fan				21.5	-0.6	1.1									
	Infiltration	Improve workmanship				10.2	5.2	0.8									

Orientation	Design parameters		Base Case Load (MJ/m²/year) Cooling	Base Case Load (MJ/m²/year) Heating	Base 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
	External shading	Eave extension west													4.8	-0.6	0.1
		Eave extension north													1	-0.8	0
		Eave extension east													2.3	-0.7	0.1
		Roller shutters west				13	-0.2	0.6									
		Roller shutters north				0.7	-0.2	0									
		Roller shutters east				2	-0.2	0.1									
	Thermal mass					-0.4	0.3	0	7.2	2.1	0.4	6.7	2.3	0.4			

C.1.2 Climate Zone 5 Single-Dimension Energy Results

Table 4-48 Energy analysis results for the Apartment Archetype for Climate Zone 5

Orientation	Design parameters		Base Case Load (MJ/m²/year) Cooling	Base Case Load (MJ/m²/year) Heating	Base 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
0°	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 west													1.8	-1.2	0
		Eave extension north													0.2	-1.1	-0.1
		Eave extension east													2.9	-0.2	0.2
		Roller shutters west				3.2	0	0.2									
		Roller shutters north				2	0	0.1									
		Roller shutters east				0.1	0	0									
	Thermal mass					4.7	1.3	0.4	2.1	1.2	0.2	5.4	1.9	0.6			
90°	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 west													1.4	-0.5	0.1

Orientation	Design parameters		Base Case Load (MJ/m²/year)		Equivalent Star Rating	Level 1 Change Saving (MJ/m²/year)		Level 1 Rating Change	Level 2 Change Saving (MJ/m²/year)		Level 2 Rating Change	Level 3 Change Saving (MJ/m²/year)		Level 3 Rating Change	Maximum Change Saving (MJ/m²/year)		Maximum Rating Change
			Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
		Eave extension north													0.9	-1.1	0
		Eave extension east													1	-0.6	0
		Roller shutters west				2.3	0	0.2									
		Roller shutters north				0.6	0	0									
		Roller shutters east				1.2	0	0.1									
	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
	External wall	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 west													2.2	0	0.2
	External shading	Eave extension north													0.4	-1.9	-0.2
	External shading	Eave extension east													2.4	-1.3	0.1
	External shading	Roller shutters west				2.4	-0.1	0.3									
	External shading	Roller shutters north				0.3	0.1	0									
	External shading	Roller shutters east				2.9	0.1	0.3									
	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
	External wall	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									
	External shading	Eave extension west													0.6	-0.7	0
	External shading	Eave extension north													1.2	0	0.1
	External shading	Eave extension east													1.5	-2.7	-0.1
	External shading	Roller shutters west				0.8	0	0.1									
	External shading	Roller shutters north				1.5	0	0.2									
	External shading	Roller shutters east				2.1	0	0.2									
	Thermal mass					5.2	0.3	0.5	1.3	0.2	0.1	5.8	0.4	0.5			

Table 4-49 Energy analysis results for the Attached Archetype for Climate Zone 5

Orientation	Design parameters		Base Case Load (MJ/m²/year) Cooling	Base Case Load (MJ/m²/year) Heating	Equivalent Star Rating	Level 1 Change Saving (MJ/m²/year) Cooling	Level 1 Change Saving (MJ/m²/year) Heating	Level 1 Rating Change	Level 2 Change Saving (MJ/m²/year) Cooling	Level 2 Change Saving (MJ/m²/year) Heating	Level 2 Rating Change	Level 3 Change Saving (MJ/m²/year) Cooling	Level 3 Change Saving (MJ/m²/year) Heating	Level 3 Rating Change	Maximum Change Saving (MJ/m²/year) Cooling	Maximum Change Saving (MJ/m²/year) Heating	Maximum Rating Change
0º	External wall	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
		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	Under Slab Insulation				-2	-1.9	-0.4							-2.9	-1.9	-0.3
	Ventilation	Ceiling fan				7.7	-0.3	0.8									
	Infiltration	Improve workmanship				2.2	9.8	1.3									
	External shading	Eave extension west															
		Eave extension north													-0.7	-0.7	-0.1
		Eave extension east															
		Roller shutters west															
		Roller shutters north				1	0	0.1									
		Roller shutters east															
	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			
		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	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 west													2.9	-0.3	0.2
		Eave extension north															
		Eave extension east													3.1	0.2	0.2
		Roller shutters west				8.30	0.00	0.8									
		Roller shutters north															
		Roller shutters east				3.30	0.00	0.2									
	Thermal mass					0.4	0.6	0	0.8	1.1	0.1	0.6	1.4	0.1			
180º		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

Orientation	Design parameters		Base 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	0.5	-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	Under Slab Insulation				-1.9	0.2	-0.2							-2.7	0.3	-0.3
	Ventilation	Ceiling fan				8	-0.1	0.7									
	Infiltration	Improve workmanship				2.6	4.1	0.6									
	External shading	Eave extension west															
		Eave extension north													-0.2	-0.3	-0.1
		Eave extension east															
		Roller shutters west															
		Roller shutters north				1	0	0									
		Roller shutters east															
	Thermal mass					-0.4	1.2	0	0.3	0.8	0.1	0	1.9	0.1			
	External wall	Insulation				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			
		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	Under Slab Insulation				-2.9	0.3	-0.2							-4	0.4	-0.2
270º	Ventilation	Ceiling fan	38.1	10.8	5.5	12	-0.3	1.2									
	Infiltration	Improve workmanship				3	7.4	1.1									
	External shading	Eave extension west													1.8	-0.2	0.2
		Eave extension north															
		Eave extension east													4.6	-0.2	0.4
		Roller shutters west				2.90	0.00	0.3									
		Roller shutters north															
		Roller shutters east				5.4	0	0.5									
	Thermal mass					1.7	0.3	0.2	0.9	0.6	0.2	2.2	0.6	0.3			

Table 4-50 Energy analysis results for the Detached Archetype for Climate Zone 5

Orientation	Design parameters		Base 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	Insulation				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	Under Slab Insulation				-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									
0°	Infiltration	Improve workmanship	36.5	17.5	4.9	3.8	7.4	0.9									
	External shading	Eave extension west													1.6	-0.5	0
		Eave extension north													2.7	-1.1	0
		Eave extension east													3.1	-0.5	0.1
		Roller shutters west				4.3	0	0.2									
		Roller shutters north				1.9	0	0									
		Roller shutters east				2.7	0	0.1									
	Thermal mass					-0.5	0.6	0	3.9	3.3	0.5	3.2	3.9	0.5			
	External wall	Insulation				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
	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	Under Slab Insulation				-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									
90°	Infiltration	Improve workmanship	37.8	17.6	4.8	3.8	7.3	0.8									
	External shading	Eave extension west													1.50	-0.50	0.0
		Eave extension north													1.60	-0.70	0.0
		Eave extension east													4.00	-1.00	0.1
		Roller shutters west				3.40	-0.10	0.10									
		Roller shutters north				1.30	-0.20	0.00									
		Roller shutters east				4.10	0.00	0.20									
	Thermal mass					-0.6	0.4	0	3	3.1	0.4	2.7	3.5	0.4			
	External wall	Insulation				0.4	0.4	0.1	0.5	0.7	0.1	0.5	0.9	0.1	0.9	1	0.2
180°		Surface colour	41.4	17.9	4.5	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									

Orientation	Design parameters		Base Case Load (MJ/m²/year) Cooling	Base Case Load (MJ/m²/year) Heating	Equivalent Star Rating	Level 1 Change Saving (MJ/m²/year) Cooling	Level 1 Change Saving (MJ/m²/year) Heating	Level 1 Rating Change	Level 2 Change Saving (MJ/m²/year) Cooling	Level 2 Change Saving (MJ/m²/year) Heating	Level 2 Rating Change	Level 3 Change Saving (MJ/m²/year) Cooling	Level 3 Change Saving (MJ/m²/year) Heating	Level 3 Rating Change	Maximum Change Saving (MJ/m²/year) Cooling	Maximum Change Saving (MJ/m²/year) Heating	Maximum Rating Change
		Surface colour				-0.1	0	0	1	-0.4	0.1	1.8	-0.6	0.1			
		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	Under Slab Insulation				-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 west													1.70	-0.30	0.10
		Eave extension north													1.20	-1.10	0.00
		Eave extension east													5.20	-0.40	0.30
		Roller shutters west				3.90	0.00	0.30									
		Roller shutters north				0.80	0.00	0.10									
		Roller shutters east				4.10	0.00	0.30									
	Thermal mass					-0.5	0.6	0	4.2	2.8	0.4	3.6	3.4	0.4			
270°	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	Under Slab Insulation				-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 west													3.8	-0.7	0.2
		Eave extension north													1	-0.6	0
		Eave extension east													1.5	-0.6	0
		Roller shutters west				7	0.2	0.3									
		Roller shutters north				1.6	-0.1	0.1									
		Roller shutters east				1.8	-0.1	0.1									
	Thermal mass					-0.3	0.6	0	3.4	3.4	0.3	2.7	4	0.3			

C.1.3 Climate Zone 6 Single-Dimension Energy Results

Table 4-51 Energy analysis results for the Apartment Archetype for Climate Zone 6

Orientation	Design parameters		Base 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	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 west													1.4	-3.1	-0.1
		Eave extension north													0.3	-4	-0.1
		Eave extension east													1.8	-1	0
		Roller shutters west				3	-0.1	0									
		Roller shutters north				0.1	0	0									
		Roller shutters east				0.9	0	0									
	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 west													0.6	-2.3	0
		Eave extension north													1.2	-5.7	-0.1
		Eave extension east													0.6	-2.1	0
		Roller shutters west				2	-0.1	0.1									
		Roller shutters north				1.1	0	0									
		Roller shutters east				0.4	0	0									
	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			
	Infiltration	Improve workmanship				0.1	49.7	1.5									
	External shading	Eave extension west													1.5	-0.4	0.1
		Eave extension north													-0.3	-1.8	0
		Eave extension east													1.3	-4.3	0
		Roller shutters west				2.1	0	0.1									
		Roller shutters north				0.8	-0.1	0.1									
		Roller shutters east				1.2	0	0.1									
	Thermal mass					7.4	-0.5	0.2	3.3	1.9	0.2	9.3	1	0.3			
270º		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

Orientation	Design parameters		Base 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	
	External wall	Surface colour				0.2	-1.3	0	0.6	-3.2	0	0.7	-3.8	0			
	Infiltration	Improve workmanship				0.8	49.7	1.4									
	External shading	Eave extension west													0.6	-1.7	0
		Eave extension north													3	-0.9	0.1
		Eave extension east													0.8	-4.6	-0.1
		Roller shutters west				0.8	0	0.1									
		Roller shutters north				1.3	0	0.1									
		Roller shutters east				1.2	0	0.1									
	Thermal mass					8	-1.2	0.2	3.4	-0.2	0.1	10.4	-1.2	0.3			

Table 4-52 Energy analysis results for the Attached Archetype for Climate Zone 6

Orientation	Design parameters		Base 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	
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	-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	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 west															
		Eave extension north													0	-2.5	-0.1
		Eave extension east															
		Roller shutters west															
		Roller shutters north				0.7	-0.3	0									
		Roller shutters east															

Orientation	Design parameters		Base Case Load (MJ/m²/year) Cooling	Base Case Load (MJ/m²/year) Heating	Base 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
	Thermal mass					1.1	-3.3	0	2.2	1.1	0.1	2.9	-1.9	0			
90º	External wall	Insulation				0.3	1.7	0.1	0.4	2.8	0.1	0.6	3.4	0.1	0.8	4.2	0.1
	External wall	Surface colour				0.3	-0.6	0	0.5	-1.2	0	0.9	-1.9	0	1.1	-2.3	0
	Roof	Roof surface type				0.3	-1	0	1.1	-2.2	0	0.6	-2.6	0			
	Roof	Surface colour				0.5	-1	0	1.1	-2.2	0	0.6	-2.5	0			
	Roof	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	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	21.2	122.6	5.6	1.9	41.8	1.2									
	External shading	Eave extension west													1.6	-1.1	0
	External shading	Eave extension north															
	External shading	Eave extension east													1.9	0.5	0.1
	External shading	Roller shutters west				5.00	-0.20	0.1									
	External shading	Roller shutters north															
	External shading	Roller shutters east				2	-0.1	0.1									
	Thermal mass					2.2	-0.9	0	2.4	0.9	0.1	4.8	-0.3	0.1			
180º	External wall	Insulation				0.1	1.6	0.1	0.1	2.8	0.1	0.1	3.5	0.1	0.2	4.3	0.2
	External wall	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			
	Roof	Surface colour				0.5	-0.9	0	0.6	-2	0	1	-2.4	-0.1			
	Roof	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
	Floor	Under Slab Insulation				-1.7	7	0.2							-2.2	10	0.3
	Ventilation	Ceiling fan	10.1	99.2	6.5	3.2	-0.9	0.1									
	Infiltration	Improve workmanship				0.2	42.4	1.3									
	External shading	Eave extension west															
	External shading	Eave extension north													-0.4	-2.3	-0.1
	External shading	Eave extension east															

Orientation	Design parameters		Base Case Load (MJ/m²/year) Cooling	Base Case Load (MJ/m²/year) Heating	Base 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
		Roller shutters west															
		Roller shutters north				1	-0.3	0.1									
		Roller shutters east															
	Thermal mass					0.5	3.6	0.2	2	2.6	0.2	2.4	5.7	0.3			
270°	External wall	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
		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	Under Slab Insulation				-2.6	6.1	0.1							-3.6	8.8	0.1
	Ventilation	Ceiling fan				5	-0.9	0.1									
	Infiltration	Improve workmanship				1.1	42	1.2									
	External shading	Eave extension west													1.4	-0.7	0
		Eave extension north															
		Eave extension east													2	-1.1	0
		Roller shutters west				2.40	-0.20	0									
		Roller shutters north															
		Roller shutters east				3.2	0	0.1									
	Thermal mass					1.5	-1.5	0	2.4	0.7	0.1	4	-1.1	0.1			

Table 4-53 Energy analysis results for the Detached Archetype for Climate Zone 6

Orientation	Design parameters		Base Case Load (MJ/m²/year) Cooling	Base Case Load (MJ/m²/year) Heating	Base 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
0°	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

Orientation	Design parameters		Base 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	Under Slab Insulation				-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 west													1.4	-1.8	0.0
		Eave extension north													2.1	-4	0.0
		Eave extension east													0.7	-2.2	0.0
		Roller shutters west				3.5	-0.1	0									
		Roller shutters north				2.3	0	0									
		Roller shutters east				0.8	0	0									
	Thermal mass					-0.7	3.5	0	0	0	0	0	0	0			
90°	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
	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	Under Slab Insulation				-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									
	Infiltration	Improve workmanship				1.8	33.6	1									
	External shading	Eave extension west													1.10	-1.70	0.0
		Eave extension north													1.60	-2.90	0.0
		Eave extension east													2.10	-3.00	0.0
		Roller shutters west				1.90	-0.10	0.00									
		Roller shutters north				2.10	-0.20	0.00									
		Roller shutters east				1.80	0.00	0.00									
	Thermal mass					-0.4	3.6	0.1	5.5	2.9	0.3	4.9	6.7	0.4			
180°	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									

Orientation	Design parameters		Base 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	
		Surface colour				0	-0.1	0	0.6	-1.4	0	0.7	-1.9	0			
		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	Under Slab Insulation				-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 west													1.30	-1.50	0.0
		Eave extension north													0.90	-3.90	-0.1
		Eave extension east													1.30	-2.80	-0.1
		Roller shutters west				2.50	-0.10	0.00									
		Roller shutters north				0.90	-0.20	0.00									
		Roller shutters east				1.50	-0.10	0.00									
	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	Under Slab Insulation				-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 west													2.3	-2.5	0
		Eave extension north													1.1	-2.2	0
		Eave extension east													1.2	-1.9	0
		Roller shutters west				4.5	-0.1	0.1									
		Roller shutters north				1.5	-0.2	0									
		Roller shutters east				0.9	-0.1	0									
	Thermal mass					-0.5	3.7	0	5	2	0.1	4.6	6	0.2			

C.1.4 Climate Zone 7 Single-Dimension Energy Results

Table 4-54 Energy analysis results for the Apartment Archetype for Climate Zone 7

Orientation	Design parameters	Base Case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
		Load (MJ/m²/year)		Equivalent Star Rating	Saving (MJ/m²/year)		Rating Improved	Saving (MJ/m²/year)		Rating Improved	Saving (MJ/m²/year)		Rating Improved	Saving (MJ/m²/year)		Rating Improved
		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
0º	Wall Insulation	36.4	195.7	4.9	-0.3	3.6	0.2	-0.2	6.9	0.2	-0.2	9.2	0.3	0.1	11.4	0.3
	Infiltration				-0.6	58.4	1.2									
	Roller Shutters West				9	-0.1	0.3									
	Roller Shutters East				0.1	0	0.1									
	Roller Shutters North				0.5	0	0.1									
	Thermal Mass				9.5	10	0.4	11.4	18	0.6	19.7	22.5	0.9			
90º	Wall Insulation	34.1	174.9	5.4	-0.8	2.7	0	-0.8	5.4	0	-0.7	7.3	0.1	-0.6	9.1	0.1
	Infiltration				-3	56	1									
	Roller Shutters West				6.7	0	0.1									
	Roller Shutters East				1.1	0	0									
	Roller Shutters North				2.2	0	0									
	Thermal Mass				8.4	11.3	0.4	11.6	27.5	0.7	20	34.5	1			
180º	Wall Insulation	32.4	185.8	5.2	-0.2	3.7	0.1	-0.1	6.6	0.2	0.2	8.7	0.2	0.1	10.9	0.2
	Infiltration				-1.7	57.4	1.1									
	Roller Shutters West				3.3	0	0.1									
	Roller Shutters East				1.5	0	0.1									
	Roller Shutters North				1.6	0	0.1									
	Thermal Mass				10.5	6.4	0.3	10.8	20.4	0.6	18.4	26.4	0.9			
270º	Wall Insulation	37.7	200.6	4.9	-0.3	4.2	0	-0.4	7.7	0.1	-0.3	9.8	0.2	-0.3	12.2	0.2
	Infiltration				-1.1	58.6	1									
	Roller Shutters West				5.7	0	0									
	Roller Shutters East				0.9	0	0									
	Roller Shutters North				0.8	0	0									

Orientation	Design parameters	Base Case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
		Load (MJ/m²/year)		Equivalent Star Rating	Saving (MJ/m²/year)		Rating Improved	Saving (MJ/m²/year)		Rating Improved	Saving (MJ/m²/year)		Rating Improved	Saving (MJ/m²/year)		Rating Improved
		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
	Thermal Mass				12	6.9	0.3	12.2	5.6	0.3	21.3	7.5	0.5			

Table 4-55 Energy analysis results for the Attached Archetype for Climate Zone 7

Orientation	Design parameters	Base Case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
		Load (MJ/m²/year)		Equivalent Star Rating	Saving (MJ/m²/year)		Rating Improved	Saving (MJ/m²/year)		Rating Improved	Saving (MJ/m²/year)		Rating Improved	Saving (MJ/m²/year)		Rating Improved
		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
0º	Wall Insulation	4	134.2	6.9	0.1	3.1	0	0.2	5.4	0.1	0.2	7	0.2	0.3	8.4	0.2
	Ceiling Insulation				0.2	3.8	0	0.5	5.3	0.1	0.7	6.7	0.2	0.8	7.5	0.2
	Slab Edge Insulation				0.1	5.1	0.1									
	Under Slab Insulation				0.3	2.7	0	0.4	3.4	0						
	Infiltration				-1.2	52.9	1									
	Roller Shutters West															
	Roller Shutters East															
	Roller Shutters North				1	-0.1	0									
	Thermal Mass				1.7	3.1	0.1	0.1	-4.6	-0.1	1.5	-1.2	0			
90º	Wall Insulation	10.1	127.5	6.9	-0.1	3	0	0	5.2	0.1	0	6.7	0.2	0.3	8	0.2
	Ceiling Insulation				0.3	3.8	0.1	0.7	5.3	0.2	1	6.8	0.2	1.2	7.6	0.2
	Slab Edge Insulation				-0.2	5	0.1									
	Under Slab Insulation				0.2	3.6	0.1	0.3	4.5	0.1						
	Infiltration				-0.3	51.4	1									
	Roller Shutters West				4	-0.1	0.1									
	Roller Shutters East				0.6	-0.1	0									
	Roller Shutters North															
	Thermal Mass				2.7	1.1	0.1	0	-2.2	0	2.7	-1.2	0			
180º	Wall Insulation	3.7	111.2	7.4	0	3.2	0	0.1	5.5	0.1	0.1	7.3	0.2	0.1	8.8	0.2
	Ceiling Insulation				0.3	4	0	0.4	5.8	0.1	0.6	7.1	0.2	0.7	7.9	0.2
	Slab Edge Insulation				-0.1	5.3	0.1									

Orientation	Design parameters	Base Case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
		Load (MJ/m²/year)		Equivalent Star Rating	Saving (MJ/m²/year)		Rating Improved	Saving (MJ/m²/year)		Rating Improved	Saving (MJ/m²/year)		Rating Improved	Saving (MJ/m²/year)		Rating Improved
		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
	Under Slab Insulation				0.1	3.1	0	0.3	3.8	0						
	Infiltration				-1.7	51.5	1									
	Roller Shutters West															
	Roller Shutters East															
	Roller Shutters North				0.7	-0.1	0									
	Thermal Mass				1.3	3.8	0.1	-0.1	-1	0	1.2	2.9	0			
270º	Wall Insulation	8.8	128.7	6.9	-0.2	3.6	0	0	6.1	0.2	0	7.9	0.2	0.2	9.6	0.2
	Ceiling Insulation				0.4	3.8	0.1	0.8	5.5	0.2	1	6.9	0.2	1	7.5	0.2
	Slab Edge Insulation				-0.2	5.1	0.1									
	Under Slab Insulation				0.2	3.3	0	0.2	4.2	0.1						
	Infiltration				-1.1	51.6	1									
	Roller Shutters West				2.3	-0.1	0									
	Roller Shutters East				0.7	-0.1	0									
	Roller Shutters North															
	Thermal Mass				3.2	0.6	0.1	-0.4	-2.8	0	3.2	-1.8	0			

Table 4-56 Energy analysis results for the Detached Archetype for Climate Zone 7

Orientation	Design parameters	Base Case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
		Load (MJ/m²/year)		Equivalent Star Rating	Saving (MJ/m²/year)		Rating Improved	Saving (MJ/m²/year)		Rating Improved	Saving (MJ/m²/year)		Rating Improved	Saving (MJ/m²/year)		Rating Improved
		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
0º	Wall Insulation	12	153.2	6.1	0.2	2.2	0.1	0.3	2.1	0.1	0.5	4.5	0.1	0.6	5.2	0.1
	Ceiling Insulation				0.2	5.3	0.1	0.6	10.1	0.2	0.8	12.8	0.3	1	15.4	0.3
	Slab Edge Insulation				0	8.7	0.2									
	Under Slab Insulation				-2.8	16.8	0.3	-3.9	23.2	0.4	-4.3	26.5	0.5	-4.7	28.5	0.5
	Infiltration				0.4	43.1	1									
	Roller Shutters West				3	0	0.1									

Orientation	Design parameters	Base Case Load (MJ/m²/year) Cooling	Base Case Load (MJ/m²/year) Heating	Base Case Equivalent Star Rating	Level 1 Change Saving (MJ/m²/year) Cooling	Level 1 Change Saving (MJ/m²/year) Heating	Level 1 Change Rating Improved	Level 2 Change Saving (MJ/m²/year) Cooling	Level 2 Change Saving (MJ/m²/year) Heating	Level 2 Change Rating Improved	Level 3 Change Saving (MJ/m²/year) Cooling	Level 3 Change Saving (MJ/m²/year) Heating	Level 3 Change Rating Improved	Maximum Change Saving (MJ/m²/year) Cooling	Maximum Change Saving (MJ/m²/year) Heating	Maximum Change Rating Improved
	Roller Shutters East				0.5	0	0									
	Roller Shutters North				0.5	0	0									
	Thermal Mass				4.7	2.1	0.2	8.2	-8.6	0	9.5	-10.1	0			
90º	Wall Insulation	11.4	151.6	6.2	0.5	2.5	0	0.5	2.5	0	0.7	5.5	0.1	0.7	6.4	0.1
	Ceiling Insulation				0.5	5.2	0.1	0.7	10.1	0.2	0.8	12.9	0.2	1	15.4	0.3
	Slab Edge Insulation				-0.1	8.5	0.1									
	Under Slab Insulation				-3	17.2	0.2	-4	23.7	0.4	-4.5	26.9	0.4	-4.8	28.8	0.5
	Infiltration				0.3	43.3	0.9									
	Roller Shutters West				2.6	-0.2	0									
	Roller Shutters East				0.1	-0.1	0									
	Roller Shutters North				0.4	-0.1	0									
	Thermal Mass				3.7	1.6	0.1	8.1	-8.8	-0.1	9	-10.4	-0.1			
180º	Wall Insulation	12.6	151.6	6.1	0.4	3.1	0.1	0.4	3.1	0.1	0.6	6.7	0.2	0.6	7.8	0.2
	Ceiling Insulation				0.5	5.3	0.2	0.8	10.2	0.3	1	12.9	0.3	1.1	15.5	0.3
	Slab Edge Insulation				0	8.8	0.2									
	Under Slab Insulation				-2.5	17.3	0.3	-3.4	23.9	0.5	-4.1	27.3	0.5	-4.3	29.3	0.6
	Infiltration				0.1	43.9	1									
	Roller Shutters West				3.7	-0.1	0.1									
	Roller Shutters East				0.4	-0.1	0									
	Roller Shutters North				0.6	-0.1	0									
	Thermal Mass				4.5	-1.6	0.1	9	-8.3	0	10.2	-10.4	0			
270º	Wall Insulation	11.9	155.2	6.1	0.3	2.6	0	0.3	2.5	0	0.4	5.5	0.1	0.5	6.4	0.1
	Ceiling Insulation				0.5	5.2	0.1	0.8	9.9	0.2	1	12.6	0.3	1	15.2	0.3
	Slab Edge Insulation				0.1	8.5	0.2									
	Under Slab Insulation				-2.5	16.6	0.3	-3.7	22.9	0.3	-4.4	26.1	0.4	-4.8	28.2	0.5
	Infiltration				-0.3	42.8	0.8									

Orientation	Design parameters	Base Case			Level 1 Change			Level 2 Change			Level 3 Change			Maximum Change		
		Load (MJ/m²/year)		Equivalent Star Rating	Saving (MJ/m²/year)		Rating Improved	Saving (MJ/m²/year)		Rating Improved	Saving (MJ/m²/year)		Rating Improved	Saving (MJ/m²/year)		Rating Improved
		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating		Cooling	Heating	
	Roller Shutters West				2.5	-0.1	0									
	Roller Shutters East				0.5	-0.1	0									
	Roller Shutters North				1.1	-0.1	0									
	Thermal Mass				8.3	-6.8	0	4.3	0.3	0.1	9.3	-8.3	0			

C.1.5 Slab Edge Insulation Single-Dimension Energy Results

Table 4-57 Energy analysis results for Slab Edge Insulation inclusion into Attached and Detached Archetypes for Climate Zones 2, 5, 6 and 7

Archetype	Climate Zone	Orientation	Energy Consumption (MJ/m²/year)								
			Baseline 6 Star NatHERS (approximately 6ACH@50 Pa)[1]	NatHERS 6 Star (6ACH@50Pa) compliant?	Baseline (approximately 15ACH@50 Pa)[2]	Slab Edge Insulation[3]	□Energy (approximately 15ACH@50Pa)[4]	Baseline (Glazing Calculator Compliant)[5]	Satisfies Glazing Calculator?	Slab Edge Insulation (Glazing Calculator Compliant)[6]	□Energy (Glazing Calculator Compliant)[7]
Attached	CZ 2	0˚	34.9	Y (Glass 1)	48.5	48.3	0.2	48.5	Y (Glass 1)	48.3	0.2
		90˚	49.6	N	65.2	65	0.2	65.2	N	65	0.2
		180˚	29.5	Y (Glass 1)	40.7	40.3	0.4	40.7	Y (Glass 1)	40.3	0.4
		270˚	56.5	N	68.9	68.2	0.7	68.9	N	68.2	0.7
	CZ 5	0˚	24.6	Y (Glass 1)	40.9	40	0.9	40.9	N	40	0.9
		90˚	33.2	Y (Glass 1)	49.9	49	0.9	49.9	N	49	0.9
		180˚	18.5	Y (Glass 1)	29.9	29.3	0.6	29.9	Y (Glass 1)	29.3	0.6
		270˚	35.8	Y (Glass 1)	49.4	48.5	0.9	49.4	N	48.5	0.9
	CZ 6	0˚	82.1	Y (Glass 1)	130.1	126.7	3.4	103.5	N	100	3.5
		90˚	86.1	Y (Glass 1)	133.4	130.1	3.3	105.4	N	102.1	3.3
		180˚	64.2	Y (Glass 1)	110	106.6	3.4	87.3	Y (Glass 5)	83.8	3.5
		270˚	86.1	Y (Glass 1)	133.8	130.3	3.5	105.7	N	102.2	3.5
	CZ 7	0˚	120.4	Y (Glass 1)	172.2	167.3	4.9	138.2	N	133	5.2
		90˚	121.8	Y (Glass 1)	172.6	167.7	4.9	137.6	N	132.8	4.8
		180˚	95	Y (Glass 1)	143.4	138.3	5.1	114.9	Y (Glass 5)	109.7	5.2
		270˚	121.4	Y (Glass 1)	172.4	167.3	5.1	137.5	N	132.6	4.9
Detached	CZ 2	0˚	40.7	Y (Glass 2)	53.1	52.2	0.9	53.1	Y (Glass 2)	52.2	0.9
		90˚	42.8	Y (Glass 2)	56.1	55	1.1	56.1	Y (Glass 2)	55	1.1
		180˚	52.1	N	65.5	64.4	1.1	65.5	Y (Glass 2)	64.4	1.1

Archetype	Climate Zone	Orientation	Energy Consumption (MJ/m²/year)								
			Baseline 6 Star NatHERS (approximately 6ACH@50 Pa)[1]	NatHERS 6 Star (6ACH@50Pa) compliant?	Baseline (approximately 15ACH@50 Pa)[2]	Slab Edge Insulation[3]	□Energy (approximately 15ACH@50Pa)[4]	Baseline (Glazing Calculator Compliant)[5]	Satisfies Glazing Calculator?	Slab Edge Insulation (Glazing Calculator Compliant)[6]	□Energy (Glazing Calculator Compliant)[7]
		270˚	48.1	N	61.8	60.5	1.3	61.8	Y (Glass 2)	60.5	1.3
	CZ 5	0˚	34.4	Y (Glass 2)	45.6	44.1	1.5	54.9	Y (Glass 1)	53.2	1.7
		90˚	34.1	Y (Glass 2)	45	43.4	1.6	52.5	Y (Glass 1)	50.8	1.7
		180˚	37.6	Y (Glass 2)	50.1	48	2.1	58.7	Y (Glass 1)	56.9	1.8
		270˚	37.1	Y (Glass 2)	49.2	47.2	2	57.6	Y (Glass 1)	55.8	1.8
	CZ 6	0˚	114.8	Y (Glass 1)	150.1	143.9	6.2	115.4	N	109.4	6
		90˚	112.4	Y (Glass 1)	148	141.6	6.4	114.2	Y (Glass 6)	108	6.2
		180˚	112.5	Y (Glass 1)	148.1	142	6.1	114.1	Y (Glass 6)	107.5	6.6
		270˚	117.6	Y (Glass 1)	152.9	146.5	6.4	117.9	N	111.9	6
	CZ 7	0˚	165.4	Y (Glass 1)	207.6	198.4	9.2	165.4	N	155.9	9.5
		90˚	162.2	Y (Glass 1)	205.1	196.1	9	163.2	N	153.8	9.4
		180˚	162.5	Y (Glass 1)	205.4	196	9.4	164.6	N	154.8	9.8
		270˚	169	Y (Glass 1)	210.9	201.7	9.2	167.4	N	158	9.4

[1] Baseline 6 Star NatHERS model includes the current practise WWR (i.e. WWRmin+10%), TIC reviews and the default infiltration (approximately 6 ACH@50Pa). The glazing type employed meet/exceeds 6 Star NatHERS in at least one orientation.

[2] The baseline model has all the building elements as per 6 Star NatHERS Baseline except the infiltration, which is approximately 15 ACH@50Pa.

[3] Slab edge insulation is included in the Baseline model.

[4] The difference between the total energy consumption of the baseline model at approximately 6 ACH@50Pa and the total energy consumption of the model with the Slab edge insulation is presented in ΔE

[5] Baseline glazing calculator compliant includes the glass type that complies with the glazing calculator at least in one orientation (infiltration rate is approximately 15 ACH@50Pa). Note that the Detached archetype in Climate Zone 7 had no glass from the AccuRate Sustainability library compliant with the glazing calculator.

[6] Slab edge insulation glazing calculator compliant refers to the baseline model that has the glass type selected to comply with the glazing calculator at least in one orientation as well as the slab edge insulation included in the model. Baseline (Glazing Calculator Compliant) is non-compliant with NCC Glazing Calculator in all orientations in Climate Zone 7 for specified glass types.

[7] ΔE is the difference between the baseline model compliant with the glazing calculator at least in one orientation and this baseline model with the slab edge insulation included.

C.2 Single-Dimensional Peak Load Results

C.2.1 Climate Zone 2 Single-Dimension Peak Load Results

Table 4-58 Peak load results for the Apartment Archetype for Climate Zone 2

Orientation	Design parameters		Base 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		Ext. wall insulation	1.55	0.97	4.9	-0.09	0.03	-0.10	0.06	-0.09	0.08	-0.08	0.10

Orientation	Design parameters		Base Case Peak Load (kW) Cooling	Base Case Peak Load (kW) Heating	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 wall	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 west										-0.45	-0.01
		Eave extension north										-0.10	-0.03
		Eave extension east										-0.35	0.00
		Roller shutters west				-0.25	0.00						
		Roller shutters north				-0.11	0.00						
		Roller shutters east				-0.36	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		
	Infiltration	Improve workmanship				-0.09	0.32						
	External shading	Eave extension west										0.10	0.00
		Eave extension north										-0.08	-0.02
		Eave extension east										-0.09	-0.03
		Roller shutters west				0.18	0.00						
		Roller shutters north				-0.11	0.00						
		Roller shutters east				-0.11	0.00						
	Thermal mass					-0.07	0.13	-0.39	0.07	-0.06	0.18		
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
		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 west										0.15	0.00
		Eave extension north										0.15	-0.03
		Eave extension east										0.02	-0.04
		Roller shutters west				0.09	0.00						
		Roller shutters north				0.14	0.00						
		Roller shutters east				0.15	0.00						
	Thermal mass					-0.04	0.10	0.06	0.04	0.41	0.10		
270º		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		Base Case Peak Load (kW) Cooling	Base Case Peak Load (kW) Heating	Base 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 wall	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 west										0.06	-0.01
		Eave extension north										0.02	-0.01
		Eave extension east										0.02	-0.01
		Roller shutters west				0.07	0.00						
		Roller shutters north				0.01	0.00						
		Roller shutters east				0.15	0.00						
	Thermal mass					0.14	0.11	0.16	0.05	0.20	0.13		

Table 4-59 Peak load results for the Attached Archetype for Climate Zone 2

Orientation	Design parameters		Base Case Peak Load (kW) Cooling	Base Case Peak Load (kW) Heating	Level 1 Change Peak Load Decrease (kW) Cooling	Level 1 Change Peak Load Decrease (kW) Heating	Level 2 Change Peak Load Decrease (kW) Cooling	Level 2 Change Peak Load Decrease (kW) Heating	Level 3 Change Peak Load Decrease (kW) Cooling	Level 3 Change Peak Load Decrease (kW) Heating	Maximum Change Peak Load Decrease (kW) Cooling	Maximum Change Peak Load Decrease (kW) Heating
0°	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	Under Slab Insulation			0.01	-0.02					-0.01	-0.03
	Ventilation	Ceiling fan			0.32	0.01						
	Infiltration	Improve workmanship			0.01	0.30						
	External shading	Eave extension west										
		Eave extension north									0.00	-0.03
		Eave extension east										
		Roller shutters west										
		Roller shutters north			0.13	-0.01						
		Roller shutters east										
	Thermal mass				-0.21	0.06	-0.36	-0.13	-0.34	-0.04		
90°	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		

Orientation	Design parameters		Base 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
		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	Under Slab Insulation			-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 west									0.25	-0.01
		Eave extension north										
		Eave extension east									0.07	0.00
		Roller shutters west			1.09	0.00						
		Roller shutters north										
		Roller shutters east			0.11	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				
	Ceiling	Insulation			0.10	0.03	-0.08	0.05	-0.08	0.05	-0.06	0.06
	Floor	Under Slab Insulation			-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 west										
		Eave extension north									-0.01	-0.01
		Eave extension east										
		Roller shutters west										
		Roller shutters north			0.01	-0.01						
		Roller shutters east										
	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
	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	Under Slab Insulation			-0.10	0.01					-0.14	0.02

Orientation	Design parameters		Base Case Peak Load (kW) Cooling	Base Case Peak Load (kW) Heating	Level 1 Change Peak Load Decrease (kW) Cooling	Level 1 Change Peak Load Decrease (kW) Heating	Level 2 Change Peak Load Decrease (kW) Cooling	Level 2 Change Peak Load Decrease (kW) Heating	Level 3 Change Peak Load Decrease (kW) Cooling	Level 3 Change Peak Load Decrease (kW) Heating	Maximum Change Peak Load Decrease (kW) Cooling	Maximum Change Peak Load Decrease (kW) Heating
	Ventilation	Ceiling fan			-0.03	0.00						
	Infiltration	Improve workmanship			0.05	0.25						
	External shading	Eave extension west									0.06	0.01
		Eave extension north										
		Eave extension east									0.04	0.00
		Roller shutters west			0.12	0.00						
		Roller shutters north										
		Roller shutters east			0.00	0.00						
	Thermal mass				0.09	0.04	-0.14	0.03	-0.08	0.07		

Table 4-60 Peak load results for the Detached Archetype for Climate Zone 2

Orientation	Design parameters		Base Case Peak Load (kW) Cooling	Base Case Peak Load (kW) Heating	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
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	Under Slab Insulation				-0.33	-0.99	-0.49	-1.24	-0.46	-1.35	-0.55	-1.39
	Ventilation	Ceiling fan				0.12	0.00						
	Infiltration	Improve workmanship				0.64	0.58						
	External shading	Eave extension west										0.47	-0.01
		Eave extension north										0.19	-0.04
		Eave extension east										0.20	-0.02
		Roller shutters west				1.26	0.00						
		Roller shutters north				0.00	0.00						
		Roller shutters east				0.26	0.00						
	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				

Orientation	Design parameters		Base 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				0.01	0.08	0.05	0.14	0.08	0.18	0.09	0.21
	Floor	Under Slab Insulation				-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 west										0.32	-0.01
		Eave extension north										0.18	-0.04
		Eave extension east										-0.20	-0.05
		Roller shutters west				0.82	0.00						
		Roller shutters north				0.00	0.00						
		Roller shutters east				0.18	0.00						
	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						
		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	Under Slab Insulation				-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 west										0.20	-0.01
		Eave extension north										0.04	-0.03
		Eave extension east										0.23	-0.03
		Roller shutters west				0.60	0.00						
		Roller shutters north				0.00	0.00						
		Roller shutters east				0.38	0.00						
	Thermal mass					0.00	0.02	0.35	0.43	0.35	0.44		
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	Under Slab Insulation				-0.42	-0.96	-0.54	-1.21	-0.59	-1.31	-0.62	-1.36
	Ventilation	Ceiling fan				-0.37	0.00						

Orientation	Design parameters		Base Case Peak Load (kW) Cooling	Base Case Peak Load (kW) Heating	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				0.15	0.57						
	External shading	Eave extension west										0.05	-0.01
		Eave extension north										0.02	-0.03
		Eave extension east										0.06	-0.02
		Roller shutters west				0.70	0.00						
		Roller shutters north				0.00	0.00						
		Roller shutters east				0.04	0.00						
	Thermal mass					-0.01	0.01	0.63	0.43	0.62	0.45		

C.2.2 Climate Zone 5 Single-Dimension Peak Load Results

Table 4-61 Peak load results for the Apartment Archetype for Climate Zone 5

Orientation	Design parameters		Base Case Peak Load (kW) Cooling	Base Case Peak Load (kW) Heating	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
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		
	Infiltration	Improve workmanship				0.02	0.34						
	External shading	Eave extension west										-0.33	0.00
		Eave extension north										0.05	-0.01
		Eave extension east										0.04	0.00
		Roller shutters west				-0.07	0.00						
		Roller shutters north				0.00	0.00						
		Roller shutters east				-0.18	0.00						
	Thermal mass					0.25	0.11	-0.05	0.09	0.23	0.18		
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 west										0.08	0.00
		Eave extension north										0.03	-0.01
		Eave extension east										0.01	0.00
		Roller shutters west				0.25	0.00						

Orientation	Design parameters		Base 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
		Roller shutters north				0.01	0.00						
		Roller shutters east				0.01	0.00						
	Thermal mass					0.66	0.10	0.00	0.09	0.45	0.17		
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
		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 west										0.16	0.00
		Eave extension north										0.00	0.00
		Eave extension east										0.05	-0.01
		Roller shutters west				-0.08	0.00						
		Roller shutters north				0.00	0.00						
		Roller shutters east				-0.04	0.00						
	Thermal mass					0.14	0.09	-0.13	0.07	0.40	0.13		
270º	External wall	Insulation	1.68	1.01	5.10	0.02	0.02	0.46	0.04	0.45	0.05	0.47	0.06
		Surface colour				0.44	0.00	0.47	0.00	0.48	0.00		
	Infiltration	Improve workmanship				0.48	0.30						
	External shading	Eave extension west										0.07	0.00
		Eave extension north										0.09	0.00
		Eave extension east										0.01	0.00
		Roller shutters west				0.15	0.00						
		Roller shutters north				0.00	0.00						
		Roller shutters east				-0.05	0.00						
	Thermal mass					0.21	0.09	0.51	0.06	0.27	0.13		

Table 4-62 Peak load results for the Attached Archetype for Climate Zone 5

Orientation	Design parameters		Base 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		

Orientation	Design parameters		Base 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
		Openness			-0.12	-0.01	-0.11	0.00				
	Ceiling	Insulation			0.02	0.02	-0.22	0.04	-0.19	0.05	-0.18	0.05
	Floor	Under Slab Insulation			-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 west										
		Eave extension north									-0.05	-0.02
		Eave extension east										
		Roller shutters west										
		Roller shutters north			0.03	0.01						
		Roller shutters east										
	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
	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	Under Slab Insulation			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 west									0.23	0.00
		Eave extension north										
		Eave extension east									0.02	0.00
		Roller shutters west			0.84	0.00						
		Roller shutters north										
		Roller shutters east			0.15	0.00						
	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	Under Slab Insulation			-0.41	-0.01					-0.38	0.00

Orientation	Design parameters		Base 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
	Ventilation	Ceiling fan			-0.21	0.00						
	Infiltration	Improve workmanship			0.11	0.48						
	External shading	Eave extension west										
		Eave extension north									-0.05	-0.01
		Eave extension east										
		Roller shutters west										
		Roller shutters north			-0.09	0.00						
		Roller shutters east										
	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	Under Slab Insulation			-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 west									0.29	-0.01
		Eave extension north										
		Eave extension east									0.28	0.00
		Roller shutters west			0.14	0.00						
		Roller shutters north										
		Roller shutters east			0.60	0.00						
	Thermal mass				0.03	0.06	0.23	-0.06	0.37	0.01		

Table 4-63 Peak load results for the Detached Archetype for Climate Zone 5

Orientation	Design parameters		Base 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	4.23	2.31	4.90	0.05	0.04	0.07	0.06	0.09	0.08	0.11	0.10
		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						

Orientation	Design parameters		Base Case Peak Load (kW) Cooling	Base Case Peak Load (kW) Heating	Base 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
		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	Under Slab Insulation				-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						
	External shading	Eave extension west										0.05	-0.01
		Eave extension north										0.05	-0.02
		Eave extension east										0.04	-0.01
		Roller shutters west				0.40	0.00						
		Roller shutters north				0.03	0.00						
		Roller shutters east				0.02	0.00						
	Thermal mass					-0.01	0.02	0.43	0.26	0.41	0.28		
90°	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	Under Slab Insulation				-0.15	-0.75	-0.29	-0.92	-0.59	-1.00	-0.63	-1.03
	Ventilation	Ceiling fan				-0.01	0.00						
	Infiltration	Improve workmanship				0.97	0.52						
	External shading	Eave extension west										0.09	-0.01
		Eave extension north										0.10	-0.02
		Eave extension east										-0.04	-0.01
		Roller shutters west				0.31	0.00						

Orientation	Design parameters		Base Case Peak Load (kW) Cooling	Base Case Peak Load (kW) Heating	Base 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
		Roller shutters north				0.10	0.00						
		Roller shutters east				0.03	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
	Floor	Under Slab Insulation				-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 west										0.07	-0.01
		Eave extension north										0.07	-0.02
		Eave extension east										0.11	-0.02
		Roller shutters west				0.32	0.00						
		Roller shutters north				0.05	0.00						
		Roller shutters east				0.03	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						
		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	Under Slab Insulation				-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						

Orientation	Design parameters		Base Case Peak Load (kW) Cooling	Base Case Peak Load (kW) Heating	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 west										0.03	-0.01
		Eave extension north										0.08	-0.02
		Eave extension east										0.05	-0.02
		Roller shutters west				0.27	0.00						
		Roller shutters north				0.07	0.00						
		Roller shutters east				0.02	0.00						
	Thermal mass					-0.01	0.02	0.80	0.26	0.89	0.28		

C.2.3 Climate Zone 6 Single-Dimension Peak Load Results

Table 4-64 Peak load results for the Apartment Archetype for Climate Zone 6

Orientation	Design parameters		Base Case Peak Load (kW) Cooling	Base Case Peak Load (kW) Heating	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
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 west										-0.19	0.00
		Eave extension north										0.02	-0.01
		Eave extension east										-0.20	0.00
		Roller shutters west				-0.23	0.00						
		Roller shutters north				-0.21	0.00						
		Roller shutters east				-0.21	0.00						
	Thermal mass					-0.09	0.10	-0.43	0.05	-0.49	0.14		
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		
	Infiltration	Improve workmanship				-0.11	0.45						

Orientation	Design parameters		Base 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 west										-0.03	0.00
		Eave extension north										0.11	-0.01
		Eave extension east										0.05	0.00
		Roller shutters west				-0.15	0.00						
		Roller shutters north				-0.03	0.00						
		Roller shutters east				0.10	0.00						
	Thermal mass					-0.45	0.11	-0.42	0.07	-0.39	0.15		
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 west										0.00	0.00
		Eave extension north										-0.19	0.00
		Eave extension east										-0.14	0.00
		Roller shutters west				0.00	0.00						
		Roller shutters north				0.00	0.00						
		Roller shutters east				-0.03	0.00						
	Thermal mass					-0.22	0.10	-0.12	0.05	0.31	0.13		
270º	External wall	Insulation	1.60	1.47	5.70	-0.01	0.02	-0.36	0.04	0.25	0.06	-0.15	0.07
		Surface colour				0.31	0.00	-0.39	0.00	-0.38	0.00		
	Infiltration	Improve workmanship				0.06	0.42						
	External shading	Eave extension west										-0.11	0.00
		Eave extension north										0.21	-0.01
		Eave extension east										-0.02	0.00
		Roller shutters west				-0.12	0.00						
		Roller shutters north				0.19	0.00						
		Roller shutters east				-0.02	0.00						
	Thermal mass					-0.22	0.10	-0.11	0.04	0.31	0.14		

Table 4-65 Peak load results for the Attached Archetype for Climate Zone 6

Orientation	Design parameters		Base 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	Under Slab Insulation			-0.60	0.05					-0.62	0.07
	Ventilation	Ceiling fan			0.46	0.00						
	Infiltration	Improve workmanship			0.33	0.52						
	External shading	Eave extension west										
		Eave extension north									0.08	-0.02
		Eave extension east										
		Roller shutters west										
		Roller shutters north			0.00	0.00						
		Roller shutters east										
	Thermal mass				0.50	0.05	-0.20	-0.08	0.38	-0.03		
90º	External wall	Insulation	3.25	2.09	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		
		Surface colour			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	Under Slab Insulation			-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 west									-0.03	0.00
		Eave extension north										
		Eave extension east									0.12	0.00
		Roller shutters west			0.89	0.00						
		Roller shutters north										
		Roller shutters east			0.03	0.00						
	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		

Orientation	Design parameters		Base 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
		Openness			-0.02	0.00	0.42	0.00				
	Ceiling	Insulation			0.40	0.01	-0.06	0.03	0.45	0.04	-0.03	0.05
	Floor	Under Slab Insulation			-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 west										
		Eave extension north									0.00	-0.01
		Eave extension east										
		Roller shutters west										
		Roller shutters north			0.00	0.00						
		Roller shutters east										
	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
	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	Under Slab Insulation			-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 west										
		Eave extension north									-0.63	0.00
		Eave extension east										
		Roller shutters west			0.12	0.00					-0.48	0.00
		Roller shutters north										
		Roller shutters east			0.22	0.00						
	Thermal mass				0.10	0.04	0.08	-0.10	0.07	-0.06		

Table 4-66 Peak load results for the Detached Archetype for Climate Zone 6

Orientation	Design parameters		Base 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

Orientation	Design parameters		Base 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				0.00	0.00						
	Roof	Surface colour				0.00	0.00	0.03	0.00	0.06	0.00		
	Roof	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	Under Slab Insulation				-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						
	External shading	Eave extension west										0.15	0.00
	External shading	Eave extension north										0.14	-0.01
	External shading	Eave extension east										0.00	0.00
	External shading	Roller shutters west				0.90	0.09						
	External shading	Roller shutters north				0.14	0.00						
	External shading	Roller shutters east				-0.02	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
	External wall	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						
	Roof	Surface colour				0.00	0.00	0.15	0.00	0.18	0.00		
	Roof	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	Under Slab Insulation				-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 west										0.10	0.00
	External shading	Eave extension north										-0.26	0.00
	External shading	Eave extension east										0.18	0.00
	External shading	Roller shutters west				0.11	0.10						
	External shading	Roller shutters north				-0.26	0.00						
	External shading	Roller shutters east				0.01	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
	External wall	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						

Orientation	Design parameters		Base 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				-0.02	0.00	-0.13	0.00	-0.12	0.00		
		Openness				0.00	-0.02	0.00	-0.03				
	Ceiling	Insulation				0.02	0.05	-0.12	0.08	-0.09	0.10	-0.21	0.12
	Floor	Under Slab Insulation				-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 west										-0.03	0.00
		Eave extension north										0.03	-0.01
		Eave extension east										0.03	-0.01
		Roller shutters west				0.40	0.10						
		Roller shutters north				0.10	0.00						
		Roller shutters east				0.13	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
	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	Under Slab Insulation				-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 west										0.11	0.00
		Eave extension north										0.13	-0.01
		Eave extension east										0.04	-0.01
		Roller shutters west				0.79	0.10						
		Roller shutters north				0.21	0.00						
		Roller shutters east				0.01	0.00						
	Thermal mass					-0.04	0.05	0.43	0.22	0.41	0.27		

C.2.4 Climate Zone 7 Single-Dimension Peak Load Results

Table 4-67 Peak load results for the Apartment Archetype for Climate Zone 7

Orientation	Design parameters	Base Case Load (kW)		Level 1 Change Saving (kW)		Level 2 Change Saving (kW)		Level 3 Change Saving (kW)		Maximum Change Saving (kW)	
		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
0º	Wall Insulation	2.514	2.050	0.007	0.034	0.017	0.052	0.021	0.063	0.026	0.074
	Infiltration			0.287	0.418						
	Roller Shutters West			0.188	0.000						
	Roller Shutters East			0.001	0.000						
	Roller Shutters North			0.000	0.000						
	Thermal Mass			0.075	0.100	0.194	-0.009	0.277	0.071		
90º	Wall Insulation	2.354	1.997	0.010	0.033	0.017	0.051	0.019	0.063	0.025	0.074
	Infiltration			0.289	0.445						
	Roller Shutters West			0.094	0.001						
	Roller Shutters East			0.019	0.000						
	Roller Shutters North			0.000	0.000						
	Thermal Mass			0.273	0.103	0.124	-0.028	0.209	0.043		
180º	Wall Insulation	2.397	1.988	0.016	0.032	0.031	0.049	0.039	0.061	0.043	0.072
	Infiltration			0.445	0.464						
	Roller Shutters West			0.045	0.000						
	Roller Shutters East			0.008	0.000						
	Roller Shutters North			0.000	0.000						
	Thermal Mass			0.384	0.092	0.219	-0.044	0.454	0.018		
270º	Wall Insulation Insulation	2.541	2.052	0.002	0.033	0.013	0.050	0.021	0.062	0.020	0.073
	Infiltration			0.047	0.428						
	Roller Shutters West			0.242	0.000						
	Roller Shutters East			-0.005	0.000						
	Roller Shutters North			0.000	0.000						
	Thermal Mass			0.469	0.095	0.170	-0.034	0.267	0.031		

Table 4-68 Peak load results for the Attached Archetype for Climate Zone 7

Orientation	Design parameters	Base Case Peak Load (kW)		Level 1 Change Peak Load Savings (kW)		Level 2 Change Peak Load Savings (kW)		Level 3 Change Peak Load Savings (kW)		Maximum Change Peak Load Savings (kW)	
		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
0º	Wall Insulation	1.336	2.089	0.010	0.033	0.014	0.059	-0.015	0.069	0.008	0.081
	Ceiling Insulation			0.027	0.029	0.040	0.042	0.143	0.051	0.157	0.064
	Slab Edge Insulation			0.000	0.037						
	Under Slab Insulation			-0.002	0.013	0.006	0.019				
	Infiltration			0.341	0.628						

Orientation	Design parameters	Base Case Peak Load (kW)		Level 1 Change Peak Load Savings (kW)		Level 2 Change Peak Load Savings (kW)		Level 3 Change Peak Load Savings (kW)		Maximum Change Peak Load Savings (kW)	
		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
	Roller Shutters West										
	Roller Shutters East										
	Roller Shutters North			0.033	0.002						
	Thermal Mass			0.531	0.084	-0.022	-0.028	0.528	0.069		
	Wall Insulation			0.019	0.043	0.031	0.060	0.041	0.073	0.049	0.084
	Ceiling Insulation			0.067	0.031	0.083	0.044	0.090	0.056	0.119	0.061
	Slab Edge Insulation			0.001	0.031						
	Under Slab Insulation			-0.522	0.018	-0.648	0.029				
90º	Infiltration	2.052	2.117	0.084	0.631						
	Roller Shutters West			0.533	0.005						
	Roller Shutters East			0.010	0.001						
	Roller Shutters North										
	Thermal Mass			0.392	0.079	0.351	-0.012	0.594	0.054		
	Wall Insulation			0.016	0.027	0.024	0.055	0.218	0.068	0.223	0.074
	Ceiling Insulation			0.035	0.019	0.044	0.035	-0.080	0.051	0.115	0.053
	Slab Edge Insulation			0.006	0.022						
	Under Slab Insulation			-0.005	0.010	-0.003	0.011				
180º	Infiltration	1.347	2.056	0.362	0.660						
	Roller Shutters West										
	Roller Shutters East										
	Roller Shutters North			0.025	-0.010						
	Thermal Mass			0.254	0.074	-0.024	-0.025	0.614	0.056		
	Wall Insulation			0.018	0.032	0.019	0.060	0.025	0.069	0.031	0.090
	Ceiling Insulation			0.120	0.036	0.171	0.047	0.185	0.056	0.201	0.067
	Slab Edge Insulation			0.102	0.026						
	Under Slab Insulation			0.000	0.015	0.000	0.013				
270º	Infiltration	1.696	2.060	0.243	0.634						
	Roller Shutters West			0.271	0.000						
	Roller Shutters East			0.115	0.001						
	Roller Shutters North										
	Thermal Mass			0.362	0.075	0.127	-0.040	0.256	0.033		

Table 4-69 Peak load results for the Detached Archetype for Climate Zone 7

Orientation	Design parameters	Base Case		Level 1 Change		Level 2 Change		Level 3 Change		Maximum Change	
		Peak Load (kW)		Peak Load Savings (kW)		Peak Load Savings (kW)		Peak Load Savings (kW)		Peak Load Savings (kW)	
		Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
	Wall Insulation			0.031	0.060	0.029	0.050	0.061	0.118	0.069	0.135
	Ceiling Insulation			0.055	0.088	0.102	0.164	0.031	0.214	0.536	0.257
	Slab Edge Insulation			0.025	0.118						
	Under Slab Insulation			-0.251	0.264	-0.186	0.352	-0.269	0.399	-0.282	0.426
0º	Infiltration	3.087	4.158	0.673	0.589						
	Roller Shutters West			0.506	0.000						
	Roller Shutters East			0.046	0.000						
	Roller Shutters North			0.000	0.000						
	Thermal Mass			1.032	0.569	1.798	0.195	1.663	0.538		
	Wall Insulation			0.608	0.062	0.606	0.053	-0.168	0.123	-0.155	0.144
	Ceiling Insulation			0.616	0.088	-0.282	0.168	-0.277	0.213	-0.171	0.258
	Slab Edge Insulation			0.006	0.118						
	Under Slab Insulation			0.204	0.252	0.006	0.340	-0.394	0.386	-0.419	0.413
90º	Infiltration	2.933	4.158	0.500	0.590						
	Roller Shutters West			0.015	-0.001						
	Roller Shutters East			-0.218	0.000						
	Roller Shutters North			0.000	-0.001						
	Thermal Mass			0.498	0.559	1.645	0.220	1.700	0.544		
	Wall Insulation			0.031	0.063	0.026	0.055	0.061	0.127	0.069	0.146
	Ceiling Insulation			0.052	0.087	-0.009	0.167	0.021	0.214	0.546	0.259
	Slab Edge Insulation			0.022	0.119						
	Under Slab Insulation			0.601	0.243	-0.205	0.326	-0.067	0.369	-0.094	0.396
180º	Infiltration	3.176	4.083	1.050	0.599						
	Roller Shutters West			0.130	0.000						
	Roller Shutters East			0.029	0.000						
	Roller Shutters North			0.000	0.000						
	Thermal Mass			1.129	0.528	1.543	0.208	2.046	0.519		
	Wall Insulation			0.030	0.060	-0.003	0.052	0.304	0.121	0.310	0.139
	Ceiling Insulation			0.007	0.087	0.309	0.165	0.028	0.213	0.060	0.258
	Slab Edge Insulation			-0.019	0.118						
	Under Slab Insulation			-0.091	0.260	-0.358	0.351	-0.403	0.397	-0.431	0.426
270º	Infiltration	2.887	4.141	0.318	0.595						
	Roller Shutters West			0.411	0.000						
	Roller Shutters East			-0.019	0.000						
	Roller Shutters North			-0.055	0.000						
	Thermal Mass			1.575	0.207	0.971	0.555	1.869	0.547		

C.2.5 Slab Edge Insulation Single-Dimension Peak Load Results

Table 4-70 Peak load results for Slab Edge Insulation inclusion into the Attached and Detached Archetype for Climate Zone 2, 5, 6 and 7

Archetype	Climate Zone	Orientation	Heating and Cooling Peak Load (kW)									
			Base Case NatHERS 6 Star (approximately 6ACH@50 Pa)[1]		Base Case (approximately 15ACH@50 Pa)[2]		Slab Edge Insulation[3]		Base Case (Glazing Calculator Compliant)[4]		Slab Edge Insulation (Glazing Calculator Compliant)[5]	
			Peak Heating (kW)	Peak Cooling (kW)	Peak Heating (kW)	Peak Cooling (kW)	Peak Heating (kW)	Peak Cooling (kW)	Peak Heating (kW)	Peak Cooling (kW)	Peak Heating (kW)	Peak Cooling (kW)
Attached	CZ 2	0°	8.98	22.65	12.62	22.57	12.5	22.5	8.98	22.65	12.62	22.57
		90°	8.63	34.06	11.93	33.42	11.78	33.4	8.63	34.06	11.93	33.42
		180°	5.53	19.81	9.82	21.63	9.48	21.59	5.53	19.81	9.82	21.63
		270°	5.46	25.65	8.34	27.06	8.18	27	5.46	25.65	8.34	27.06
	CZ 5	0°	8.67	22.67	13.3	23.91	13.1	23.91	8.67	22.67	13.3	23.91
		90°	8.95	30.12	13.87	32.77	13.54	32.72	8.95	30.12	13.87	32.77
		180°	8.25	22.39	13.41	22.6	13.07	22.44	8.25	22.39	13.41	22.6
		270°	9.04	29.78	14.04	29.9	13.75	29.76	9.04	29.78	14.04	29.9
	CZ 6	0°	15.53	17.81	22.03	21.34	21.79	21.28	17.77	21.4	17.52	21.36
		90°	16.53	28.68	22.65	30.35	22.35	29.1	18.45	24.78	18.2	25.55
		180°	15.59	18.06	21.97	18.1	21.71	18.08	17.88	21.19	17.62	19.92
		270°	16.62	21.7	22.68	25.95	22.46	25.92	18.48	18.4	18.23	18.42
	CZ 7	0°	20.49	14.69	27.15	16.89	26.79	16.93	22.56	14.43	22.16	14.43
		90°	21.02	29.86	27.43	32.98	27.1	35.3	22.86	22.16	22.53	22.15
		180°	19.84	15.74	26.77	16.97	26.42	16.94	22.21	14.55	21.97	14.49
		270°	20.07	21.19	26.55	25.49	26.31	25.45	22.25	18.32	21.91	17.22
Detached	CZ 2	0°	14.89	36.8	21.54	37.58	20.65	37.47	14.89	36.8	21.54	37.58
		90°	15.13	31.54	21.81	33.54	20.9	33.53	15.13	31.54	21.81	33.54
		180°	13.65	33.43	20.5	36.31	19.53	36.18	13.65	33.43	20.5	36.31
		270°	14.9	33.35	21.56	34.86	20.64	34.76	14.9	33.35	21.56	34.86
	CZ 5	0°	17.71	30.41	23.69	37.59	22.82	37.42	25.9	42.42	25.07	42.29
		90°	17.69	28.49	23.67	38.11	22.74	38.38	25.87	43.01	25.02	42.89
		180°	17.39	28.87	23.37	37.33	22.47	37.13	25.59	42.42	24.72	42.87
		270°	17.76	26.48	23.64	35.82	22.73	35.7	25.87	41.79	25.03	41.65
	CZ 6	0°	34.5	32.36	39.55	35.39	38.76	35.3	33.22	28.63	32.36	28.54
		90°	34.4	32.87	39.48	34.76	38.67	34.65	33.16	27.48	32.28	27.4
		180°	34.03	31.03	39.23	35.49	38.4	34.71	32.95	27.62	32.07	27.62
		270°	34.38	32.59	39.49	33.31	38.67	33.25	33.15	25.83	32.3	25.91
	CZ 7	0°	46.43	38	52.47	42.45	51.12	42.25	44.85	33.31	43.5	33.04
		90°	46.41	35.05	52.48	42.27	51.14	42.07	44.85	31.69	43.47	31.61
		180°	45.37	34.59	51.46	41.82	50.11	39.85	44.03	34.31	42.67	34.04

Archetype	Climate Zone	Orientation	Heating and Cooling Peak Load (kW)									
			Base Case NatHERS 6 Star (approximately 6ACH@50 Pa)[1]		Base Case (approximately 15ACH@50 Pa)[2]		Slab Edge Insulation[3]		Base Case (Glazing Calculator Compliant)[4]		Slab Edge Insulation (Glazing Calculator Compliant)[5]	
			Peak Heating (kW)	Peak Cooling (kW)	Peak Heating (kW)	Peak Cooling (kW)	Peak Heating (kW)	Peak Cooling (kW)	Peak Heating (kW)	Peak Cooling (kW)	Peak Heating (kW)	Peak Cooling (kW)
		270°	46.2	34.87	52.23	41.69	50.88	41.43	44.66	31.16	43.28	31.37

1 Baseline 6 Star NatHERS model includes the current practise WWR (i.e. WWRmin+10%), TAG reviews and the default infiltration (approximately 6 ACH@50Pa). The glazing type employed meet/exceeds 6 Star NatHERS in at least one orientation.

2 The baseline model has all the building elements as per 6 Star NatHERS Baseline except the infiltration, which is approximately 15 ACH@50Pa.

3 Slab edge insulation is included in the Base Case model.

4 Base Case glazing calculator compliant includes the glass type that complies with the glazing calculator at least in one orientation (infiltration rate is approximately 15 ACH@50Pa). Note that the Detached Archetype in Climate Zone 7 had no glass from the AccuRate Sustainability default library compliant with the glazing calculator

5 Slab edge insulation glazing calculator compliant refers to the baseline model that has the glass type selected to comply with the glazing calculator at least in one orientation as well as the slab edge insulation included in the model.

Appendix D - Economic Modelling Details for Multi-Dimensional Packages of Measures

D.1 Benefit Cost Analysis

The benefit cost ratio is calculated by dividing the lifecycle energy cost savings over the differential capital cost less network adjustments.

For example, from the table for conservative trajectory numbers Table 4-71, for Climate Zone 2, 180º , 0 year scenario, the BCR value would be:

$$\frac{2{,}342}{[(66{,}538-61{,}206)-1{,}240]} = \frac{2{,}342}{4{,}092} = 0.57$$

The lifecycle costs are calculated based on the economic modelling methodology described in Appendix A -

The tables in the sub sections below represent the following information:

- **Model –** refers to the modelling scenario for the particular archetype for the particular year.
- **Base Construction Cost –** refers to the assumed absolute construction cost of relevant works (not accounting for HVAC variation).
- **HVAC sizing capital cost adjustment -** refers to the change in capital cost of (assumed) split HVAC system, due to variation in peak demand, relative to base case.
- **Capital Cost (not inc. network adjustments) –** refers to base construction cost + HVAC adjustments.
- **Energy Use (kWh) –** refers to entire building yearly energy use.
- **Peak Demand (kW) –** refers to peak HVAC electricity demand for the year.
- **Network adjustments to capital cost –** refers to incremental variation in capital cost due to change in peak demand relative to the base case.
- **Lifecycle energy cost savings (today) –** refers to energy cost savings accrued over the lifetime of the technology (40 years) for measures implemented at 0 years (2019) into the future. Calculated in $ (dollars).
- **Lifecycle energy cost savings (5 yrs) -** refers to energy cost savings accrued over the lifetime of the technology (40 years) for measures implemented at 5 years (2024) into the future. Calculated in $ (dollars).
- **Lifecycle energy cost savings (10 yrs) -** refers to energy cost savings accrued over the lifetime of the technology (40 years) for measures implemented at 10 years (2029) into the future. Calculated in $ (dollars).
- **Lifecycle energy cost savings (15 yrs) -** refers to energy cost savings accrued over the lifetime of the technology (40 years) for measures implemented at 15 years (2034) into the future. Calculated in $ (dollars).
- **BC Ratio – Today -** refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost of measures implemented at 0 years (2019) into the future.
- **BC Ratio - 5 yrs -** refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost of measures implemented at 5 years (2024) into the future.
- **BC Ratio - 10 yrs** - refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost of measures implemented at 10 years (2029) into the future.
- **BC Ratio - 15 yrs -** refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost of measures implemented at 15 years (2034) into the future.
- **BC Ratio (without network adjustment) – Today -** refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost less network adjustments implemented at 0 years (2019) into the future.
- **BC Ratio (without network adjustment) – 5 yrs -** refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost less network adjustments implemented at 5 years (2024) into the future.
- **BC Ratio (without network adjustment) – 10 yrs -** refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost less network adjustments implemented at 10 years (2029) into the future.

- **BC Ratio (without network adjustment) – 15 yrs –** refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost less network adjustments implemented at 15 years (2034) into the future.

The area size used for the different archetypes is as follows:

Apartment area - 76.42 m^2
Attached area - 134.50 m^2
Detached house area - 189.39 m^2

The tables presented below contain the full breakdown of all the inputs which made up the benefit cost calculation. Results are given for both archetype orientations that were used in the multi- dimensional tuning, those with the highest and lowest yearly energy consumption. The construction costs are fixed and implemented by years for scenarios given in Table 2-8 to Table 2-13.

D.1.1 Conservative Trajectory

Presented in the table below are the benefit cost ratio results for the package of measures included in the multidimensional conservative energy efficiency trajectories/scenarios.

Table 4-71 Benefit Cost Ratios of different archetypes and orientation (conservative trajectory)

	Model	Base Construction Cost	HVAC sizing capital cost adjustment	Capital Cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
Attached CZ2 180°	**Base case**	$61,206		$61,206	1,284	2.97													
	0 yrs	$67,458	-$920	$66,538	817	1.68	-$1,240	2,342				0.57				0.44			
	5 yrs	$68,205	-$1,150	$67,055	713	1.42	-$1,477		3,315				0.76				0.57		
	10 yrs	$68,205	-$1,380	$66,825	662	1.25	-$1,628			3,982				1.00				0.71	
	15 yrs	$68,205	-$1,610	$66,595	651	1.16	-$1,699				4,406				1.19				0.82
Attached CZ2 270°	**Base case**	$64,608		$64,608	1,484	2.88													
	0 yrs	$68,040	-$460	$67,580	900	2.11	-$741	2,929				1.31				0.99			
	5 yrs	$70,637	-$690	$69,947	736	1.82	-$1,012		4,338				1.00				0.81		
	10 yrs	$70,637	-$920	$69,717	683	1.60	-$1,209			5,126				1.31				1.00	
	15 yrs	$73,462	-$1,380	$72,082	670	1.48	-$1,316				5,667				0.92				0.76
Attached CZ5 180°	**Base case**	$64,034		$64,034	1,165	2.80													
	0 yrs	$68,428	-$690	$67,738	761	1.70	-$1,059	2,028				0.77				0.55			
	5 yrs	$69,028	-$920	$68,108	671	1.49	-$1,256		2,869				1.02				0.70		
	10 yrs	$69,855	-$1,150	$68,705	623	1.30	-$1,421			3,468				1.07				0.74	
	15 yrs	$71,644	-$1,610	$70,034	608	1.21	-$1,492				3,876				0.86				0.65
Attached CZ5 270°	**Base case**	$64,034		$64,034	1,364	3.41													
	0 yrs	$68,428	-$920	$67,508	838	2.16	-$1,205	2,637				1.16				0.76			
	5 yrs	$69,028	-$1,150	$67,878	738	1.89	-$1,457		3,631				1.52				0.94		
	10 yrs	$69,855	-$1,610	$68,245	681	1.60	-$1,715			4,366				1.75				1.04	
	15 yrs	$71,644	-$1,840	$69,804	658	1.48	-$1,811				4,912				1.24				0.85

	Model	Base Construction Cost	HVAC sizing capital cost adjustment	Capital Cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
Attached CZ6 180°	Base case	$67,382		$67,382	1,982	2.69													
	0 yrs	$73,541	-$690	$72,851	1,031	1.75	-$907	4,765				1.04				0.87			
	5 yrs	$75,930	-$690	$75,240	860	1.65	-$1,000		6,505				0.95				0.83		
	10 yrs	$76,782	-$920	$75,862	793	1.45	-$1,179			7,606				1.04				0.90	
	15 yrs	$76,782	-$1,150	$75,632	769	1.34	-$1,271				8,443				1.21				1.02
Attached CZ6 270°	Base case	$67,382		$67,382	2,224	3.05													
	0 yrs	$74,341	-$920	$73,421	1,153	1.71	-$1,291	5,372				1.13				0.89			
	5 yrs	$76,730	-$1,150	$75,580	963	1.50	-$1,478		7,316				1.09				0.89		
	10 yrs	$77,582	-$1,380	$76,202	884	1.32	-$1,636			8,575				1.19				0.97	
	15 yrs	$79,432	-$1,610	$77,822	839	1.34	-$1,597				9,641				1.09				0.92
Attached CZ7 180°	Base case	$67,382		$67,382	2,322	3.14													
	0 yrs	$73,122	-$1,150	$71,972	1,205	1.57	-$1,506	5,601				1.82				1.22			
	5 yrs	$76,293	-$1,380	$74,913	1,015	1.31	-$1,741		7,584				1.31				1.01		
	10 yrs	$75,708	-$1,610	$74,098	930	1.15	-$1,877			8,908				1.84				1.33	
	15 yrs	$80,949	-$2,070	$78,879	878	1.00	-$2,000				10,053				1.06				0.87
Attached CZ7 270°	Base case	$67,382		$67,382	2,618	3.10													
	0 yrs	$74,972	-$1,150	$73,822	1,339	1.57	-$1,480	6,412				1.29				1.00			
	5 yrs	$78,143	-$1,380	$76,763	1,126	1.30	-$1,716		8,652				1.13				0.92		
	10 yrs	$80,383	-$1,610	$78,773	1,028	1.16	-$1,836			10,172				1.06				0.89	
	15 yrs	$82,799	-$2,070	$80,729	981	1.00	-$1,968				11,394				1.00				0.85
Detached CZ2 0°	Base case	$81,492		$81,492	2,396	4.54													

	Model	Base Construction Cost	HVAC sizing capital cost adjustment	Capital Cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	0 yrs	$86,590	-$920	$85,670	1,543	3.19	-$1,297	4,278				1.49				1.02			
	5 yrs	$89,907	-$1,150	$88,757	1,358	2.78	-$1,673		6,021				1.08				0.83		
	10 yrs	$89,907	-$1,610	$88,297	1,239	2.73	-$1,709			7,398				1.45				1.09	
	15 yrs	$89,907	-$1,840	$88,067	1,216	2.50	-$1,907				8,211				1.76				1.25
Detached CZ2 180°	Base case	$80,786		$80,786	2,354	3.80													
	0 yrs	$87,640	-$690	$86,950	1,593	2.82	-$949	3,817				0.73				0.62			
	5 yrs	$91,207	-$920	$90,287	1,402	2.46	-$1,283		5,524				0.67				0.58		
	10 yrs	$91,207	-$1,380	$89,827	1,286	2.24	-$1,473			6,832				0.90				0.76	
	15 yrs	$91,207	-$1,610	$89,597	1,258	2.07	-$1,627				7,629				1.06				0.87
Detached CZ5 90°	Base case	$82,707		$82,707	2,317	4.80													
	0 yrs	$90,328	-$1,610	$88,718	1,556	2.45	-$2,258	3,816				1.02				0.63			
	5 yrs	$91,931	-$1,840	$90,091	1,288	2.31	-$2,376		5,966				1.19				0.81		
	10 yrs	$95,199	-$2,300	$92,899	1,171	2.06	-$2,586			7,328				0.96				0.72	
	15 yrs	$95,199	-$2,760	$92,439	1,155	1.90	-$2,712				8,087				1.15				0.83
Detached CZ5 180°	Base case	$85,312		$85,312	2,348	4.54													
	0 yrs	$90,328	-$1,380	$88,948	1,567	2.57	-$1,900	3,913				2.25				1.08			
	5 yrs	$91,931	-$1,610	$90,321	1,288	2.31	-$2,133		6,144				2.14				1.23		
	10 yrs	$93,924	-$2,530	$91,394	1,171	1.70	-$2,686			7,525				2.22				1.24	
	15 yrs	$93,924	-$2,990	$90,934	1,155	1.58	-$2,776				8,301				2.92				1.48
Detached CZ6 90°	Base case	$85,164		$85,164	3,898	4.49													
	0 yrs	$97,866	-$1,380	$96,486	2,154	2.61	-$1,818	8,744				0.92				0.77			

	Model	Base Construction Cost	HVAC sizing capital cost adjustment	Capital Cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	5 yrs	$98,466	-$1,610	$96,856	1,891	2.27	-$2,118		11,642				1.22				1.00		
	10 yrs	$103,666	-$2,070	$101,596	1,708	2.00	-$2,357			14,005				0.99				0.85	
	15 yrs	$103,666	-$2,530	$101,136	1,638	1.85	-$2,479				15,735				1.17				0.99
Detached CZ6 270°	Base case	$85,164		$85,164	3,977	4.50													
	0 yrs	$96,816	-$1,380	$95,436	2,187	2.60	-$1,822	8,977				1.06				0.87			
	5 yrs	$97,416	-$1,610	$95,806	1,919	2.27	-$2,122		11,936				1.40				1.12		
	10 yrs	$102,616	-$2,070	$100,546	1,731	2.00	-$2,361			14,371				1.10				0.93	
	15 yrs	$102,616	-$2,530	$100,086	1,657	1.84	-$2,483				16,149				1.30				1.08
Detached CZ7 90°	Base case	$85,164		$85,164	4,822	5.70													
	0 yrs	$99,750	-$1,840	$97,910	2,504	3.26	-$2,354	11,624				1.12				0.91			
	5 yrs	$104,244	-$2,300	$101,944	1,980	2.55	-$3,008		16,483				1.20				0.98		
	10 yrs	$108,202	-$2,990	$105,212	1,774	2.22	-$3,287			19,499				1.16				0.97	
	15 yrs	$108,202	-$3,680	$104,522	1,696	2.05	-$3,422				21,761				1.37				1.12
Detached CZ7 270°	Base case	$85,164		$85,164	4,914	5.68													
	0 yrs	$98,642	-$1,840	$96,802	2,421	3.14	-$2,447	12,502				1.36				1.07			
	5 yrs	$100,664	-$2,300	$98,364	1,993	2.55	-$2,987		16,946				1.66				1.28		
	10 yrs	$103,389	-$2,990	$100,399	1,803	2.22	-$3,267			19,899				1.66				1.31	
	15 yrs	$104,246	-$3,450	$100,796	1,723	2.04	-$3,402				22,217				1.82				1.42
Apartment CZ2 180°	Base case	$50,159		$50,159	1,214	1.95													
	0 yrs	$53,187	-$690	$52,497	795	1.04	-$885	2,104				1.45				0.90			
	5 yrs	$53,787	-$690	$53,097	701	0.90	-$1,002		2,979				1.54				1.01		

	Model	Base Construction Cost	HVAC sizing capital cost adjustment	Capital Cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	10 yrs	$56,015	-$920	$55,095	658	0.80	-$1,096			3,557				0.93				0.72	
	15 yrs	$56,015	-$1,150	$54,865	646	0.67	-$1,203				3,956				1.13				0.84
Apartment CZ2 90°	**Base case**	$49,611		$49,611	1,207	2.25													
	0 yrs	$53,137	-$920	$52,217	792	0.92	-$1,281	2,085				1.57				0.80			
	5 yrs	$53,737	-$920	$52,817	698	0.80	-$1,381		2,955				1.62				0.92		
	10 yrs	$55,628	-$1,380	$54,248	656	0.71	-$1,460			3,528				1.11				0.76	
	15 yrs	$55,628	-$1,380	$54,248	644	0.70	-$1,454				3,924				1.23				0.85
Apartment CZ5 270°	**Base case**	$52,036		$52,036	1,204	2.09													
	0 yrs	$55,191	-$460	$54,731	765	1.26	-$793	2,200				1.16				0.82			
	5 yrs	$56,591	-$690	$55,901	675	1.10	-$939		3,067				1.05				0.79		
	10 yrs	$56,591	-$920	$55,671	636	0.97	-$1,055			3,636				1.41				1.00	
	15 yrs	$57,791	-$1,380	$56,411	621	0.72	-$1,281				4,061				1.31				0.93
Apartment CZ5 90°	**Base case**	$51,339		$51,339	1,181	2.02													
	0 yrs	$55,816	-$690	$55,126	761	0.97	-$1,009	2,109				0.76				0.56			
	5 yrs	$57,216	-$690	$56,526	671	0.85	-$1,117		2,959				0.73				0.57		
	10 yrs	$57,216	-$920	$56,296	632	0.74	-$1,204			3,513				0.94				0.71	
	15 yrs	$57,791	-$1,150	$56,641	617	0.72	-$1,210				3,928				0.96				0.74
Apartment CZ6 90°	**Base case**	$49,087		$49,087	2,007	2.36													
	0 yrs	$54,378	-$690	$53,688	987	1.29	-$1,031	5,112				1.43				1.11			
	5 yrs	$56,355	-$920	$55,435	849	0.99	-$1,313		6,712				1.33				1.06		
	10 yrs	$57,165	-$1,150	$56,015	783	0.85	-$1,425			7,826				1.42				1.13	

	Model	Base Construction Cost	HVAC sizing capital cost adjustment	Capital Cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	15 yrs	$57,165	-$1,380	$55,785	759	0.79	-$1,475				8,683				1.66				1.30
Apartment CZ6 270°	**Base case**	$53,482		$53,482	2,002	2.33													
	0 yrs	$54,328	-$690	$53,638	1,086	1.37	-$923	4,591				negative cost				29.53			
	5 yrs	$56,305	-$690	$55,615	930	1.18	-$1,094		6,216				5.98				2.91		
	10 yrs	$57,115	-$1,150	$55,965	858	0.86	-$1,390			7,317				6.69				2.95	
	15 yrs	$57,115	-$1,380	$55,735	826	0.79	-$1,440				8,182				10.06				3.63
Apartment CZ7 90°	**Base case**	$48,682		$48,682	2,256	2.79													
	0 yrs	$58,298	-$1,380	$56,918	957	0.88	-$1,840	6,509				1.02				0.79			
	5 yrs	$59,709	-$1,380	$58,329	843	0.77	-$1,929		8,196				1.06				0.85		
	10 yrs	$60,421	-$1,840	$58,581	776	0.66	-$2,009			9,466				1.20				0.96	
	15 yrs	$60,421	-$2,070	$58,351	753	0.61	-$2,035				10,462				1.37				1.08
Apartment CZ7 270°	**Base case**	$50,612		$50,612	2,347	2.76													
	0 yrs	$58,298	-$1,380	$56,918	1,153	0.94	-$1,760	5,989				1.32				0.95			
	5 yrs	$59,709	-$1,380	$58,329	1,013	0.82	-$1,857		7,739				1.32				1.00		
	10 yrs	$60,421	-$1,840	$58,581	924	0.71	-$1,945			9,100				1.51				1.14	
	15 yrs	$60,421	-$2,070	$58,351	886	0.65	-$1,976				10,170				1.76				1.31

D.1.2 Accelerated Deployment Trajectory

Presented in the table below are the benefit cost ratio results for the package of measures included in the multidimensional Accelerated Deployment energy efficiency trajectories/scenarios.

Table 4-72 Benefit Cost Ratios of different archetypes and orientation (accelerated deployment trajectory)

		Base Construction Cost	HVAC sizing capital cost adjustment	Capital Cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
Attached CZ2 180°	**Base case**	$61,206		$61,206	1,284	2.97													
	0 yrs	$89,841	-$1,610	$88,231	689	1.54	-$1,379	2,988				0.12				0.11			
	5 yrs	$90,441	-$1,150	$89,291	640	1.36	-$1,538		3,736				0.14				0.13		
	10 yrs	$90,441	-$1,380	$89,061	599	1.20	-$1,671			4,385				0.17				0.16	
	15 yrs	$90,441	-$1,840	$88,601	592	1.13	-$1,728				4,819				0.19				0.18
Attached CZ2 270°	**Base case**	$64,608		$64,608	1,484	2.88													
	0 yrs	$95,099	-$1,380	$93,719	703	1.59	-$1,246	3,919				0.14				0.13			
	5 yrs	$95,699	-$1,150	$94,549	653	1.40	-$1,412		4,822				0.17				0.16		
	10 yrs	$95,699	-$1,380	$94,319	610	1.24	-$1,550			5,591				0.20				0.19	
	15 yrs	$95,699	-$1,610	$94,089	602	1.16	-$1,611				6,139				0.22				0.21
Attached CZ5 180°	**Base case**	$64,034		$64,034	1,165	2.80													
	0 yrs	$90,885	-$1,610	$89,275	641	1.22	-$1,529	2,629				0.11				0.10			
	5 yrs	$91,485	-$1,150	$90,335	598	1.07	-$1,651		3,290				0.13				0.13		

		Base Construction Cost	HVAC sizing capital cost adjustment	Capital Cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	10 yrs	$91,485	-$1,610	$89,875	561	0.95	-$1,756			3,866				0.16				0.15	
	15 yrs	$91,485	-$1,840	$89,645	558	0.89	-$1,789				4,230				0.18				0.17
Attached CZ5 270°	**Base case**	$64,034		$64,034	1,364	3.41													
	0 yrs	$93,965	-$2,300	$91,665	672	1.30	-$2,039	3,469				0.14				0.13			
	5 yrs	$94,565	-$1,610	$92,955	626	1.14	-$2,166		4,282				0.16				0.15		
	10 yrs	$94,565	-$2,070	$92,495	586	1.01	-$2,272			4,978				0.19				0.17	
	15 yrs	$94,565	-$2,300	$92,265	580	0.95	-$2,306				5,456				0.21				0.19
Attached CZ6 180°	**Base case**	$67,382		$67,382	1,982	2.69													
	0 yrs	$93,072	-$1,610	$91,462	881	1.19	-$1,452	5,516				0.24				0.23			
	5 yrs	$93,672	-$1,150	$92,522	811	1.05	-$1,572		6,788				0.29				0.27		
	10 yrs	$93,672	-$1,380	$92,292	752	0.92	-$1,675			7,863				0.34				0.32	
	15 yrs	$93,672	-$1,840	$91,832	731	0.87	-$1,707				8,703				0.38				0.36
Attached CZ6 270°	**Base case**	$67,382		$67,382	2,224	3.05													
	0 yrs	$96,098	-$1,840	$94,258	979	1.24	-$1,745	6,245				0.25				0.23			

		Base Construction Cost	HVAC sizing capital cost adjustment	Capital Cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	5 yrs	$96,698	-$1,380	$95,318	898	1.09	-$1,868		7,696				0.30				0.28		
	10 yrs	$96,698	-$1,840	$94,858	830	0.96	-$1,971			8,920				0.35				0.32	
	15 yrs	$96,698	-$2,070	$94,628	802	0.91	-$2,005				9,903				0.39				0.36
Attached CZ7 180°	Base case	$67,382		$67,382	2,322	3.14													
	0 yrs	$92,492	-$1,840	$90,652	1,063	1.34	-$1,727	6,315				0.29				0.27			
	5 yrs	$93,092	-$1,380	$91,712	972	1.18	-$1,862		7,832				0.35				0.32		
	10 yrs	$93,092	-$1,840	$91,252	897	1.05	-$1,975			9,119				0.42				0.38	
	15 yrs	$93,092	-$2,070	$91,022	862	0.98	-$2,015				10,163				0.47				0.43
Attached CZ7 270°	Base case	$67,382		$67,382	2,618	3.10													
	0 yrs	$94,923	-$1,840	$93,083	1,181	1.35	-$1,692	7,204				0.30				0.28			
	5 yrs	$95,523	-$1,380	$94,143	1,077	1.19	-$1,827		8,938				0.36				0.33		
	10 yrs	$95,523	-$1,840	$93,683	991	1.05	-$1,940			10,407				0.43				0.40	
	15 yrs	$95,523	-$2,070	$93,453	948	0.99	-$1,981				11,625				0.48				0.45
Detached CZ2 0°	Base case	$81,492		$81,492	2,396	4.54													

		Base Construction Cost	HVAC sizing capital cost adjustment	Capital Cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	0 yrs	$136,750	-$2,300	$134,450	1,235	2.47	-$1,992	5,823				0.11				0.11			
	5 yrs	$137,350	-$1,840	$135,510	1,146	2.18	-$2,248		7,253				0.14				0.13		
	10 yrs	$137,350	-$2,300	$135,050	1,074	1.94	-$2,459			8,456				0.17				0.16	
	15 yrs	$137,350	-$2,760	$134,590	1,063	1.80	-$2,561				9,279				0.18				0.17
Detached CZ2 180°	**Base case**	$80,786		$80,786	2,354	3.80													
	0 yrs	$137,000	-$1,840	$135,160	1,275	2.03	-$1,713	5,412				0.10				0.10			
	5 yrs	$137,600	-$1,380	$136,220	1,181	1.79	-$1,923		6,804				0.13				0.12		
	10 yrs	$137,600	-$1,840	$135,760	1,106	1.58	-$2,100			7,984				0.15				0.15	
	15 yrs	$137,600	-$2,300	$135,300	1,092	1.48	-$2,175				8,786				0.17				0.16
Detached CZ5 90°	**Base case**	$82,707		$82,707	2,317	4.80													
	0 yrs	$141,439	-$3,450	$137,989	1,201	1.57	-$3,105	5,594				0.11				0.10			
	5 yrs	$142,582	-$2,530	$140,052	1,116	1.39	-$3,253		6,965				0.13				0.12		
	10 yrs	$142,582	-$2,990	$139,592	1,047	1.22	-$3,378			8,119				0.15				0.14	
	15 yrs	$142,582	-$3,680	$138,902	1,039	1.15	-$3,410				8,896				0.17				0.16

		Base Construction Cost	HVAC sizing capital cost adjustment	Capital Cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
Detached CZ5 180°	**Base case**	$85,312		$85,312	2,348	4.54													
	0 yrs	$141,167	-$3,220	$137,947	1,209	1.50	-$2,927	5,710				0.11				0.11			
	5 yrs	$142,309	-$2,300	$140,009	1,122	1.33	-$3,069		7,105				0.14				0.13		
	10 yrs	$142,309	-$2,990	$139,319	1,053	1.17	-$3,190			8,278				0.16				0.15	
	15 yrs	$142,309	-$3,450	$138,859	1,044	1.10	-$3,218				9,072				0.18				0.17
Detached CZ6 90°	**Base case**	$85,164		$85,164	3,898	4.49													
	0 yrs	$154,757	-$2,990	$151,767	1,768	1.76	-$2,631	10,682				0.17				0.16			
	5 yrs	$155,357	-$2,070	$153,287	1,618	1.56	-$2,804		13,225				0.20				0.19		
	10 yrs	$155,357	-$2,760	$152,597	1,498	1.37	-$2,949			15,350				0.24				0.23	
	15 yrs	$155,357	-$3,220	$152,137	1,448	1.29	-$2,998				17,055				0.27				0.25
Detached CZ6 270°	**Base case**	$85,164		$85,164	3,977	4.50													
	0 yrs	$153,707	-$2,990	$150,717	1,783	1.77	-$2,631	11,004				0.17				0.17			
	5 yrs	$154,307	-$2,070	$152,237	1,631	1.56	-$2,804		13,608				0.21				0.20		
	10 yrs	$154,307	-$2,760	$151,547	1,510	1.38	-$2,950			15,781				0.25				0.24	

		Base Construction Cost	HVAC sizing capital cost adjustment	Capital Cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	15 yrs	$154,307	-$3,220	$151,087	1,459	1.29	-$2,999				17,532				0.28				0.27
Detached CZ7 90°	Base case	$85,164		$85,164	4,822	5.70													
	0 yrs	$140,637	-$3,680	$136,957	1,839	2.24	-$3,336	14,960				0.31				0.29			
	5 yrs	$141,237	-$2,760	$138,477	1,681	1.98	-$3,554		18,221				0.37				0.34		
	10 yrs	$141,237	-$3,450	$137,787	1,555	1.75	-$3,733			20,899				0.43				0.40	
	15 yrs	$141,237	-$3,910	$137,327	1,499	1.63	-$3,807				23,131				0.48				0.44
Detached CZ7 270°	Base case	$85,164		$85,164	4,914	5.68													
	0 yrs	$138,729	-$3,680	$135,049	1,867	2.24	-$3,311	15,279				0.33				0.31			
	5 yrs	$139,329	-$2,760	$136,569	1,706	1.98	-$3,529		18,609				0.39				0.36		
	10 yrs	$139,329	-$3,450	$135,879	1,577	1.75	-$3,709			21,344				0.45				0.42	
	15 yrs	$140,187	-$3,910	$136,277	1,520	1.64	-$3,783				23,629				0.50				0.46
Apartment CZ2 180°	Base case	$50,159		$50,159	1,214	1.95													
	0 yrs	$70,742	-$1,150	$69,592	687	0.82	-$1,093	2,645				0.14				0.14			
	5 yrs	$71,342	-$920	$70,422	646	0.72	-$1,174		3,297				0.17				0.16		

		Base Construction Cost	HVAC sizing capital cost adjustment	Capital Cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	10 yrs	$71,342	-$1,150	$70,192	598	0.64	-$1,241			3,941				0.21				0.20	
	15 yrs	$71,342	-$1,150	$70,192	590	0.60	-$1,269				4,344				0.23				0.22
Apartment CZ2 90°	Base case	$49,611		$49,611	1,207	2.25													
	0 yrs	$70,843	-$1,380	$69,463	680	0.83	-$1,369	2,642				0.14				0.13			
	5 yrs	$71,443	-$1,150	$70,293	640	0.73	-$1,449		3,290				0.17				0.16		
	10 yrs	$71,443	-$1,380	$70,063	593	0.65	-$1,514			3,929				0.21				0.19	
	15 yrs	$71,443	-$1,610	$69,833	586	0.61	-$1,540				4,329				0.23				0.21
Apartment CZ5 270°	Base case	$52,036		$52,036	1,204	2.09													
	0 yrs	$67,069	-$1,150	$65,919	671	0.87	-$1,172	2,675				0.21				0.19			
	5 yrs	$67,669	-$920	$66,749	632	0.77	-$1,258		3,321				0.25				0.23		
	10 yrs	$67,669	-$1,150	$66,519	585	0.68	-$1,328			3,958				0.30				0.27	
	15 yrs	$67,669	-$1,380	$66,289	579	0.63	-$1,358				4,355				0.34				0.31
Apartment CZ5 90°	Base case	$51,339		$51,339	1,181	2.02													
	0 yrs	$67,744	-$1,150	$66,594	647	0.84	-$1,130	2,677				0.19				0.18			
	5 yrs	$68,344	-$920	$67,424	611	0.75	-$1,214		3,308				0.22				0.21		

		Base Construction Cost	HVAC sizing capital cost adjustment	Capital Cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	10 yrs	$68,344	-$1,150	$67,194	567	0.66	-$1,282			3,930				0.27				0.25	
	15 yrs	$68,344	-$1,380	$66,964	562	0.62	-$1,311				4,313				0.30				0.28
Apartment CZ6 90°	Base case	$49,087		$49,087	2,007	2.36													
	0 yrs	$70,710	-$1,610	$69,100	767	0.80	-$1,502	6,215				0.34				0.31			
	5 yrs	$71,310	-$1,150	$70,160	717	0.71	-$1,577		7,480				0.38				0.35		
	10 yrs	$71,310	-$1,380	$69,930	662	0.63	-$1,639			8,600				0.45				0.41	
	15 yrs	$71,310	-$1,610	$69,700	648	0.59	-$1,661				9,456				0.50				0.46
Apartment CZ6 270°	Base case	$53,482		$53,482	2,002	2.33													
	0 yrs	$70,035	-$1,610	$68,425	882	0.82	-$1,450	5,612				0.42				0.38			
	5 yrs	$70,635	-$1,150	$69,485	819	0.72	-$1,528		6,859				0.47				0.43		
	10 yrs	$70,635	-$1,380	$69,255	754	0.64	-$1,592			7,982				0.56				0.51	
	15 yrs	$70,635	-$1,610	$69,025	731	0.60	-$1,616				8,842				0.63				0.57
Apartment CZ7 90°	Base case	$48,682		$48,682	2,256	2.79													
	0 yrs	$71,247	-$2,070	$69,177	830	0.79	-$1,929	7,147				0.38				0.35			

		Base Construction Cost	HVAC sizing capital cost adjustment	Capital Cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	5 yrs	$71,847	-$1,610	$70,237	773	0.69	-$1,999		8,600				0.44				0.40		
	10 yrs	$71,847	-$1,840	$70,007	712	0.61	-$2,055			9,871				0.51				0.46	
	15 yrs	$71,847	-$2,070	$69,777	694	0.57	-$2,073				10,872				0.57				0.52
Apartment CZ7 270°	**Base case**	$50,612		$50,612	2,347	2.76													
	0 yrs	$70,572	-$2,070	$68,502	995	0.83	-$1,860	6,778				0.42				0.38			
	5 yrs	$71,172	-$1,380	$69,792	919	0.74	-$1,935		8,282				0.48				0.43		
	10 yrs	$71,172	-$1,840	$69,332	844	0.65	-$1,996			9,616				0.57				0.51	
	15 yrs	$71,172	-$2,070	$69,102	813	0.61	-$2,017				10,679				0.65				0.58

Appendix E - Economic Modelling Details for Single-dimensional Measures

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. Capital costs refer to the actual costs of physical works, of which the incremental cost over the base case is used for the econmic analysis. Network adjustments are based on an overall network (rather than local dwelling) impact on required network sizing based on the peak demand to be serviced. HVAC adjustment costs are derived from the reduction in HVAC unit capacity required to service the peak cooling or heating load (whichever is higher).

E.1 Benefit Cost Analysis

The benefit cost ratio is calculated by dividing the lifecycle energy cost savings over the differential capital cost less network adjustments.

For example, from the table for conservative trajectory numbers Table 4-71, for Climate Zone 2, 180°, 0 year scenario, the BCR value would be:

$$\frac{2{,}342}{[(66{,}538-61{,}206)-1{,}240]} = \frac{2{,}342}{4{,}092} = 0.57$$

The lifecycle costs are calculated based on the economic modelling methodology described in Appendix A -

The tables in the sub sections below represent the following information:

- **Model –** refers to the modelling scenario for the particular archetype for the particular year.
- **Base Construction Cost –** refers to the assumed absolute construction cost of relevant works (not accounting for HVAC variation).
- **HVAC sizing capital cost adjustment -** refers to the change in capital cost of (assumed) split HVAC system, due to variation in peak demand, relative to base case.
- **Capital Cost (not inc. network adjustments) –** refers to base construction cost + HVAC adjustments.
- **Energy Use (kWh) –** refers to entire building yearly energy use.
- **Peak Demand (kW) –** refers to peak HVAC electricity demand for the year.
- **Network adjustments to capital cost –** refers to incremental variation in capital cost due to change in peak demand relative to the base case.
- **Lifecycle energy cost savings (today) –** refers to energy cost savings accrued over the lifetime of the technology (40 years) for measures implemented at 0 years (2019) into the future. Calculated in $ (dollars).
- **Lifecycle energy cost savings (5 yrs) -** refers to energy cost savings accrued over the lifetime of the technology (40 years)for measures implemented at 5 years (2024) into the future. Calculated in $ (dollars).
- **Lifecycle energy cost savings (10 yrs) -** refers to energy cost savings accrued over the lifetime of the technology (40 years) for measures implemented at 10 years (2029) into the future. Calculated in $ (dollars).
- **Lifecycle energy cost savings (15 yrs) -** refers to energy cost savings accrued over the lifetime of the technology (40 years) for measures implemented at 15 years (2034) into the future. Calculated in $ (dollars).
- **BC Ratio – Today -** refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost of measures implemented at 0 years (2019) into the future.
- **BC Ratio - 5 yrs -** refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost of measures implemented at 5 years (2024) into the future.
- **BC Ratio - 10 yrs** - refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost of measures implemented at 10 years (2029) into the future.
- **BC Ratio - 15 yrs -** refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost of measures implemented at 15 years (2034) into the future.
- **BC Ratio (without network adjustment) – Today -** refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost less network adjustments implemented at 0 years (2019) into the future.

- **BC Ratio (without network adjustment) – 5 yrs -** refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost less network adjustments implemented at 5 years (2024) into the future.
- **BC Ratio (without network adjustment) – 10 yrs -** refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost less network adjustments implemented at 10 years (2029) into the future.
- **BC Ratio (without network adjustment) – 15 yrs –** refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost less network adjustments implemented at 15 years (2034) into the future.

The area size used for the different archetypes is as follows:

Apartment area - 76.42 m^2
Attached area - 134.50 m^2
Detached house area - 189.39 m^2

The tables presented below contain the full breakdown of all the inputs which made up the benefit cost calculation. Results are given for both archetype orientations that were used in the multi- dimensional tuning, those with the highest and lowest yearly energy consumption. The construction costs are fixed and implemented by years for scenarios given in Table 2-8 to Table 2-13.

E.2 Infiltration

E.2.1 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.

E.2.2 Benefit Cost Analysis

		Performance value	Base Construction Cost	HVAC sizing capital cost adjustment	Capital cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 yrs	BC Ratio - 15 yrs	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
Attached CZ2	Base case	14.5 ACH at 50	$ -		0.00	554.6	2.8													
	Level 1	5.3 ACH at 50 Pa	$ 800	$ -	800.00	435.6	2.7	-101.88	365.47	427.23	482.95	538.21	0.52	0.86	1.61	1.79	0.46	0.71	1.21	1.35
Attached CZ5	Base case	14.5 ACH at 50	$ -		0.00	401.2	2.7													
	Level 1	5.3 ACH at 50 Pa	$ 800	$ -	800.00	295.1	2.7	-12.71	325.56	380.57	430.21	479.43	0.41	0.65	1.11	1.24	0.41	0.63	1.08	1.20
Attached CZ6	Base case	14.5 ACH at 50	$ -		0.00	1351.8	2.7													
	Level 1	5.3 ACH at 50 Pa	$ 800	$ -	800.00	910.1	2.5	-144.52	1356.23	1585.42	1792.19	1997.25	2.07	3.48	6.94	7.69	1.70	2.64	4.48	4.99
Attached CZ7	Base case	14.5 ACH at 50	$ -		0.00	1346.2	2.1													
	Level 1	5.3 ACH at 50 Pa	$ 800	-$ 230	570.00	828.6	1.7	-333.19	1589.44	1858.04	2100.37	2340.69	6.71	19.70	negative cost	negative cost	2.79	4.35	7.37	8.21
Detached CZ2	Base case	14.5 ACH at 50 Pa	$ -		0.00	1164.1	4.0													
	Level 1	5.8 ACH at 50 Pa	$ 800	-$ 230	570.00	937.9	3.5	-444.48	694.55	811.92	917.81	1022.82	5.53	negative cost	negative cost	negative cost	1.22	1.90	3.22	3.59
Detached CZ5	Base case	14.5 ACH at 50 Pa	$ -		0.00	919.7	3.6													
	Level 1	5.8 ACH at 50 Pa	$ 800	-$ 230	570.00	730.4	3.2	-363.52	581.48	679.74	768.40	856.32	2.82	10.62	negative cost	negative cost	1.02	1.59	2.70	3.00
Detached CZ6	Base case	14.5 ACH at 50 Pa	$ -		0.00	2587.6	2.3													
	Level 1	5.8 ACH at 50 Pa	$ 800	$ -	800.00	2015.9	2.2	-107.05	1755.62	2052.30	2319.97	2585.42	2.53	4.16	7.86	8.74	2.19	3.42	5.80	6.46
Detached CZ7	Base case	14.5 ACH at 50 Pa	$ -		0.00	2668.5	4.1													
	Level 1	5.8 ACH at 50 Pa	$ 800	-$ 230	570.00	2085.1	3.7	-427.31	1791.66	2094.42	2367.58	2638.48	12.56	10813.41	negative cost	negative cost	3.14	4.90	8.31	9.26
Apartment CZ2	Base case	14.5 ACH at 50 Pa	$ -		0.00	342.5	3.5													
	Level 1	7 ACH at 50 Pa	$ 800	$ -	800.00	286.3	3.4	-98.13	172.60	201.76	228.08	254.17	0.25	0.40	0.75	0.83	0.22	0.34	0.57	0.64
Apartment CZ5	Base case	14.5 ACH at 50 Pa	$ -		0.00	310.8	2.2													
	Level 1	7 ACH at 50 Pa	$ 800	$ -	800.00	234.3	2.3	8.92	235.12	274.85	310.70	346.25	0.29	0.45	0.76	0.85	0.29	0.46	0.78	0.87
Apartment CZ6	Base case	14.5 ACH at 50 Pa	$ -		0.00	967.8	2.1													
	Level 1	7 ACH at 50 Pa	$ 800	$ -	800.00	632.8	2.1	-20.07	1028.85	1202.72	1359.58	1515.14	1.32	2.07	3.57	3.98	1.29	2.00	3.40	3.79

		Performance value	Base Construction Cost	HVAC sizing capital cost adjustment	Capital cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 yrs	BC Ratio - 15 yrs	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
Apartment CZ7	Base case	14.5 ACH at 50 Pa	$ -		0.00	1510.5	2.5													
	Level 1	7 ACH at 50 Pa	$ 800	$ -	800.00	1133.6	2.4	-90.69	1157.52	1353.13	1529.61	1704.63	1.63	2.66	4.92	5.47	1.45	2.26	3.82	4.26

E.3 Wall Insulation

E.3.1 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

E.3.2 Benefit Cost Analysis

		Performance value (e.g. R value)	Base Construction Cost	HVAC sizing capital cost adjustment	Capital Cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
Attached CZ2	Base case	R2.8	$ 1,006.97		$ 1,006.97	554.6	2.8													
	Level 1	R3.5	$ 1,660.17	$ -	$ 1,660.17	550.2	2.8	-$ 13.38	$ 21.72	$ 25.13	$ 27.71	$ 30.16	0.03	0.04	0.04	0.05	0.03	0.04	0.04	0.05
	Level 2	R4.2	$ 2,228.17	$ -	$ 2,228.17	548.2	2.8	-$ 18.51	$ 31.95	$ 36.96	$ 40.75	$ 44.35	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.04
	Level 3	R4.9	$ 2,796.17	$ -	$ 2,796.17	546.4	2.8	-$ 21.19	$ 40.89	$ 47.30	$ 52.16	$ 56.77	0.02	0.03	0.03	0.03	0.02	0.03	0.03	0.03
	Level 4	R5.8	$ 3,648.17	$ -	$ 3,648.17	545.7	2.7	-$ 27.88	$ 44.72	$ 51.74	$ 57.05	$ 62.09	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Attached CZ5	Base case	R2.8	$ 1,006.97		$ 1,006.97	401.2	2.7													
	Level 1	R3.5	$ 1,660.17	$ -	$ 1,660.17	396.3	2.7	-$ 13.16	$ 24.28	$ 28.09	$ 30.97	$ 33.71	0.04	0.04	0.05	0.05	0.04	0.04	0.05	0.05
	Level 2	R4.2	$ 2,228.17	$ -	$ 2,228.17	392.7	2.7	-$ 6.24	$ 42.17	$ 48.78	$ 53.79	$ 58.54	0.03	0.04	0.04	0.05	0.03	0.04	0.04	0.05
	Level 3	R4.9	$ 2,796.17	$ -	$ 2,796.17	390.4	2.8	$ 20.29	$ 53.67	$ 62.09	$ 68.46	$ 74.51	0.03	0.03	0.04	0.04	0.03	0.03	0.04	0.04
	Level 4	R5.8	$ 3,648.17	$ -	$ 3,648.17	387.4	2.8	$ 21.63	$ 69.00	$ 79.83	$ 88.03	$ 95.80	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.04
Attached CZ6	Base case	R2.8	$ 1,006.97		$ 1,006.97	1351.8	2.7													
	Level 1	R3.5	$ 1,660.17	$ -	$ 1,660.17	1333.7	2.7	-$ 8.25	$ 90.72	$ 104.96	$ 115.74	$ 125.96	0.14	0.16	0.18	0.20	0.14	0.16	0.18	0.19
	Level 2	R4.2	$ 2,228.17	$ -	$ 2,228.17	1321.2	2.5	-$ 138.94	$ 153.34	$ 177.39	$ 195.61	$ 212.88	0.14	0.16	0.18	0.20	0.13	0.15	0.16	0.17
	Level 3	R4.9	$ 2,796.17	$ -	$ 2,796.17	1313.6	2.7	-$ 18.51	$ 191.67	$ 221.74	$ 244.51	$ 266.10	0.11	0.13	0.14	0.15	0.11	0.12	0.14	0.15
	Level 4	R5.8	$ 3,648.17	$ -	$ 3,648.17	1304.1	2.5	-$ 127.34	$ 238.95	$ 276.43	$ 304.83	$ 331.74	0.10	0.11	0.12	0.13	0.09	0.10	0.12	0.13
Attached CZ7	Base case	R2.8	$ 1,006.97		$ 1,006.97	1346.2	2.1													
	Level 1	R3.5	$ 1,660.17	$ -	$ 1,660.17	1313.8	2.0	-$ 38.14	$ 162.28	$ 187.74	$ 207.02	$ 225.30	0.26	0.31	0.34	0.37	0.25	0.29	0.32	0.34
	Level 2	R4.2	$ 2,228.17	$ -	$ 2,228.17	1288.8	2.0	-$ 35.24	$ 287.51	$ 332.61	$ 366.77	$ 399.16	0.24	0.28	0.31	0.34	0.24	0.27	0.30	0.33
	Level 3	R4.9	$ 2,796.17	$ -	$ 2,796.17	1271.8	2.0	-$ 42.60	$ 373.12	$ 431.65	$ 475.99	$ 518.02	0.21	0.25	0.27	0.30	0.21	0.24	0.27	0.29

		Performance value (e.g. R value)	Base Construction Cost	HVAC sizing capital cost adjustment	Capital Cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	Level 4	R5.8	$ 3,648.17	$ -	$ 3,648.17	1255.2	2.0	-$ 53.30	$ 456.18	$ 527.74	$ 581.95	$ 633.33	0.18	0.20	0.22	0.24	0.17	0.20	0.22	0.24
Detached CZ2	Base case	R2.8	$ 2,191.66		$ 2,191.66	1164.1	4.0													
	Level 1	R3.5	$ 3,613.33	$ -	$ 3,613.33	1100.6	3.6	-$ 302.64	$ 318.51	$ 368.47	$ 406.32	$ 442.20	0.28	0.33	0.36	0.39	0.22	0.26	0.29	0.31
	Level 2	R4.2	$ 4,849.57	$ -	$ 4,849.57	1093.3	3.9	-$ 88.98	$ 355.03	$ 410.72	$ 452.90	$ 492.89	0.14	0.16	0.18	0.19	0.13	0.15	0.17	0.19
	Level 3	R4.9	$ 6,085.81	$ -	$ 6,085.81	1090.9	3.9	-$ 69.58	$ 367.20	$ 424.80	$ 468.43	$ 509.79	0.10	0.11	0.12	0.13	0.09	0.11	0.12	0.13
	Level 4	R5.6	$ 7,569.30	$ -	$ 7,569.30	1082.0	3.9	-$ 82.74	$ 411.83	$ 476.43	$ 525.37	$ 571.76	0.08	0.09	0.10	0.11	0.08	0.09	0.10	0.11
Detached CZ5	Base case	R2.8	$ 2,191.66		$ 2,191.66	919.7	3.6													
	Level 1	R3.5	$ 3,613.33	$ -	$ 3,613.33	904.3	3.5	-$ 46.83	$ 77.09	$ 89.18	$ 98.34	$ 107.03	0.06	0.06	0.07	0.08	0.05	0.06	0.07	0.08
	Level 2	R4.2	$ 4,849.57	$ -	$ 4,849.57	894.6	3.5	-$ 24.09	$ 125.78	$ 145.51	$ 160.46	$ 174.63	0.05	0.06	0.06	0.07	0.05	0.05	0.06	0.07
	Level 3	R4.9	$ 6,085.81	$ -	$ 6,085.81	890.2	3.5	-$ 64.68	$ 148.10	$ 171.33	$ 188.93	$ 205.61	0.04	0.04	0.05	0.05	0.04	0.04	0.05	0.05
	Level 4	R5.6	$ 7,569.30	$ -	$ 7,569.30	882.1	3.5	-$ 80.29	$ 188.67	$ 218.27	$ 240.69	$ 261.94	0.04	0.04	0.05	0.05	0.04	0.04	0.04	0.05
Detached CZ6	Base case	R2.8	$ 2,191.66		$ 2,191.66	2587.6	2.3													
	Level 1	R3.5	$ 3,613.33	$ -	$ 3,613.33	2539.1	2.3	-$ 40.14	$ 243.45	$ 281.64	$ 310.56	$ 337.98	0.18	0.20	0.22	0.24	0.17	0.20	0.22	0.24
	Level 2	R4.2	$ 4,849.57	$ -	$ 4,849.57	2507.5	2.3	-$ 24.09	$ 401.69	$ 464.70	$ 512.43	$ 557.67	0.15	0.18	0.19	0.21	0.15	0.17	0.19	0.21
	Level 3	R4.9	$ 6,085.81	-$ 230.00	$ 5,855.81	2486.0	1.9	-$ 379.13	$ 509.21	$ 589.09	$ 649.59	$ 706.95	0.16	0.18	0.20	0.21	0.14	0.16	0.18	0.19
	Level 4	R5.6	$ 7,569.30	$ -	$ 7,569.30	2468.6	2.2	-$ 75.83	$ 596.44	$ 690.01	$ 760.88	$ 828.06	0.11	0.13	0.14	0.16	0.11	0.13	0.14	0.15
Detached CZ7	Base case	R2.8	$ 2,191.66		$ 2,191.66	2668.5	4.1													
	Level 1	R3.5	$ 3,613.33	$ -	$ 3,613.33	2605.4	4.1	-$ 72.48	$ 316.48	$ 366.13	$ 403.73	$ 439.38	0.23	0.27	0.30	0.33	0.22	0.26	0.28	0.31
	Level 2	R4.2	$ 4,849.57	$ -	$ 4,849.57	2621.2	4.1	-$ 37.24	$ 237.36	$ 274.59	$ 302.80	$ 329.53	0.09	0.10	0.12	0.13	0.09	0.10	0.11	0.12
	Level 3	R4.9	$ 6,085.81	$ -	$ 6,085.81	2569.8	4.0	-$ 87.20	$ 495.01	$ 572.66	$ 631.48	$ 687.23	0.13	0.15	0.17	0.18	0.13	0.15	0.16	0.18
	Level 4	R5.6	$ 7,569.30	$ -	$ 7,569.30	2554.4	4.0	-$ 100.58	$ 572.10	$ 661.84	$ 729.82	$ 794.26	0.11	0.13	0.14	0.15	0.11	0.12	0.14	0.15
Apartment CZ2	Base case	R2.9/R3.4	$ 1,636.96		$ 1,636.96	342.5	3.5													

		Performance value (e.g. R value)	Base Construction Cost	HVAC sizing capital cost adjustment	Capital Cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	Level 1	R3.5/R4.2	$ 2,447.39	$ -	$ 2,447.39	335.9	3.4	-$ 37.91	$ 32.91	$ 38.07	$ 41.98	$ 45.68	0.04	0.05	0.05	0.06	0.04	0.05	0.05	0.06
	Level 2	R4.2/R5	$ 3,176.18	$ -	$ 3,176.18	329.7	3.5	$ -	$ 64.13	$ 74.18	$ 81.80	$ 89.03	0.04	0.05	0.05	0.06	0.04	0.05	0.05	0.06
	Level 3	R4.9/RR5.8	$ 3,889.41	$ -	$ 3,889.41	326.8	3.4	-$ 84.75	$ 78.47	$ 90.78	$ 100.10	$ 108.94	0.04	0.04	0.05	0.05	0.03	0.04	0.04	0.05
	Level 4	R5.8/RR6.8	$ 4,756.22	$ -	$ 4,756.22	323.3	3.4	-$ 100.36	$ 96.19	$ 111.28	$ 122.71	$ 133.54	0.03	0.04	0.04	0.04	0.03	0.04	0.04	0.04
Apartment CZ5	Base case	R2.9/R3.4	$ 1,076.87		$ 1,076.87	310.8	2.2													
	Level 1	R3.5/R4.2	$ 1,685.78	$ -	$ 1,685.78	291.3	2.2	-$ 11.15	$ 97.88	$ 113.23	$ 124.86	$ 135.88	0.16	0.19	0.21	0.23	0.16	0.19	0.21	0.22
	Level 2	R4.2/R5	$ 2,447.39	$ -	$ 2,447.39	296.5	2.2	-$ 72.26	$ 71.72	$ 82.97	$ 91.49	$ 99.57	0.06	0.06	0.07	0.08	0.05	0.06	0.07	0.07
	Level 3	R4.9/RR5.8	$ 3,062.99	$ -	$ 3,062.99	288.6	2.1	-$ 133.81	$ 111.38	$ 128.85	$ 142.08	$ 154.63	0.06	0.07	0.08	0.08	0.06	0.06	0.07	0.08
	Level 4	R5.8/RR6.8	$ 3,873.43	$ -	$ 3,873.43	304.3	2.2	-$ 75.83	$ 32.91	$ 38.07	$ 41.98	$ 45.68	0.01	0.01	0.02	0.02	0.01	0.01	0.02	0.02
Apartment CZ6	Base case	R2.9/R3.4	$ 1,076.87		$ 1,076.87	967.8	2.1													
	Level 1	R3.5/R4.2	$ 1,685.78	$ -	$ 1,685.78	941.9	2.1	$ 8.92	$ 129.94	$ 150.32	$ 165.76	$ 180.40	0.21	0.24	0.27	0.29	0.21	0.25	0.27	0.30
	Level 2	R4.2/R5	$ 2,447.39	$ -	$ 2,447.39	939.4	2.0	-$ 72.26	$ 142.59	$ 164.96	$ 181.91	$ 197.97	0.11	0.13	0.14	0.15	0.10	0.12	0.13	0.14
	Level 3	R4.9/RR5.8	$ 3,062.99	-$ 230.00	$ 2,832.99	928.4	1.5	-$ 608.84	$ 197.44	$ 228.41	$ 251.87	$ 274.11	0.17	0.20	0.22	0.24	0.11	0.13	0.14	0.16
	Level 4	R5.8/RR6.8	$ 3,873.43	$ -	$ 3,873.43	948.5	2.0	-$ 46.83	$ 97.03	$ 112.25	$ 123.78	$ 134.71	0.04	0.04	0.05	0.05	0.03	0.04	0.04	0.05
Apartment CZ7	Base case	R2.9/R3.4	$ 1,076.87		$ 1,076.87	1510.5	2.5													
	Level 1	R3.5/R4.2	$ 1,685.78	$ -	$ 1,685.78	1489.3	2.4	-$ 85.94	$ 106.31	$ 122.99	$ 135.62	$ 147.60	0.20	0.24	0.26	0.28	0.17	0.20	0.22	0.24
	Level 2	R4.2/R5	$ 2,447.39	$ -	$ 2,447.39	1468.3	2.5	-$ 5.35	$ 211.78	$ 245.00	$ 270.17	$ 294.02	0.16	0.18	0.20	0.22	0.15	0.18	0.20	0.21
	Level 3	R4.9/RR5.8	$ 3,062.99	$ -	$ 3,062.99	1453.3	2.5	-$ 6.84	$ 286.88	$ 331.88	$ 365.97	$ 398.28	0.14	0.17	0.18	0.20	0.14	0.17	0.18	0.20
	Level 4	R5.8/RR6.8	$ 3,873.43	$ -	$ 3,873.43	1438.3	2.5	-$ 8.33	$ 361.97	$ 418.75	$ 461.76	$ 502.53	0.13	0.15	0.17	0.18	0.13	0.15	0.17	0.18

The results indicate limited benefits for increased wall insulation.

E.4 Wall Colour

E.4.1 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.

E.4.2 Benefit Cost Analysis

		Performance value	Base Construction Cost	HVAC sizing capital cost adjustment	Capital cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 yrs	BC Ratio - 15 yrs	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
Attached CZ2	Base case	External render, 65%	$ 4,910		$ 4,910.08	554.6	2.8													
	Level 1	50%, light green external render	$ 4,910	$ -	$ 4,910.08	552.8	2.8	-$ 10.93	$ 4.66	$ 5.34	$ 5.86	$ 6.20	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	30%, light cream	$ 4,910	$ -	$ 4,910.08	550.5	2.8	-$ 19.18	$ 10.66	$ 12.21	$ 13.39	$ 14.18	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 3	23%, white	$ 4,910	$ -	$ 4,910.08	549.0	2.7	-$ 28.99	$ 14.65	$ 16.79	$ 18.41	$ 19.49	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
Attached CZ5	Base case	External render, 65%	$ 3,633		$ 3,632.59	401.2	2.7													
	Level 1	50%, light green external render	$ 3,633	$ -	$ 3,632.59	400.6	2.7	-$ 10.70	$ 1.33	$ 1.53	$ 1.67	$ 1.77	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	30%, light cream	$ 3,633	$ -	$ 3,632.59	399.4	2.7	-$ 4.01	$ 4.66	$ 5.34	$ 5.86	$ 6.20	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 3	23%, white	$ 3,633	$ -	$ 3,632.59	400.6	2.8	$ 16.50	$ 1.33	$ 1.53	$ 1.67	$ 1.77	0.08	0.09	0.10	0.11	negative cost	negative cost	negative cost	negative cost
Attached CZ6	Base case	External render, 65%	$ 4,281		$ 4,280.75	1351.8	2.7													
	Level 1	50%, light green external render	$ 4,281	$ -	$ 4,280.75	1356.4	2.7	-$ 6.69	-$ 11.99	-$ 13.74	-$ 15.06	-$ 15.95	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	30%, light cream	$ 4,281	$ -	$ 4,280.75	1361.5	2.7	-$ 11.37	-$ 25.31	-$ 29.00	-$ 31.80	-$ 33.67	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 3	23%, white	$ 4,281	$ -	$ 4,280.75	1365.5	2.5	-$ 132.03	-$ 35.97	-$ 41.21	-$ 45.19	-$ 47.84	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
Detached CZ2	Base case	External render, 65%	$ 10,740		$ 10,739.52	1164.1	4.0													
	Level 1	50%, light green external render	$ 10,740	$ -	$ 10,739.52	1159.7	3.9	-$ 30.78	$ 11.63	$ 13.33	$ 14.62	$ 15.47	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	30%, light cream	$ 10,740	$ -	$ 10,739.52	1156.4	3.8	-$ 193.80	$ 20.09	$ 23.02	$ 25.25	$ 26.73	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 3	23%, white	$ 10,740	$ -	$ 10,739.52	1149.1	3.8	-$ 187.78	$ 39.13	$ 44.83	$ 49.16	$ 52.05	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
Detached CZ5	Base case	External render, 65%	$ 7,945		$ 7,945.34	919.7	3.6													
	Level 1	50%, light green external render	$ 7,945	$ -	$ 7,945.34	918.9	3.5	-$ 42.37	$ 2.12	$ 2.42	$ 2.66	$ 2.81	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	30%, light cream	$ 7,945	$ -	$ 7,945.34	918.5	3.6	$ -	$ 3.17	$ 3.64	$ 3.99	$ 4.22	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 3	23%, white	$ 7,945	$ -	$ 7,945.34	912.8	3.6	$ 84.75	$ 17.98	$ 20.60	$ 22.59	$ 23.91	0.21	0.24	0.27	0.29	negative cost	negative cost	negative cost	negative cost

		Performance value	Base Construction Cost	HVAC sizing capital cost adjustment	Capital cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 yrs	BC Ratio - 15 yrs	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
Detached CZ6	Base case	External render, 65%	$ 9,363		$ 9,363.02	2587.6	2.3													
	Level 1	50%, light green external render	$ 9,363	$ -	$ 9,363.02	2600.6	2.3	-$ 42.37	-$ 33.84	-$ 38.78	-$ 42.52	-$ 45.01	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	30%, light cream	$ 9,363	$ -	$ 9,363.02	2616.3	2.3	$ -	-$ 75.08	-$ 86.03	-$ 94.34	-$ 99.87	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 3	23%, white	$ 9,363	$ -	$ 9,363.02	2635.8	2.6	$ 229.71	-$ 125.85	-$ 144.20	-$ 158.12	-$ 167.40	-0.55	-0.63	-0.70	-0.75	negative cost	negative cost	negative cost	negative cost
Apartment CZ2	Base case	External render, 65%	$ 10,740		$ 10,739.52	342.5	3.5													
	Level 1	50%, light green external render	$ 10,740	$ -	$ 10,739.52	341.3	3.4	-$ 46.83	$ 3.08	$ 3.53	$ 3.87	$ 4.10	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	30%, light cream	$ 10,740	$ -	$ 10,739.52	339.9	3.5	$ -	$ 6.60	$ 7.56	$ 8.29	$ 8.78	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 3	23%, white	$ 10,740	$ -	$ 10,739.52	340.3	3.5	$ 78.06	$ 5.72	$ 6.55	$ 7.18	$ 7.61	0.07	0.08	0.09	0.10	negative cost	negative cost	negative cost	negative cost
Apartment CZ5	Base case	External render, 65%	$ 2,149		$ 2,149.36	310.8	2.2													
	Level 1	50%, light green the external render	$ 2,149	$ -	$ 2,149.36	312.0	2.2	-$ 42.37	-$ 3.08	-$ 3.53	-$ 3.87	-$ 4.10	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	30%, light cream	$ 2,149	$ -	$ 2,149.36	316.7	2.3	$ 24.09	-$ 15.39	-$ 17.64	-$ 19.34	-$ 20.48	-0.64	-0.73	-0.82	-0.87	negative cost	negative cost	negative cost	negative cost
	Level 3	23%, white	$ 2,149	$ -	$ 2,149.36	317.4	2.4	$ 138.27	-$ 17.15	-$ 19.65	-$ 21.55	-$ 22.82	-0.12	-0.14	-0.16	-0.17	negative cost	negative cost	negative cost	negative cost
Apartment CZ6	Base case	External render, 65%	$ 2,533		$ 2,532.86	967.8	2.1													
	Level 1	50%, light green the external render	$ 2,533	$ -	$ 2,532.86	977.1	2.1	-$ 17.84	-$ 24.19	-$ 27.72	-$ 30.40	-$ 32.18	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	30%, light cream	$ 2,533	$ -	$ 2,532.86	989.4	2.1	$ 24.09	-$ 56.30	-$ 64.51	-$ 70.74	-$ 74.89	-2.34	-2.68	-2.99	-3.20	negative cost	negative cost	negative cost	negative cost
	Level 3	23%, white	$ 2,533	$ 230	$ 2,762.86	992.4	2.4	$ 347.91	-$ 64.21	-$ 73.58	-$ 80.69	-$ 85.42	-0.11	-0.13	-0.14	-0.15	-0.28	-0.32	-0.35	-0.37

E.5 Roof Insulation

E.5.1 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 4-73. 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

E.5.2 Benefit Cost Analysis

		Performance value (e.g. R value)	Base Construction Cost	HVAC sizing capital cost adjustment	Capital Cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
Attached CZ2	Base case	R2.5	$ 2,840.00		$ 2,840.00	554.6	2.8													
	Level 1	R4.45	$ 3,294.40	$ -	$ 3,294.40	546.9	2.7	-$ 35.24	$ 38.33	$ 44.35	$ 48.90	$ 53.22	0.09	0.11	0.12	0.13	0.08	0.10	0.11	0.12
	Level 2	R5.3	$ 3,862.40	$ -	$ 3,862.40	541.6	2.8	$ 0.45	$ 65.17	$ 75.39	$ 83.14	$ 90.48	0.06	0.07	0.08	0.09	0.06	0.07	0.08	0.09
	Level 3	R6.6	$ 4,430.40	$ -	$ 4,430.40	526.9	2.7	-$ 25.65	$ 138.77	$ 160.54	$ 177.03	$ 192.66	0.09	0.10	0.11	0.12	0.09	0.10	0.11	0.12
	Level 4	R8.7	$ 5,140.40	$ -	$ 5,140.40	542.9	2.7	-$ 52.41	$ 58.78	$ 68.00	$ 74.98	$ 81.61	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.04
Attached CZ5	Base case	R2.5	$ 2,840.00		$ 2,840.00	401.2	2.7													
	Level 1	R4.45	$ 3,294.40	$ -	$ 3,294.40	393.3	2.7	-$ 16.64	$ 39.61	$ 45.83	$ 50.53	$ 54.99	0.09	0.10	0.12	0.13	0.09	0.10	0.11	0.12
	Level 2	R5.3	$ 3,862.40	$ -	$ 3,862.40	389.4	2.8	$ 48.62	$ 58.78	$ 68.00	$ 74.98	$ 81.61	0.05	0.06	0.07	0.08	0.06	0.07	0.07	0.08
	Level 3	R6.6	$ 4,430.40	$ -	$ 4,430.40	369.9	2.8	$ 27.65	$ 156.66	$ 181.23	$ 199.85	$ 217.50	0.10	0.11	0.12	0.13	0.10	0.11	0.13	0.14
	Level 4	R8.7	$ 5,140.40	$ -	$ 5,140.40	384.1	2.8	$ 24.09	$ 85.61	$ 99.04	$ 109.22	$ 118.86	0.04	0.04	0.05	0.05	0.04	0.04	0.05	0.05
Attached CZ6	Base case	R2.5	$ 2,840.00		$ 2,840.00	1351.8	2.7													
	Level 1	R4.45	$ 3,294.40	$ -	$ 3,294.40	1322.5	2.5	-$ 209.86	$ 146.95	$ 170.00	$ 187.46	$ 204.01	0.60	0.70	0.75	0.81	0.32	0.37	0.41	0.45
	Level 2	R5.3	$ 3,862.40	$ -	$ 3,862.40	1308.5	2.7	-$ 18.96	$ 217.23	$ 251.30	$ 277.12	$ 301.59	0.22	0.25	0.28	0.30	0.21	0.25	0.27	0.29
	Level 3	R6.6	$ 4,430.40	$ -	$ 4,430.40	1290.7	2.6	-$ 95.45	$ 306.16	$ 354.19	$ 390.57	$ 425.06	0.20	0.24	0.26	0.28	0.19	0.22	0.25	0.27
	Level 4	R8.7	$ 5,140.40	$ -	$ 5,140.40	1288.6	2.6	-$ 44.83	$ 316.90	$ 366.61	$ 404.26	$ 439.96	0.14	0.16	0.18	0.19	0.14	0.16	0.18	0.19
Attached CZ7	Base case	R2.5	$ 2,840.00		$ 2,840.00	1346.2	2.1													
	Level 1	R4.45	$ 3,294.40	$ -	$ 3,294.40	1303.9	2.1	-$ 25.65	$ 212.12	$ 245.39	$ 270.60	$ 294.49	0.49	0.57	0.63	0.69	0.47	0.54	0.60	0.65
	Level 2	R5.3	$ 3,862.40	$ -	$ 3,862.40	1284.2	2.1	-$ 26.54	$ 310.51	$ 359.22	$ 396.11	$ 431.09	0.31	0.36	0.40	0.43	0.30	0.35	0.39	0.42
	Level 3	R6.6	$ 4,430.40	$ -	$ 4,430.40	1267.7	2.0	-$ 31.45	$ 393.57	$ 455.30	$ 502.07	$ 546.40	0.25	0.29	0.32	0.35	0.25	0.29	0.32	0.34
	Level 4	R8.7	$ 5,140.40	$ -	$ 5,140.40	1259.0	2.0	-$ 38.14	$ 437.01	$ 505.57	$ 557.49	$ 606.72	0.19	0.22	0.25	0.27	0.19	0.22	0.24	0.26
Detached CZ2	Base case	R2.93	$ 2,854.02		$ 2,854.02	1164.1	4.0													
	Level 1	R3.7	$ 3,144.16	$ -	$ 3,144.16	1144.7	3.9	-$ 31.00	$ 97.38	$ 112.65	$ 124.23	$ 135.19	0.38	0.43	0.48	0.52	0.34	0.39	0.43	0.47

		Performance value (e.g. R value)	Base Construction Cost	HVAC sizing capital cost adjustment	Capital Cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	Level 2	R4.45	$ 3,434.31	$ -	$ 3,434.31	1132.2	3.9	-$ 61.78	$ 160.27	$ 185.41	$ 204.45	$ 222.51	0.31	0.36	0.39	0.43	0.28	0.32	0.35	0.38
	Level 3	R5.2	$ 3,724.45	$ -	$ 3,724.45	991.2	3.8	-$ 177.97	$ 867.07	$ 1,003.09	$ 1,106.12	$ 1,203.79	1.25	1.45	1.59	1.73	1.00	1.15	1.27	1.38
	Level 4	R5.82	$ 3,966.24	$ -	$ 3,966.24	954.5	3.8	-$ 171.73	$ 1,050.88	$ 1,215.72	$ 1,340.60	$ 1,458.97	1.12	1.29	1.42	1.54	0.94	1.09	1.21	1.31
Detached CZ5	Base case	R2.93	$ 2,854.02		$ 2,854.02	919.7	3.6													
	Level 1	R3.7	$ 3,144.16	$ -	$ 3,144.16	896.3	3.5	-$ 28.99	$ 117.67	$ 136.12	$ 150.11	$ 163.36	0.45	0.52	0.57	0.62	0.41	0.47	0.52	0.56
	Level 2	R4.45	$ 3,434.31	$ -	$ 3,434.31	879.3	3.5	-$ 48.17	$ 202.87	$ 234.70	$ 258.80	$ 281.65	0.38	0.44	0.49	0.53	0.35	0.40	0.45	0.49
	Level 3	R5.2	$ 3,724.45	$ -	$ 3,724.45	736.3	3.4	-$ 169.50	$ 919.82	$ 1,064.11	$ 1,173.41	$ 1,277.02	1.31	1.52	1.67	1.81	1.06	1.22	1.35	1.47
	Level 4	R5.82	$ 3,966.24	-$ 230.00	$ 3,736.24	698.0	3.1	-$ 414.82	$ 1,111.74	$ 1,286.13	$ 1,418.24	$ 1,543.46	2.38	2.75	2.98	3.22	1.26	1.46	1.61	1.75
Detached CZ6	Base case	R3.45	$ 3,047.45		$ 3,047.45	2587.6	2.3													
	Level 1	R4.45	$ 3,337.59	$ -	$ 3,337.59	2516.4	2.3	-$ 31.22	$ 357.05	$ 413.06	$ 455.49	$ 495.71	1.38	1.60	1.76	1.91	1.23	1.42	1.57	1.71
	Level 2	R5.2	$ 3,724.45	$ -	$ 3,724.45	2465.8	2.2	-$ 72.26	$ 610.64	$ 706.43	$ 778.99	$ 847.78	1.01	1.17	1.29	1.40	0.90	1.04	1.15	1.25
	Level 3	R5.82	$ 4,014.60	-$ 230.00	$ 3,784.60	2322.8	1.7	-$ 615.54	$ 1,327.59	$ 1,535.85	$ 1,693.60	$ 1,843.14	10.92	12.63	12.71	13.26	1.80	2.08	2.30	2.50
	Level 4	R6.9	$ 4,401.46	-$ 230.00	$ 4,171.46	2271.6	1.9	-$ 423.74	$ 1,584.43	$ 1,832.98	$ 2,021.24	$ 2,199.71	2.26	2.62	2.85	3.09	1.41	1.63	1.80	1.96
Detached CZ7	Base case	R3.45	$ 3,047.45		$ 3,047.45	2668.5	4.1													
	Level 1	R4.45	$ 3,337.59	$ -	$ 3,337.59	2587.6	4.0	-$ 121.77	$ 405.74	$ 469.39	$ 517.60	$ 563.31	2.41	2.79	3.03	3.28	1.40	1.62	1.78	1.94
	Level 2	R5.2	$ 3,724.45	$ -	$ 3,724.45	2493.7	3.9	-$ 198.04	$ 876.41	$ 1,013.89	$ 1,118.03	$ 1,216.74	1.83	2.12	2.32	2.51	1.29	1.50	1.65	1.80
	Level 3	R5.82	$ 4,014.60	$ -	$ 4,014.60	2446.8	3.9	-$ 242.87	$ 1,111.74	$ 1,286.13	$ 1,418.24	$ 1,543.46	1.53	1.78	1.95	2.11	1.15	1.33	1.47	1.60
	Level 4	R6.9	$ 4,401.46	$ -	$ 4,401.46	2403.1	3.8	-$ 281.90	$ 1,330.84	$ 1,539.61	$ 1,697.74	$ 1,847.65	1.24	1.44	1.58	1.71	0.98	1.14	1.25	1.36

E.6 Roller Shutters

E.6.1 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.

E.6.2 Benefit Cost Analysis

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		Performance value (e.g. R value)	Base Construction Cost	HVAC sizing capital cost adjustment	Capital Cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
Attached W CZ2	Base case	No shutters	$ -		$ -	554.6	2.8													
	Level 1	Shutters installed	$ 2,337.50	$ -	$ 2,337.50	507.7	2.5	-$ 290.60	$ 144.00	$ 168.33	$ 190.28	$ 212.06	0.07	0.08	0.09	0.10	0.06	0.07	0.08	0.09
Attached N CZ2	Base case	No shutters	$ -		$ -	554.6	2.8													
	Level 1	Shutters installed	$ 2,337.50	$ -	$ 2,337.50	548.2	2.7	-$ 32.56	$ 19.56	$ 22.87	$ 25.85	$ 28.81	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Attached E CZ2	Base case	No shutters	$ -		$ -	554.6	2.8													
	Level 1	Shutters installed	$ 2,337.50	$ -	$ 2,337.50	519.4	2.7	-$ 28.77	$ 108.00	$ 126.25	$ 142.71	$ 159.04	0.05	0.05	0.06	0.07	0.05	0.05	0.06	0.07
Attached W CZ5	Base case	No shutters	$ -		$ -	401.2	2.7													
	Level 1	Shutters installed	$ 2,337.50	$ -	$ 2,337.50	372.6	2.5	-$ 237.74	$ 87.65	$ 102.46	$ 115.83	$ 129.08	0.04	0.05	0.06	0.06	0.04	0.04	0.05	0.06
Attached N CZ5	Base case	No shutters	$ -		$ -	401.2	2.7													
	Level 1	Shutters installed	$ 2,337.50	$ -	$ 2,337.50	396.1	2.8	$ 13.38	$ 15.65	$ 18.30	$ 20.68	$ 23.05	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Attached E CZ5	Base case	No shutters	$ -		$ -	401.2	2.7													
	Level 1	Shutters installed	$ 2,337.50	$ -	$ 2,337.50	379.0	2.6	-$ 181.09	$ 68.09	$ 79.59	$ 89.97	$ 100.27	0.03	0.04	0.04	0.05	0.03	0.03	0.04	0.04
Attached W CZ6	Base case	No shutters	$ -		$ -	1351.8	2.7													
	Level 1	Shutters installed	$ 2,337.50	$ -	$ 2,337.50	1333.9	2.4	-$ 241.98	$ 54.78	$ 64.04	$ 72.39	$ 80.67	0.03	0.03	0.03	0.04	0.02	0.03	0.03	0.03
Attached N CZ6	Base case	No shutters	$ -		$ -	1351.8	2.7													
	Level 1	Shutters installed	$ 2,337.50	$ -	$ 2,337.50	1349.0	2.7	$ -	$ 8.61	$ 10.06	$ 11.38	$ 12.68	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01
Attached E CZ6	Base case	No shutters	$ -		$ -	1351.8	2.7													
	Level 1	Shutters installed	$ 2,337.50	$ -	$ 2,337.50	1338.8	2.6	-$ 61.78	$ 39.91	$ 46.66	$ 52.74	$ 58.78	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.03
Attached W CZ7	Base case	No shutters	$ -		$ -	2287.6	2.5													
	Level 1	Shutters installed	$ 2,337.50	$ -	$ 2,337.50	2224.9	2.3	-$ 136.93	$ 192.52	$ 225.05	$ 254.40	$ 283.51	0.09	0.10	0.12	0.13	0.08	0.10	0.11	0.12
Attached N CZ7	Base case	No shutters	$ -		$ -	2287.6	2.5													
	Level 1	Shutters installed	$ 2,337.50	$ -	$ 2,337.50	2274.6	2.5	$ -	$ 39.91	$ 46.66	$ 52.74	$ 58.78	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.03

		Performance value (e.g. R value)	Base Construction Cost	HVAC sizing capital cost adjustment	Capital Cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
Attached E CZ7	Base case	No shutters	$ -		$ -	2287.6	2.5													
	Level 1	Shutters installed	$ 2,337.50	$ -	$ 2,337.50	2278.5	2.4	-$ 5.58	$ 28.17	$ 32.93	$ 37.23	$ 41.49	0.01	0.01	0.02	0.02	0.01	0.01	0.02	0.02
Detached W CZ2	Base case	No shutters	$ -		$ -	1164.1	4.0													
	Level 1	Shutters installed	$ 2,287.50	-$ 460.00	$ 1,827.50	1040.7	3.1	-$ 815.58	$ 378.96	$ 443.00	$ 500.77	$ 558.07	0.37	0.44	0.49	0.54	0.21	0.24	0.27	0.31
Detached N CZ2	Base case	No shutters	$ -		$ -	1164.1	4.0													
	Level 1	Shutters installed	$ 2,287.50	$ -	$ 2,287.50	884.1	4.0	$ -	$ 859.80	$ 1,005.09	$ 1,136.18	$ 1,266.18	0.38	0.44	0.50	0.55	0.38	0.44	0.50	0.55
Detached E CZ2	Base case	No shutters	$ -		$ -	1164.1	4.0													
	Level 1	Shutters installed	$ 2,287.50	$ -	$ 2,287.50	851.7	3.7	-$ 205.18	$ 959.19	$ 1,121.29	$ 1,267.53	$ 1,412.56	0.46	0.54	0.61	0.68	0.42	0.49	0.55	0.62
Detached W CZ5	Base case	No shutters	$ -		$ -	919.7	4.2													
	Level 1	Shutters installed	$ 2,287.50	$ -	$ 2,287.50	844.1	3.8	-$ 314.01	$ 232.34	$ 271.61	$ 307.03	$ 342.16	0.12	0.14	0.16	0.17	0.10	0.12	0.13	0.15
Detached N CZ5	Base case	No shutters	$ -		$ -	919.7	4.2													
	Level 1	Shutters installed	$ 2,287.50	$ -	$ 2,287.50	898.3	4.1	-$ 58.43	$ 65.85	$ 76.98	$ 87.02	$ 96.98	0.03	0.03	0.04	0.04	0.03	0.03	0.04	0.04
Detached E CZ5	Base case	No shutters	$ -		$ -	919.7	4.2													
	Level 1	Shutters installed	$ 2,287.50	$ -	$ 2,287.50	868.7	4.1	-$ 24.31	$ 156.55	$ 183.01	$ 206.88	$ 230.55	0.07	0.08	0.09	0.10	0.07	0.08	0.09	0.10
Detached W CZ6	Base case	No shutters	$ -		$ -	2587.6	3.4													
	Level 1	Shutters installed	$ 2,287.50	-$ 230.00	$ 2,057.50	2539.1	2.8	-$ 529.45	$ 149.10	$ 174.29	$ 197.02	$ 219.57	0.10	0.11	0.13	0.14	0.07	0.08	0.10	0.11
Detached N CZ6	Base case	No shutters	$ -		$ -	2587.6	3.4													
	Level 1	Shutters installed	$ 2,287.50	$ -	$ 2,287.50	2473.9	3.3	-$ 47.95	$ 349.14	$ 408.14	$ 461.37	$ 514.16	0.16	0.18	0.21	0.23	0.15	0.18	0.20	0.22
Detached E CZ6	Base case	No shutters	$ -		$ -	2587.6	3.4													
	Level 1	Shutters installed	$ 2,287.50	$ -	$ 2,287.50	2478.4	3.4	-$ 31.22	$ 335.47	$ 392.16	$ 443.31	$ 494.03	0.15	0.17	0.20	0.22	0.15	0.17	0.19	0.22
Detached W CZ7	Base case	No shutters	$ -		$ -	2668.5	3.0													
	Level 1	Shutters installed	$ 2,287.50	$ -	$ 2,287.50	2455.7	2.8	-$ 255.80	$ 653.54	$ 763.98	$ 863.63	$ 962.44	0.32	0.38	0.42	0.47	0.29	0.33	0.38	0.42

		Performance value (e.g. R value)	Base Construction Cost	HVAC sizing capital cost adjustment	Capital Cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
Detached N CZ7	Base case	No shutters	$ -		$ -	2668.5	3.0													
	Level 1	Shutters installed	$ 2,287.50	$ -	$ 2,287.50	2660.4	3.0	$ 13.16	$ 24.85	$ 29.05	$ 32.84	$ 36.59	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.02
Detached E CZ7	Base case	No shutters	$ -		$ -	2668.5	3.0													
	Level 1	Shutters installed	$ 2,287.50	$ -	$ 2,287.50	2654.0	3.1	$ 38.81	$ 44.73	$ 52.29	$ 59.11	$ 65.87	0.02	0.02	0.03	0.03	0.02	0.02	0.03	0.03
Apartment W CZ2	Base case	No shutters	$ -		$ -	342.5	1.6													
	Level 1	Shutters installed	$ 900.00	$ -	$ 900.00	302.7	1.5	-$ 22.08	$ 121.95	$ 142.56	$ 161.16	$ 179.59	0.14	0.16	0.18	0.20	0.14	0.16	0.18	0.20
Apartment N CZ2	Base case	No shutters	$ -		$ -	342.5	1.6													
	Level 1	Shutters installed	$ 900.00	$ -	$ 900.00	325.8	1.6	$ 17.62	$ 51.16	$ 59.80	$ 67.60	$ 75.34	0.06	0.07	0.07	0.08	0.06	0.07	0.08	0.08
Apartment E CZ2	Base case	No shutters	$ -		$ -	342.5	1.6													
	Level 1	Shutters installed	$ 900.00	$ -	$ 900.00	312.2	1.6	$ 37.69	$ 93.02	$ 108.73	$ 122.92	$ 136.98	0.10	0.12	0.13	0.15	0.10	0.12	0.14	0.15
Apartment W CZ5	Base case	No shutters	$ -		$ -	310.8	1.6													
	Level 1	Shutters installed	$ 900.00	$ -	$ 900.00	296.4	1.5	-$ 60.66	$ 44.44	$ 51.95	$ 58.73	$ 65.45	0.05	0.06	0.07	0.08	0.05	0.06	0.07	0.07
Apartment N CZ5	Base case	No shutters	$ -		$ -	310.8	1.6													
	Level 1	Shutters installed	$ 900.00	$ -	$ 900.00	303.3	1.6	-$ 2.23	$ 23.25	$ 27.18	$ 30.73	$ 34.24	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.04
Apartment E CZ5	Base case	No shutters	$ -		$ -	310.8	1.6													
	Level 1	Shutters installed	$ 900.00	$ -	$ 900.00	300.1	1.7	$ 59.55	$ 33.07	$ 38.66	$ 43.70	$ 48.70	0.03	0.04	0.05	0.05	0.04	0.04	0.05	0.05
Apartment W CZ6	Base case	No shutters	$ -		$ -	967.8	1.1													
	Level 1	Shutters installed	$ 900.00	$ -	$ 900.00	954.9	1.3	$ 121.55	$ 39.79	$ 46.51	$ 52.58	$ 58.60	0.04	0.05	0.05	0.06	0.04	0.05	0.06	0.07
Apartment N CZ6	Base case	No shutters	$ -		$ -	967.8	1.1													
	Level 1	Shutters installed	$ 900.00	$ -	$ 900.00	892.9	1.1	$ 11.60	$ 229.95	$ 268.81	$ 303.87	$ 338.64	0.25	0.29	0.33	0.37	0.26	0.30	0.34	0.38
Apartment E CZ6	Base case	No shutters	$ -		$ -	967.8	1.1													
	Level 1	Shutters installed	$ 900.00	$ -	$ 900.00	890.7	1.2	$ 38.58	$ 236.67	$ 276.67	$ 312.75	$ 348.54	0.25	0.29	0.33	0.37	0.26	0.31	0.35	0.39

		Performance value (e.g. R value)	Base Construction Cost	HVAC sizing capital cost adjustment	Capital Cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
Apartment W CZ7	Base case	No shutters	$ -		$ -	1510.5	2.5													
	Level 1	Shutters installed	$ 900.00	$ -	$ 900.00	1469.1	2.3	-$ 136.93	$ 127.12	$ 148.60	$ 167.98	$ 187.20	0.17	0.19	0.22	0.24	0.14	0.17	0.19	0.21
Apartment N CZ7	Base case	No shutters	$ -		$ -	1510.5	2.5													
	Level 1	Shutters installed	$ 900.00	$ -	$ 900.00	1502.0	2.5	$ -	$ 26.35	$ 30.81	$ 34.83	$ 38.81	0.03	0.03	0.04	0.04	0.03	0.03	0.04	0.04
Apartment E CZ7	Base case	No shutters	$ -		$ -	1510.5	2.5													
	Level 1	Shutters installed	$ 900.00	$ -	$ 900.00	1504.5	2.4	-$ 5.58	$ 18.60	$ 21.75	$ 24.58	$ 27.40	0.02	0.02	0.03	0.03	0.02	0.02	0.03	0.03

E.7 Roof Ventilation

E.7.1 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.

E.7.2 Benefit Cost Analysis

		Performance value (e.g. R value)	Base Construction Cost	HVAC sizing capital cost adjustment	Capital Cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
Attached CZ2	Base case	Standard	$ -		$ -	554.6	2.8													
	Level 1	Ventilated	$ 442.00	$ -	$ 442.00	551.8	2.7	-$ 34.57	$ 11.48	$ 12.69	$ 13.50	$ 14.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
	Level 2	Highly Ventilated	$ 884.00	$ -	$ 884.00	549.5	2.7	-$ 48.84	$ 20.87	$ 23.08	$ 24.54	$ 25.53	0.02	0.03	0.03	0.03	0.02	0.03	0.03	0.03
Attached CZ5	Base case	Standard	$ -		$ -	401.2	2.7													
	Level 1	Ventilated	$ 442.00	$ -	$ 442.00	398.9	2.8	$ 14.50	$ 9.39	$ 10.39	$ 11.04	$ 11.49	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.03
	Level 2	Highly Ventilated	$ 884.00	$ -	$ 884.00	398.6	2.7	-$ 2.90	$ 10.44	$ 11.54	$ 12.27	$ 12.77	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Attached CZ6	Base case	Standard	$ -		$ -	1351.8	2.7													
	Level 1	Ventilated	$ 442.00	$ -	$ 442.00	1356.4	2.6	-$ 43.04	-$ 18.78	-$ 20.77	-$ 22.09	-$ 22.98	-0.05	-0.05	-0.06	-0.06	-0.04	-0.05	-0.05	-0.05
	Level 2	Highly Ventilated	$ 884.00	$ -	$ 884.00	1357.4	2.5	-$ 191.13	-$ 22.96	-$ 25.39	-$ 26.99	-$ 28.09	-0.03	-0.04	-0.04	-0.04	-0.03	-0.03	-0.03	-0.03
Detached CZ2	Base case	Standard	$ -		$ -	1164.1	4.0													
	Level 1	Ventilated	$ 884.00	$ -	$ 884.00	1169.8	3.8	-$ 104.15	-$ 23.20	-$ 25.65	-$ 27.27	-$ 28.38	-0.03	-0.03	-0.03	-0.04	-0.03	-0.03	-0.03	-0.03
	Level 2	Highly Ventilated	$ 1,768.00	$ -	$ 1,768.00	1168.6	3.9	-$ 86.98	-$ 18.23	-$ 20.15	-$ 21.43	-$ 22.30	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Detached CZ5	Base case	Standard	$ -		$ -	919.7	3.6													
	Level 1	Ventilated	$ 884.00	$ -	$ 884.00	922.6	3.5	-$ 75.83	-$ 11.60	-$ 12.83	-$ 13.64	-$ 14.19	-0.01	-0.02	-0.02	-0.02	-0.01	-0.01	-0.02	-0.02
	Level 2	Highly Ventilated	$ 1,768.00	$ -	$ 1,768.00	924.2	3.6	$ 48.17	-$ 18.23	-$ 20.15	-$ 21.43	-$ 22.30	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Detached CZ6	Base case	Standard	$ -		$ -	2587.6	2.3													
	Level 1	Ventilated	$ 884.00	$ -	$ 884.00	2630.5	2.3	$ 6.69	-$ 175.62	-$ 194.21	-$ 206.50	-$ 214.86	-0.20	-0.22	-0.23	-0.24	-0.20	-0.22	-0.23	-0.24
	Level 2	Highly Ventilated	$ 1,768.00	$ -	$ 1,768.00	2636.2	2.4	$ 72.26	-$ 198.82	-$ 219.86	-$ 233.77	-$ 243.24	-0.11	-0.12	-0.13	-0.13	-0.11	-0.12	-0.13	-0.14

E.8 Eaves Extension

E.8.1 Capital Costs

The capital costs for the attached archetype 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 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 archetype 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 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

E.8.2 Benefit Cost Analysis

		Performance value	Base Construction Cost	HVAC sizing capital cost adjustment	Capital cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 yrs	BC Ratio - 15 yrs	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
Attached W CZ2	Base case	Eaves 0.45m length	$ -		$ -	554.6	2.8													
	Level 1	Eaves 1.2m length	$ 381	$ -	$ 380.55	539.3	2.7	-$ 75.60	$ 39.97	$ 45.79	$ 50.22	$ 53.16	0.13	0.15	0.16	0.17	0.11	0.12	0.13	0.14
Attached N CZ2	Base case	Eaves 0.45m length	$ -		$ -	554.6	2.8													
	Level 1	Eaves 1.2m length	$ 381	$ -	$ 380.55	560.2	2.8	$ 1.34	-$ 14.65	-$ 16.79	-$ 18.41	-$ 19.49	-0.04	-0.04	-0.05	-0.05	-0.04	-0.04	-0.05	-0.05
Attached E CZ2	Base case	Eaves 0.45m length	$ -		$ -	554.6	2.8													
	Level 1	Eaves 1.2m length	$ 381	$ -	$ 380.55	533.2	2.7	-$ 26.09	$ 55.95	$ 64.11	$ 70.30	$ 74.43	0.16	0.18	0.20	0.21	0.15	0.17	0.18	0.20
Attached W CZ5	Base case	Eaves 0.45m length	$ -		$ -	401.2	2.7													
	Level 1	Eaves 1.2m length	$ 307	$ -	$ 307.48	390.4	2.6	-$ 125.11	$ 27.98	$ 32.06	$ 35.15	$ 37.21	0.15	0.18	0.19	0.20	0.09	0.10	0.11	0.12
Attached N CZ5	Base case	Eaves 0.45m length	$ -		$ -	401.2	2.7													
	Level 1	Eaves 1.2m length	$ 307	$ -	$ 307.48	406.0	2.8	$ 23.86	-$ 12.66	-$ 14.50	-$ 15.90	-$ 16.83	-0.04	-0.04	-0.05	-0.05	-0.04	-0.05	-0.05	-0.05
Attached E CZ5	Base case	Eaves 0.45m length	$ -		$ -	401.2	2.7													
	Level 1	Eaves 1.2m length	$ 307	$ -	$ 307.48	381.5	2.7	-$ 72.26	$ 51.29	$ 58.77	$ 64.44	$ 68.22	0.22	0.25	0.27	0.29	0.17	0.19	0.21	0.22
Attached W CZ6	Base case	Eaves 0.45m length	$ -		$ -	1351.8	2.7													
	Level 1	Eaves 1.2m length	$ 297	$ -	$ 297.44	1348.7	2.8	$ 159.24	$ 7.99	$ 9.16	$ 10.04	$ 10.63	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.04
Attached N CZ6	Base case	Eaves 0.45m length	$ -		$ -	1351.8	2.7													
	Level 1	Eaves 1.2m length	$ 297	$ -	$ 297.44	1365.0	2.8	$ 131.36	-$ 34.64	-$ 39.69	-$ 43.52	-$ 46.07	-0.08	-0.09	-0.10	-0.11	-0.12	-0.13	-0.15	-0.15
Attached E CZ6	Base case	Eaves 0.45m length	$ -		$ -	1351.8	2.7													
	Level 1	Eaves 1.2m length	$ 297	$ -	$ 297.44	1343.4	2.8	$ 88.32	$ 21.98	$ 25.19	$ 27.62	$ 29.24	0.06	0.07	0.07	0.08	0.07	0.08	0.09	0.10
Detached W CZ2	Base case	Eaves 0.45m length	$ -		$ -	1161.4	4.0													
	Level 1	Eaves 1.2m length	$ 1,672	$ -	$ 1,672.36	1134.6	3.7	-$ 250.23	$ 77.20	$ 88.46	$ 97.00	$ 102.69	0.05	0.06	0.07	0.07	0.05	0.05	0.06	0.06
Detached N CZ2	Base case	Eaves 0.45m length	$ -		$ -	1161.4	4.0													
	Level 1	Eaves 1.2m length	$ 1,672	$ -	$ 1,672.36	1155.2	3.8	-$ 103.70	$ 23.27	$ 26.66	$ 29.23	$ 30.95	0.01	0.02	0.02	0.02	0.01	0.02	0.02	0.02
Detached E CZ2	Base case	Eaves 0.45m length	$ -		$ -	1161.4	4.0													

		Performance value	Base Construction Cost	HVAC sizing capital cost adjustment	Capital cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 yrs	BC Ratio - 15 yrs	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	Level 1	Eaves 1.2m length	$ 1,672	$ -	$ 1,672.36	1093.7	3.9	-$ 68.91	$ 184.01	$ 210.84	$ 231.21	$ 244.76	0.11	0.13	0.14	0.15	0.11	0.13	0.14	0.15
Detached W CZ5	Base case	Eaves 0.45m length	$ -		$ -	919.7	4.2													
	Level 1	Eaves 1.2m length	$ 1,423	$ -	$ 1,422.78	893.0	4.1	-$ 56.65	$ 69.80	$ 79.98	$ 87.70	$ 92.84	0.05	0.06	0.06	0.07	0.05	0.06	0.06	0.07
Detached N CZ5	Base case	Eaves 0.45m length	$ -		$ -	919.7	4.2													
	Level 1	Eaves 1.2m length	$ 1,423	$ -	$ 1,422.78	907.6	4.1	-$ 70.92	$ 31.73	$ 36.35	$ 39.86	$ 42.20	0.02	0.03	0.03	0.03	0.02	0.03	0.03	0.03
Detached E CZ5	Base case	Eaves 0.45m length	$ -		$ -	919.7	4.2													
	Level 1	Eaves 1.2m length	$ 1,423	$ -	$ 1,422.78	874.0	4.1	-$ 36.58	$ 119.50	$ 136.93	$ 150.15	$ 158.96	0.09	0.10	0.11	0.11	0.08	0.10	0.11	0.11
Detached W CZ6	Base case	Eaves 0.45m length	$ -		$ -	2587.6	3.4													
	Level 1	Eaves 1.2m length	$ 1,437	$ -	$ 1,437.40	2552.8	3.3	-$ 78.95	$ 90.95	$ 104.21	$ 114.27	$ 120.97	0.07	0.08	0.08	0.09	0.06	0.07	0.08	0.08
Detached N CZ6	Base case	Eaves 0.45m length	$ -		$ -	2587.6	3.4													
	Level 1	Eaves 1.2m length	$ 1,437	$ -	$ 1,437.40	2576.7	3.4	-$ 10.26	$ 28.55	$ 32.72	$ 35.88	$ 37.98	0.02	0.02	0.03	0.03	0.02	0.02	0.02	0.03
Detached E CZ6	Base case	Eaves 0.45m length	$ -		$ -	2587.6	3.4													
	Level 1	Eaves 1.2m length	$ 1,437	$ -	$ 1,437.40	2565.8	3.3	-$ 60.44	$ 57.11	$ 65.43	$ 71.75	$ 75.96	0.04	0.05	0.05	0.06	0.04	0.05	0.05	0.05
Apartment W CZ2	Base case	Eaves 0.45m length	$ -		$ -	342.5	1.6													
	Level 1	Eaves 1.2m length	$ 516	$ -	$ 516.09	319.2	1.6	$ 33.45	$ 60.70	$ 69.55	$ 76.26	$ 80.74	0.11	0.13	0.14	0.15	0.12	0.13	0.15	0.16
Apartment W CZ5	Base case	Eaves 0.45m length	$ -		$ -	310.8	1.6													
	Level 1	Eaves 1.2m length	$ 417	$ -	$ 416.99	304.8	1.6	$ 4.91	$ 15.83	$ 18.14	$ 19.90	$ 21.06	0.04	0.04	0.05	0.05	0.04	0.04	0.05	0.05
Apartment W CZ6	Base case	Eaves 0.45m length	$ -		$ -	967.8	1.1													
	Level 1	Eaves 1.2m length	$ 403	$ -	$ 403.38	973.5	1.2	$ 79.40	-$ 14.95	-$ 17.13	-$ 18.79	-$ 19.89	-0.03	-0.04	-0.04	-0.04	-0.04	-0.04	-0.05	-0.05
Apartment N CZ2	Base case	Eaves 0.45m length	$ -		$ -	342.5	1.6													
	Level 1	Eaves 1.2m length	$ 516	$ -	$ 516.09	332.9	1.6	$ 4.91	$ 25.07	$ 28.73	$ 31.50	$ 33.35	0.05	0.06	0.06	0.06	0.05	0.06	0.06	0.06
Apartment N CZ5	Base case	Eaves 0.45m length	$ -		$ -	310.8	1.6													
	Level 1	Eaves 1.2m length	$ 417	$ -	$ 416.99	313.2	1.6	-$ 39.25	-$ 6.16	-$ 7.06	-$ 7.74	-$ 8.19	-0.02	-0.02	-0.02	-0.02	-0.01	-0.02	-0.02	-0.02

		Performance value	Base Construction Cost	HVAC sizing capital cost adjustment	Capital cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 yrs	BC Ratio - 15 yrs	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
Apartment N CZ6	Base case	Eaves 0.45m length	$ -		$ -	967.8	1.1													
	Level 1	Eaves 1.2m length	$ 403	$ -	$ 403.38	981.6	1.1	-$ 37.24	-$ 36.07	-$ 41.33	-$ 45.32	-$ 47.97	-0.10	-0.11	-0.12	-0.13	-0.09	-0.10	-0.11	-0.12
Apartment E CZ2	Base case	Eaves 0.45m length	$ -		$ -	342.5	1.6													
	Level 1	Eaves 1.2m length	$ 516	$ -	$ 516.09	321.3	1.6	$ 94.34	$ 55.42	$ 63.50	$ 69.63	$ 73.72	0.09	0.10	0.11	0.12	0.11	0.12	0.13	0.14
Apartment E CZ5	Base case	Eaves 0.45m length	$ -		$ -	310.8	1.6													
	Level 1	Eaves 1.2m length	$ 417	$ -	$ 416.99	305.8	1.6	-$ 24.31	$ 13.19	$ 15.12	$ 16.58	$ 17.55	0.03	0.04	0.04	0.04	0.03	0.04	0.04	0.04
Apartment E CZ6	Base case	Eaves 0.45m length	$ -		$ -	967.8	1.1													
	Level 1	Eaves 1.2m length	$ 403	$ -	$ 403.38	980.4	1.2	$ 76.05	-$ 32.99	-$ 37.80	-$ 41.45	-$ 43.88	-0.07	-0.08	-0.09	-0.09	-0.08	-0.09	-0.10	-0.11

E.9 Slab Edge Insulation

E.9.1 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.

E.9.2 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.

E.10 Thermal Mass

E.10.1 Capital Costs

The capital costs for the attached archetype 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 m² (attached)		

The capital costs for the detached archetype 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 m² (detached)		

The capital costs for the apartment archetype 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 m² (apartment)		

E.10.2 Benefit Cost Analysis

		Performance value	Base Construction Cost	HVAC sizing capital cost adjustment	Capital cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 yrs	BC Ratio - 15 yrs	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
Attached CZ2	Base case	200 mm concrete and carpet, brick veneer	$ 47,125.37		$ 47,125.37	554.6	2.8													
	Level 1	200 mm concrete and carpet, reverse brick veneer	$ 55,745.44	$ -	$ 55,745.44	543.4	2.8	$ 14.05	$ 56.22	$ 65.04	$ 71.72	$ 78.06	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Level 2	Increase concrete floor to 300mm and leave it expose	$ 50,505.62	$ -	$ 50,505.62	555.3	3.0	$ 180.65	-$ 3.83	-$ 4.43	-$ 4.89	-$ 5.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Level 3	300 mm exposed concretes floors and reverse brick veneer	$ 54,644.38	$ -	$ 54,644.38	538.3	2.9	$ 122.88	$ 81.78	$ 94.61	$ 104.33	$ 113.54	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02
Attached CZ5	Base case	200 mm concrete and carpet, brick veneer	$ 50,959.50		$ 50,959.50	401.2	2.7													
	Level 1	200 mm concrete and carpet, reverse brick veneer	$ 59,306.76	$ -	$ 59,306.76	398.3	2.8	$ 67.80	$ 14.06	$ 16.26	$ 17.93	$ 19.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Level 2	Increase concrete floor to 300mm and leave it expose	$ 53,011.15	$ -	$ 53,011.15	386.6	3.0	$ 208.30	$ 72.84	$ 84.26	$ 92.92	$ 101.12	0.03	0.04	0.04	0.04	0.04	0.04	0.05	0.05
	Level 3	300 mm exposed concretes floors and reverse brick veneer	$ 56,596.93	$ -	$ 56,596.93	387.1	2.9	$ 150.32	$ 70.28	$ 81.30	$ 89.66	$ 97.57	0.01	0.01	0.02	0.02	0.01	0.01	0.02	0.02
Attached CZ6	Base case	200 mm concrete and carpet, brick veneer	$ 54,307.95		$ 54,307.95	1351.8	2.7													
	Level 1	200 mm concrete and carpet, reverse brick veneer	$ 63,262.01	$ -	$ 63,262.01	1343.6	2.4	-$ 298.40	$ 40.89	$ 47.30	$ 52.16	$ 56.77	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01
	Level 2	Increase concrete floor to 300mm and leave it expose	$ 54,479.23	$ -	$ 54,479.23	1315.3	2.8	$ 153.21	$ 182.73	$ 211.39	$ 233.10	$ 253.69	0.56	0.65	0.72	0.79	1.07	1.23	1.36	1.48
	Level 3	300 mm exposed concretes floors and reverse brick veneer	$ 59,549.00	$ -	$ 59,549.00	1309.7	2.5	-$ 130.69	$ 210.84	$ 243.91	$ 268.97	$ 292.72	0.04	0.05	0.05	0.06	0.04	0.05	0.05	0.06
Attached CZ7	Base case	200 mm concrete and carpet, brick veneer	$ 54,307.95		$ 54,307.95	1346.2	2.1													
	Level 1	200 mm concrete and carpet, reverse brick veneer	$ 63,262.01	$ -	$ 63,262.01	1301.6	2.0	-$ 56.20	$ 223.62	$ 258.70	$ 285.27	$ 310.46	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.03
	Level 2	Increase concrete floor to 300mm and leave it expose	$ 54,479.23	$ -	$ 54,479.23	1374.2	2.1	$ 5.65	-$ 140.56	-$ 162.61	-$ 179.31	-$ 195.14	-0.79	-0.92	-1.01	-1.10	-0.82	-0.95	-1.05	-1.14

		Performance value	Base Construction Cost	HVAC sizing capital cost adjustment	Capital cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 yrs	BC Ratio - 15 yrs	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	Level 3	300 mm exposed concretes floors and reverse brick veneer	$ 59,549.00	$ -	$ 59,549.00	1327.6	2.0	-$ 49.36	$ 93.28	$ 107.91	$ 119.00	$ 129.50	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Detached CZ2	Base case	200 mm concrete and carpet & brick veneer	$ 54,678.09		$ 54,678.09	1164.1	4.0													
	Level 1	400 mm concrete and carpet & brick veneer	$ 67,311.65	$ -	$ 67,311.65	1166.1	3.9	-$ 55.75	-$ 10.14	-$ 11.73	-$ 12.94	-$ 14.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Level 2	200 mm concrete and carpet & reverse brick veneer	$ 63,731.50	-$ 230.00	$ 63,501.50	1003.9	3.4	-$ 581.19	$ 803.37	$ 929.40	$ 1,024.86	$ 1,115.35	0.10	0.11	0.12	0.14	0.09	0.11	0.12	0.13
	Level 3	400 mm concrete and carpet & reverse brick veneer	$ 76,367.08	-$ 230.00	$ 76,137.08	1007.5	3.4	-$ 574.28	$ 785.11	$ 908.27	$ 1,001.56	$ 1,090.00	0.04	0.04	0.05	0.05	0.04	0.04	0.05	0.05
Detached CZ5	Base case	200 mm concrete and carpet & brick veneer	$ 59,815.96		$ 59,815.96	919.7	3.6													
	Level 1	400 mm concrete and carpet & brick veneer	$ 73,283.95	$ -	$ 73,283.95	918.5	3.6	$ 42.37	$ 6.09	$ 7.04	$ 7.76	$ 8.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Level 2	200 mm concrete and carpet & reverse brick veneer	$ 67,657.13	$ -	$ 67,657.13	810.1	3.6	$ -	$ 549.78	$ 636.03	$ 701.35	$ 763.28	0.07	0.08	0.09	0.10	0.07	0.08	0.09	0.10
	Level 3	400 mm concrete and carpet & reverse brick veneer	$ 81,127.14	$ -	$ 81,127.14	810.5	3.3	-$ 281.01	$ 547.75	$ 633.68	$ 698.77	$ 760.46	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.04
Detached CZ6	Base case	200 mm concrete and carpet & brick veneer	$ 63,398.13		$ 63,398.13	2587.6	2.3													
	Level 1	400 mm concrete and carpet & brick veneer	$ 79,177.46	$ -	$ 79,177.46	2536.6	2.4	$ 49.06	$ 255.62	$ 295.72	$ 326.09	$ 354.88	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	Level 2	200 mm concrete and carpet & reverse brick veneer	$ 74,488.11	$ -	$ 74,488.11	2501.4	2.3	-$ 24.09	$ 432.12	$ 499.90	$ 551.25	$ 599.92	0.04	0.05	0.05	0.05	0.04	0.05	0.05	0.05
	Level 3	400 mm concrete and carpet & reverse brick veneer	$ 90,267.43	$ -	$ 90,267.43	2459.3	2.2	-$ 129.35	$ 643.10	$ 743.99	$ 820.40	$ 892.84	0.02	0.03	0.03	0.03	0.02	0.03	0.03	0.03
Detached CZ7	Base case	200 mm concrete and carpet & brick veneer	$ 63,398.13		$ 63,398.13	2668.5	4.1													
	Level 1	400 mm concrete and carpet & brick veneer	$ 79,177.46	-$ 230.00	$ 78,947.46	2622.0	3.8	-$ 328.73	$ 233.30	$ 269.90	$ 297.62	$ 323.90	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

		Performance value	Base Construction Cost	HVAC sizing capital cost adjustment	Capital cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 yrs	BC Ratio - 15 yrs	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	Level 2	200 mm concrete and carpet & reverse brick veneer	$ 74,488.11	-$ 230.00	$ 74,258.11	2651.5	3.6	-$ 517.63	$ 85.21	$ 98.57	$ 108.70	$ 118.29	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Level 3	400 mm concrete and carpet & reverse brick veneer	$ 90,267.43	-$ 460.00	$ 89,807.43	2673.4	3.4	-$ 688.02	-$ 24.34	-$ 28.16	-$ 31.06	-$ 33.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apartment CZ2	Base case	200 mm concrete and carpet, Brick veneer	$ 31,107.58		$ 31,107.58	342.5	4.1													
	Level 1	200 mm concrete and carpet, reverse Brick veneer	$ 33,556.55	$ -	$ 33,556.55	291.3	4.2	$ 98.13	$ 256.50	$ 296.74	$ 327.22	$ 356.11	0.10	0.12	0.13	0.14	0.10	0.12	0.13	0.15
	Level 2	Increase concrete floor to 300mm and leave it expose	$ 33,266.03	$ -	$ 33,266.03	312.8	3.9	-$ 148.75	$ 148.50	$ 171.80	$ 189.44	$ 206.17	0.07	0.09	0.09	0.10	0.07	0.08	0.09	0.10
	Level 3	300 mm exposed concretes floors and reverse brick veneer	$ 35,715.00	$ -	$ 35,715.00	277.3	3.9	-$ 136.27	$ 326.53	$ 377.75	$ 416.55	$ 453.33	0.07	0.08	0.09	0.10	0.07	0.08	0.09	0.10
Apartment CZ5	Base case	200 mm concrete and carpet, Brick veneer	$ 33,252.16		$ 33,252.16	310.8	1.0													
	Level 1	200 mm concrete and carpet, reverse Brick veneer	$ 35,373.62	$ -	$ 35,373.62	271.1	0.9	-$ 96.12	$ 199.13	$ 230.36	$ 254.02	$ 276.45	0.10	0.11	0.13	0.14	0.09	0.11	0.12	0.13
	Level 2	Increase concrete floor to 300mm and leave it expose	$ 34,756.37	$ -	$ 34,756.37	286.8	0.9	-$ 73.82	$ 120.66	$ 139.58	$ 153.92	$ 167.51	0.08	0.10	0.11	0.12	0.08	0.09	0.10	0.11
	Level 3	300 mm exposed concretes floors and reverse brick veneer	$ 36,877.83	$ -	$ 36,877.83	259.0	0.9	-$ 145.41	$ 259.88	$ 300.64	$ 331.52	$ 360.79	0.07	0.09	0.10	0.10	0.07	0.08	0.09	0.10
Apartment CZ6	Base case	200 mm concrete and carpet, Brick veneer	$ 34,697.81		$ 34,697.81	967.8	1.5													
	Level 1	200 mm concrete and carpet, reverse Brick veneer	$ 37,696.98	$ -	$ 37,696.98	918.3	1.4	-$ 99.69	$ 248.06	$ 286.98	$ 316.45	$ 344.39	0.09	0.10	0.11	0.12	0.08	0.10	0.11	0.11
	Level 2	Increase concrete floor to 300mm and leave it expose	$ 36,066.39	$ -	$ 36,066.39	927.9	1.4	-$ 49.73	$ 199.97	$ 231.34	$ 255.10	$ 277.62	0.15	0.18	0.19	0.21	0.15	0.17	0.19	0.20
	Level 3	300 mm exposed concretes floors and reverse brick veneer	$ 39,066.34	$ -	$ 39,066.34	895.6	1.3	-$ 134.04	$ 361.97	$ 418.75	$ 461.76	$ 502.53	0.09	0.10	0.11	0.12	0.08	0.10	0.11	0.12
Apartment CZ7	Base case	200 mm concrete and carpet, Brick veneer	$ 34,697.81		$ 34,697.81	1510.5	2.5													

		Performance value	Base Construction Cost	HVAC sizing capital cost adjustment	Capital cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 yrs	BC Ratio - 15 yrs	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	Level 1	200 mm concrete and carpet, reverse Brick veneer	$ 37,696.98	$ -	$ 37,696.98	1384.3	2.4	-$ 71.37	$ 632.81	$ 732.08	$ 807.28	$ 878.56	0.22	0.25	0.28	0.30	0.21	0.24	0.27	0.29
	Level 2	Increase concrete floor to 300mm and leave it expose	$ 36,066.39	$ -	$ 36,066.39	1312.8	2.4	-$ 106.60	$ 991.41	$ 1,146.93	$ 1,264.73	$ 1,376.40	0.79	0.91	1.00	1.09	0.72	0.84	0.92	1.01
	Level 3	300 mm exposed concretes floors and reverse brick veneer	$ 39,066.34	$ -	$ 39,066.34	1224.0	2.3	-$ 146.75	$ 1,436.91	$ 1,662.31	$ 1,833.06	$ 1,994.91	0.34	0.39	0.43	0.47	0.33	0.38	0.42	0.46

E.11 Lighting

E.11.1 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.

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.

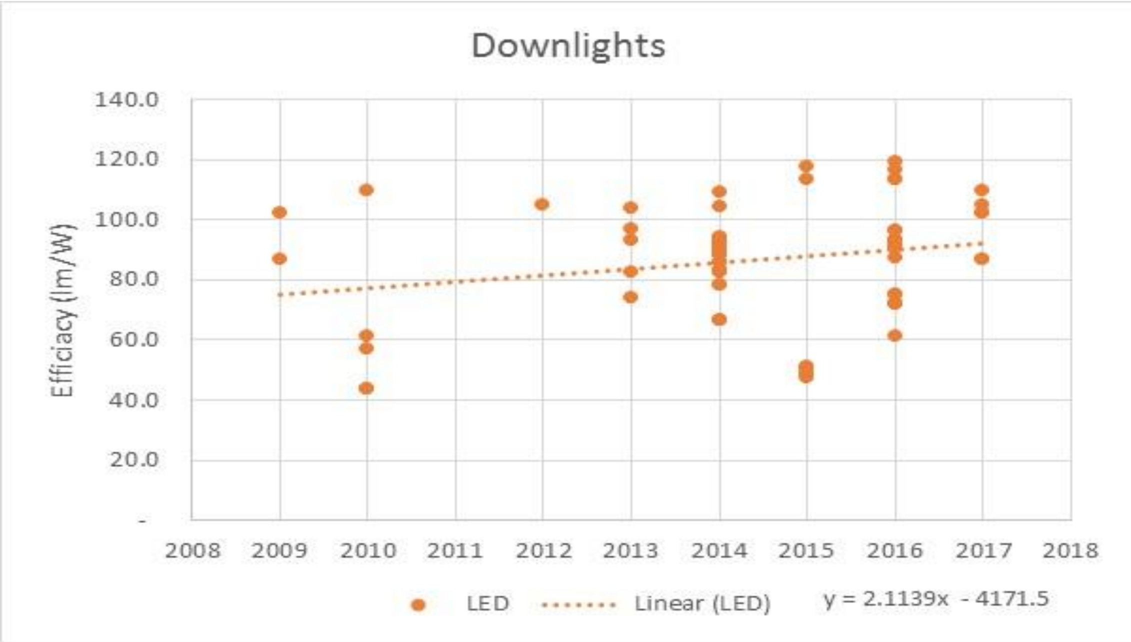

Figure 88: Pricing learning rate for LED down lights over time

According to the graph in Figure 88 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.

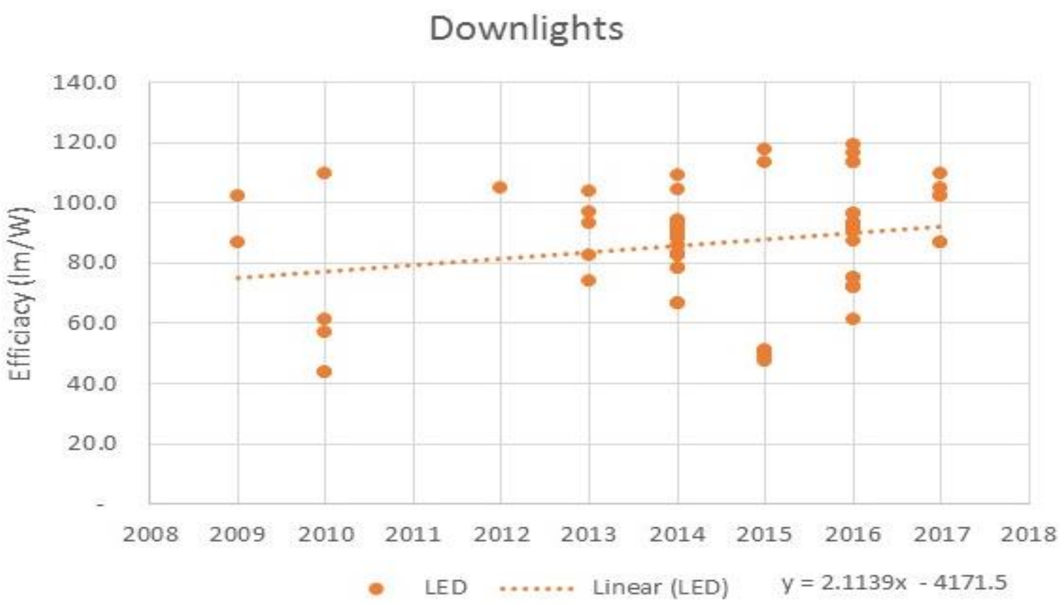

Figure 89: Efficacy learning rate for LED down lights over time

According to the graph in Figure 89, 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.

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 4-74. Lighting annual energy demand for CFL and LED technologies for each archetype.

	Design Technology	Details	Lighting Power Density (W/m²)	Annual Energy (kWh/year)	Annual Energy Density (kWh/m²/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/m²/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/m²/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/m²/year)				0.46

E.11.2 Benefit Cost Analysis

		Performance value (e.g. R value)	Base Construction Cost	HVAC sizing capital cost adjustment	Capital Cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
Attached	Base case	CFL	$ 2,677.15		$ 2,677.15	526.0	0.3													
	Level 1	LED	$ 3,034.50	$ -	$ 3,034.50	406.0	0.2	-$ 75.15	$ 368.48	$ 430.75	$ 486.93	$ 542.64	1.31	negative cost	negative cost	negative cost	0.00	0.00	0.00	0.00
Detached	Base case	CFL	$ 3,518.54		$ 3,518.54	760.0	0.4													
	Level 1	LED	$ 3,974.60	$ -	$ 3,974.60	594.0	0.3	-$ 90.56	$ 509.73	$ 595.87	$ 673.58	$ 750.65	1.39	negative cost	negative cost	negative cost	0.00	0.00	0.00	0.00
Apartment	Base case	CFL	$ 2,065.23		$ 2,065.23	270.0	0.2													
	Level 1	LED	$ 2,092.65	$ -	$ 2,092.65	203.0	0.1	-$ 41.91	$ 205.73	$ 240.50	$ 271.87	$ 302.97	negative cost	negative cost	negative cost	negative cost	0.00	0.00	0.00	0.00

Table 4-75. 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.

E.12 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.

E.12.1 Scenario Formulation

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

Table 4-76. 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

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 1.8kWh/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 4-77. DHW energy use calculations for the townhouse

Technology	Annual water use (litres)	Water use energy (kWhe)	Standing losses (kWhth)	Standing losses (kWhe)	Annual energy use (kWhe)
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 4-78: DHW calculations for the detached house.

Technology	Annual water use (litres)	Water use energy (kWhe)	Standing losses (kWhth)	Standing losses (kWhe)	Annual energy use (kWhe)
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.

E.12.2 Results – Baseline Analysis

All three upgraded technologies are cost effective relative to direct electric heating, as shown in Figure 90.

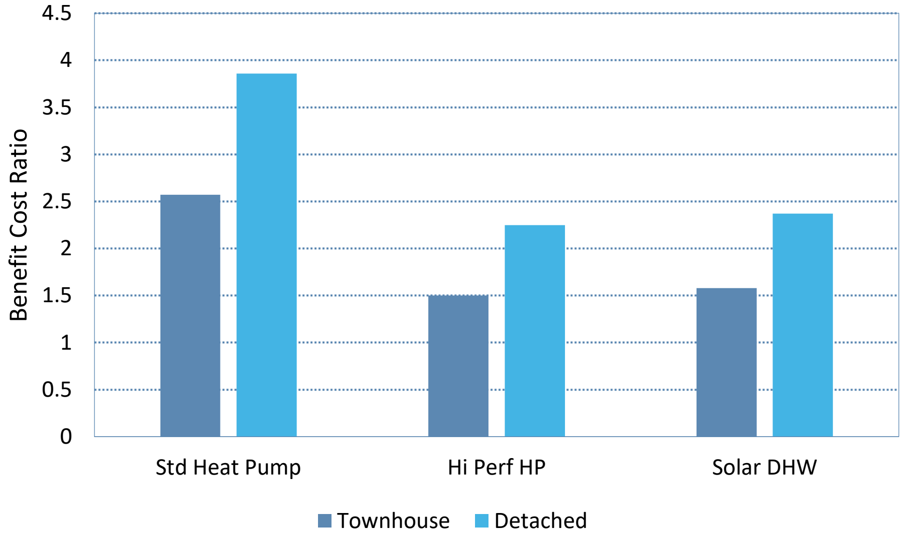

Figure 90: Benefit cost results for DHW technologies relative to direct electric.

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 water51, 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.

E.12.3 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).

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 CO2 units. As there are few technical differences between the R134a and CO2 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.

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51 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

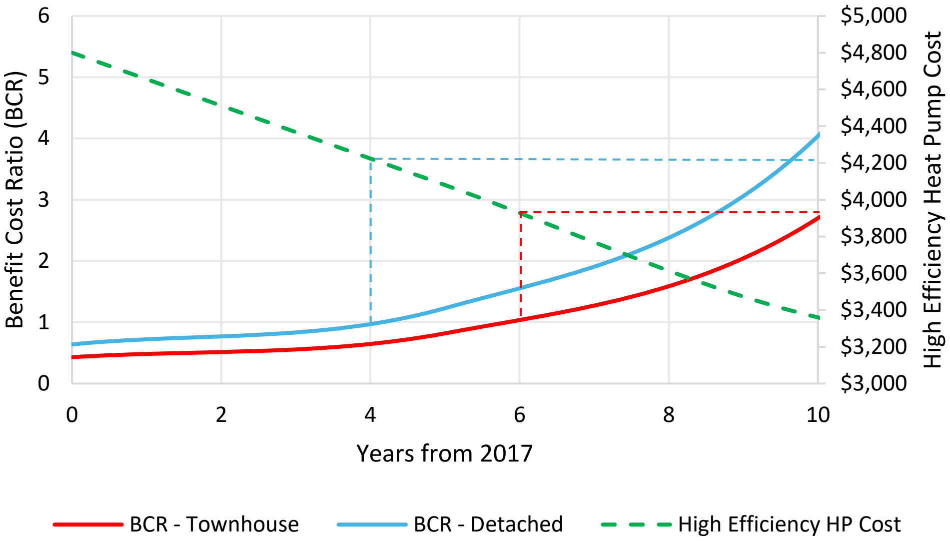

Figure 91: Projected future economics of high efficiency heat pumps (relative to standard heat pumps) based on an assumed learning curve for capital cost. It can be seen that the technology is expected to become cost effective relative to standard heat pumps win 4-6 years at a capital cost of $3900-$4200.

E.13 Photovoltaics (PV) Analysis

E.13.1 Analysis

The benefit of using PV systems for the attached and detached residential archetypes was analysed using online PVWatts calculator14F52 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 23 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°. 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 m² for the detached archetype, 14.5 m² for the attached archetype), as were the East and West facing sections (37 m² for the detached archetype and 29 m² 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).

Table 4-79. 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

52 http://pvwatts.nrel.gov/pvwatts.php

Table 4-80. Roof areas of the Attached and Detached houses (0 degree orientation).

Orientation	Detached house			Attached house		
	Roof area (m²)	Roof pitch (o)	DC system size* (kW)	Roof area (m²)	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 (m²) × 1 kW/m² × Module Efficiency (%), based on average roof sizes of 80m² and 37m² 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 25 to Table 27 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 4-81. 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 4-82. 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 4-83. 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 4-81 to Table 4-83 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 4-84: 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 4-85. 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 4-86. 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

E.13.2 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.

E.13.3 Benefit Cost Analysis

		Performance value	Base Construction Cost	HVAC sizing capital cost adjustment	Capital cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 yrs	BC Ratio - 15 yrs	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
Attached CZ2	Base case	No PV	$ -		$ -	0.0	0.0													
	Level 1	PV - full export	$ -	$ 8,625.00	$ 8,625.00	-1650.6	0.0	$ -	$ 5,160.11	$ 5,866.43	$ 6,336.34	$ 6,656.89	0.60	0.85	1.22	1.29	0.60	0.85	1.22	1.29
	Level 2	PV - full internal use	$ -	$ 8,625.00	$ 8,625.00	-5187.5	0.0	$ -	$ 16,217.50	$ 18,437.37	$ 19,914.22	$ 20,921.66	1.88	2.67	3.85	4.04	1.88	2.67	3.85	4.04
	Level 3	PV - 0yr partial	$ -	$ 8,625.00	$ 8,625.00	-3447.3	0.0	$ -	$ 10,777.27	$ 12,252.47	$ 13,233.90	$ 13,903.39	1.25	1.78	2.56	2.69	1.25	1.78	2.56	2.69
	Level 4	PV - 5yr partial	$ -	$ 8,625.00	$ 8,625.00	-2426.9	0.0	$ -	$ 7,587.21	$ 8,625.75	$ 9,316.68	$ 9,788.01	0.88	1.25	1.80	1.89	0.88	1.25	1.80	1.89
Attached CZ5	Base case	No PV	$ -		$ -	0.0	0.0													
	Level 1	PV - full export	$ -	$ 8,625.00	$ 8,625.00	-1494.5	0.0	$ -	$ 4,672.20	$ 5,311.74	$ 5,737.21	$ 6,027.45	0.54	0.77	1.11	1.16	0.54	0.77	1.11	1.16
	Level 2	PV - full internal use	$ -	$ 8,625.00	$ 8,625.00	-4697.0	0.0	$ -	$ 14,684.07	$ 16,694.03	$ 18,031.24	$ 18,943.43	1.70	2.42	3.48	3.66	1.70	2.42	3.48	3.66
	Level 3	PV - 0yr partial	$ -	$ 8,625.00	$ 8,625.00	-3448.0	0.0	$ -	$ 10,779.44	$ 12,254.94	$ 13,236.57	$ 13,906.20	1.25	1.78	2.56	2.69	1.25	1.78	2.56	2.69
	Level 4	PV - 5yr partial	$ -	$ 8,625.00	$ 8,625.00	-2426.4	0.0	$ -	$ 7,585.65	$ 8,623.99	$ 9,314.78	$ 9,786.00	0.88	1.25	1.80	1.89	0.88	1.25	1.80	1.89
Attached CZ6	Base case	No PV	$ -		$ -	0.0	0.0													
	Level 1	PV - full export	$ -	$ 8,625.00	$ 8,625.00	-1471.8	0.0	$ -	$ 4,601.08	$ 5,230.88	$ 5,649.88	$ 5,935.70	0.53	0.76	1.09	1.15	0.53	0.76	1.09	1.15
	Level 2	PV - full internal use	$ -	$ 8,625.00	$ 8,625.00	-4625.5	0.0	$ -	$ 14,460.54	$ 16,439.91	$ 17,756.76	$ 18,655.06	1.68	2.38	3.43	3.60	1.68	2.38	3.43	3.60
	Level 3	PV - 0yr partial	$ -	$ 8,625.00	$ 8,625.00	-3447.6	0.0	$ -	$ 10,778.03	$ 12,253.34	$ 13,234.84	$ 13,904.38	1.25	1.78	2.56	2.69	1.25	1.78	2.56	2.69
	Level 4	PV - 5yr partial	$ -	$ 8,625.00	$ 8,625.00	-2427.3	0.0	$ -	$ 7,588.50	$ 8,627.22	$ 9,318.26	$ 9,789.67	0.88	1.25	1.80	1.89	0.88	1.25	1.80	1.89
Attached CZ7	Base case	No PV	$ -		$ -	0.0	0.0													
	Level 1	PV - full export	$ -	$ 8,625.00	$ 8,625.00	-1667.3	0.0	$ -	$ 5,212.34	$ 5,925.81	$ 6,400.47	$ 6,724.26	0.60	0.86	1.24	1.30	0.60	0.86	1.24	1.30
	Level 2	PV - full internal use	$ -	$ 8,625.00	$ 8,625.00	-5240.0	0.0	$ -	$ 16,381.63	$ 18,623.96	$ 20,115.76	$ 21,133.40	1.90	2.70	3.89	4.08	1.90	2.70	3.89	4.08

		Performance value	Base Construction Cost	HVAC sizing capital cost adjustment	Capital cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 yrs	BC Ratio - 15 yrs	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	Level 3	PV - 0yr partial	$ -	$ 8,625.00	$ 8,625.00	-3448.3	0.0	$ -	$ 10,780.23	$ 12,255.84	$ 13,237.54	$ 13,907.22	1.25	1.78	2.56	2.69	1.25	1.78	2.56	2.69
	Level 4	PV - 5yr partial	$ -	$ 8,625.00	$ 8,625.00	-2426.5	0.0	$ -	$ 7,585.81	$ 8,624.16	$ 9,314.97	$ 9,786.20	0.88	1.25	1.80	1.89	0.88	1.25	1.80	1.89
Detached CZ2	Base case	No PV	$ -		$ -	0.0	0.0													
	Level 1	PV - full export	$ -	$ 30,187.50	$ 30,187.50	-5778.2	0.0	$ -	$ 18,064.13	$ 20,536.76	$ 22,181.77	$ 23,303.93	0.60	0.85	1.22	1.29	0.60	0.85	1.22	1.29
	Level 2	PV - full internal use	$ -	$ 30,187.50	$ 30,187.50	-18160.0	0.0	$ -	$ 56,772.97	$ 64,544.11	$ 69,714.15	$ 73,240.93	1.88	2.67	3.85	4.04	1.88	2.67	3.85	4.04
	Level 3	PV - 0yr partial	$ -	$ 30,187.50	$ 30,187.50	-12068.1	0.0	$ -	$ 37,728.22	$ 42,892.49	$ 46,328.22	$ 48,671.93	1.25	1.78	2.56	2.69	1.25	1.78	2.56	2.69
	Level 4	PV - 5yr partial	$ -	$ 30,187.50	$ 30,187.50	-8496.0	0.0	$ -	$ 26,560.72	$ 30,196.37	$ 32,615.13	$ 34,265.10	0.88	1.25	1.80	1.89	0.88	1.25	1.80	1.89
Detached CZ5	Base case	No PV	$ -		$ -	0.0	0.0													
	Level 1	PV - full export	$ -	$ 30,187.50	$ 30,187.50	-5230.6	0.0	$ -	$ 16,352.21	$ 18,590.52	$ 20,079.64	$ 21,095.45	0.54	0.77	1.11	1.16	0.54	0.77	1.11	1.16
	Level 2	PV - full internal use	$ -	$ 30,187.50	$ 30,187.50	-16439.0	0.0	$ -	$ 51,392.67	$ 58,427.34	$ 63,107.43	$ 66,299.98	1.70	2.42	3.48	3.66	1.70	2.42	3.48	3.66
	Level 3	PV - 0yr partial	$ -	$ 30,187.50	$ 30,187.50	-12067.7	0.0	$ -	$ 37,726.89	$ 42,890.98	$ 46,326.59	$ 48,670.21	1.25	1.78	2.56	2.69	1.25	1.78	2.56	2.69
	Level 4	PV - 5yr partial	$ -	$ 30,187.50	$ 30,187.50	-8492.2	0.0	$ -	$ 26,548.98	$ 30,183.04	$ 32,600.72	$ 34,249.97	0.88	1.25	1.80	1.89	0.88	1.25	1.80	1.89
Detached CZ6	Base case	No PV	$ -		$ -	0.0	0.0													
	Level 1	PV - full export	$ -	$ 30,187.50	$ 30,187.50	-5148.7	0.0	$ -	$ 16,096.07	$ 18,299.32	$ 19,765.11	$ 20,765.01	0.53	0.76	1.09	1.15	0.53	0.76	1.09	1.15
	Level 2	PV - full internal use	$ -	$ 30,187.50	$ 30,187.50	-16181.5	0.0	$ -	$ 50,587.65	$ 57,512.14	$ 62,118.91	$ 65,261.46	1.68	2.38	3.43	3.60	1.68	2.38	3.43	3.60
	Level 3	PV - 0yr partial	$ -	$ 30,187.50	$ 30,187.50	-12066.3	0.0	$ -	$ 37,722.29	$ 42,885.76	$ 46,320.95	$ 48,664.28	1.25	1.78	2.56	2.69	1.25	1.78	2.56	2.69
	Level 4	PV - 5yr partial	$ -	$ 30,187.50	$ 30,187.50	-8491.6	0.0	$ -	$ 26,547.02	$ 30,180.80	$ 32,598.31	$ 34,247.43	0.88	1.25	1.80	1.89	0.88	1.25	1.80	1.89
Detached CZ7	Base case	No PV	$ -		$ -	0.0	0.0													

		Performance value	Base Construction Cost	HVAC sizing capital cost adjustment	Capital cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 yrs	BC Ratio - 15 yrs	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	Level 1	PV - full export	$ -	$ 30,762.50	$ 30,762.50	-5832.9	0.0	$ -	$ 18,235.22	$ 20,731.27	$ 22,391.87	$ 23,524.65	0.59	0.84	1.21	1.27	0.59	0.84	1.21	1.27
	Level 2	PV - full internal use	$ -	$ 30,762.50	$ 30,762.50	-18332.0	0.0	$ -	$ 57,310.69	$ 65,155.43	$ 70,374.44	$ 73,934.62	1.86	2.65	3.81	4.01	1.86	2.65	3.81	4.01
	Level 3	PV - 0yr partial	$ -	$ 30,762.50	$ 30,762.50	-12301.2	0.0	$ -	$ 38,456.77	$ 43,720.77	$ 47,222.85	$ 49,611.81	1.25	1.78	2.56	2.69	1.25	1.78	2.56	2.69
	Level 4	PV - 5yr partial	$ -	$ 30,762.50	$ 30,762.50	-8652.7	0.0	$ -	$ 27,050.64	$ 30,753.36	$ 33,216.73	$ 34,897.14	0.88	1.25	1.80	1.89	0.88	1.25	1.80	1.89

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.

E.14 Ceiling fans

E.14.1 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

E.14.2 Cost Benefit Analysis

		Performance value (e.g. R value)	Base Construction Cost	HVAC sizing capital cost adjustment	Capital Cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
Attached CZ2	Base case	0	$ -		$ -	554.6	2.8													
	Level 1	2 x 1200mm 3 x 900mm	$ 656.00	$ -	$ 656.00	358.3	2.7	-$ 75.83	$ 826.58	$ 955.22	$ 1,069.70	$ 1,180.53	1.42	1.65	1.84	2.03	1.26	1.46	1.63	1.80
Attached CZ5	Base case	0	$ -		$ -	401.2	2.7													
	Level 1	2 x 1200mm 3 x 900mm	$ 640.00	$ -	$ 640.00	302.0	2.8	$ 13.60	$ 417.58	$ 482.57	$ 540.41	$ 596.40	0.64	0.74	0.83	0.91	0.65	0.75	0.84	0.93
Attached CZ6	Base case	0	$ -		$ -	1351.8	2.7													
	Level 1	2 x 1200mm 3 x 900mm	$ 580.00	$ -	$ 580.00	1320.7	2.4	-$ 303.08	$ 130.96	$ 151.35	$ 169.48	$ 187.04	0.47	0.55	0.60	0.66	0.23	0.26	0.29	0.32
Detached CZ2	Base case	0	$ -		$ -	1164.1	4.0													
	Level 1	1 x 1400 mm 2 x 1200mm 5 x 900mm	$ 1,027.00	$ -	$ 1,027.00	849.7	3.9	-$ 11.60	$ 1,324.24	$ 1,530.33	$ 1,713.74	$ 1,891.30	1.30	1.51	1.69	1.86	1.29	1.49	1.67	1.84
Detached CZ5	Base case	0	$ -		$ -	919.7	3.6													
	Level 1	1 x 1400 mm 2 x 1200mm 5 x 900mm	$ 1,003.00	-$ 690.00	$ 313.00	737.6	2.5	-$ 1,001.36	$ 766.93	$ 886.29	$ 992.51	$ 1,095.35	negative cost	negative cost	negative cost	negative cost	2.45	2.83	3.17	3.50
Detached CZ6	Base case	0	$ -		$ -	2587.6	2.3													
	Level 1	1 x 1400 mm 2 x 1200mm 5 x 900mm	$ 913.00	$ -	$ 913.00	2541.1	2.0	-$ 256.47	$ 195.99	$ 226.50	$ 253.64	$ 279.92	0.30	0.34	0.38	0.42	0.21	0.25	0.28	0.31
Apartment CZ2	Base case	1 x 1200mm 3 x 900mm 3 x 900mm	$ 499.00		$ 499.00	342.5	3.5													

		Performance value (e.g. R value)	Base Construction Cost	HVAC sizing capital cost adjustment	Capital Cost (not inc network adjustments)	Energy Use (kWh)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	Level 1	0	$ -	$ -	$ -	341.3	3.4	-$ 46.83	$ 4.96	$ 5.73	$ 6.42	$ 7.09	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
Apartment CZ5	Base case	1 x 1200mm 3 x 900mm 3 x 900mm	$ 487.00		$ 487.00	310.8	2.2													
	Level 1	0	$ -	$ -	$ -	312.0	2.2	-$ 42.37	-$ 4.96	-$ 5.73	-$ 6.42	-$ 7.09	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
Apartment CZ6	Base case	1 x 1200mm 3 x 900mm 3 x 900mm	$ 442.00		$ 442.00	967.8	2.1													
	Level 1	0	$ -	$ -	$ -	977.1	2.1	-$ 17.84	-$ 38.99	-$ 45.05	-$ 50.45	-$ 55.68	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost

E.15 Energy Efficiency Ratio for Residential air conditioning (HVAC)

E.15.1 Background and Scope

Air conditioning systems make up a significant proportion of residential energy use in Australian homes on account of the hot climate. Currently, there exist regulatory standards defining the minimum EER for each type of air conditioning system. Split units or ducted splits are the most typical air conditioning systems found in homes due to the conditioned area requirement. For the purpose of this study, only the currently available ducted splits systems will be investigated. This is because they typically have the suitable cooling and heating capacity to service one residential building on its own, as opposed to split units, which usually require multiple units for separate rooms.

E.15.2 Objective

The current minimum EER rating in Australia for ducted split systems is 3.10 (E3, 2016). This study will review the state of the current ducted splits market in Australia by comparison against a determined baseline to identify the trajectory for future energy efficiency ratio improvements and provide recommendations for setting the minimum EER standard in the NCC for 2019.

E.15.3 Methodology

Cost and efficiency data for a sample of 86 different single phase ducted split systems were collected from Australian retailers. A baseline case was determined from the group lying in the lower quartile of EER ratings of the sample. To account for economic viability, only units with a BCR (benefit cost ratio) greater than 1 or negative cost will be analysed. Using this base case to determine a baseline cost, the BCRs for all units were calculated in 9 separate scenarios (3 climate zones and 3 archetypes). Units with a BCR greater than 1 or having negative cost were then segmented to obtain their EER distribution, from which a recommendation for the minimum EER target for NCC 2019 was determined.

E.15.4 Base Case

The EER versus the cost per kW capacity of cooling is plotted below for the sample with the current minimum EER standard shown as a line.

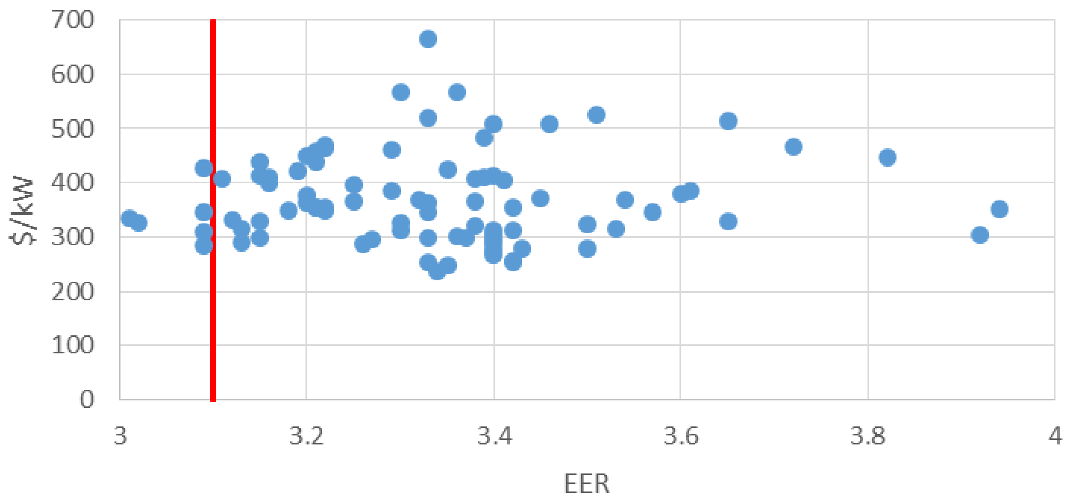

Figure 92Comparison of EER to cost per kW cooling capacity of ducted split units. The red line indicates the current minimum EER standard of 3.1

The lower quartile of in terms of EER were identified and their cost per kW capacity was plotted as a function of cooling capacity to determine the base case function for cost per kW capacity.

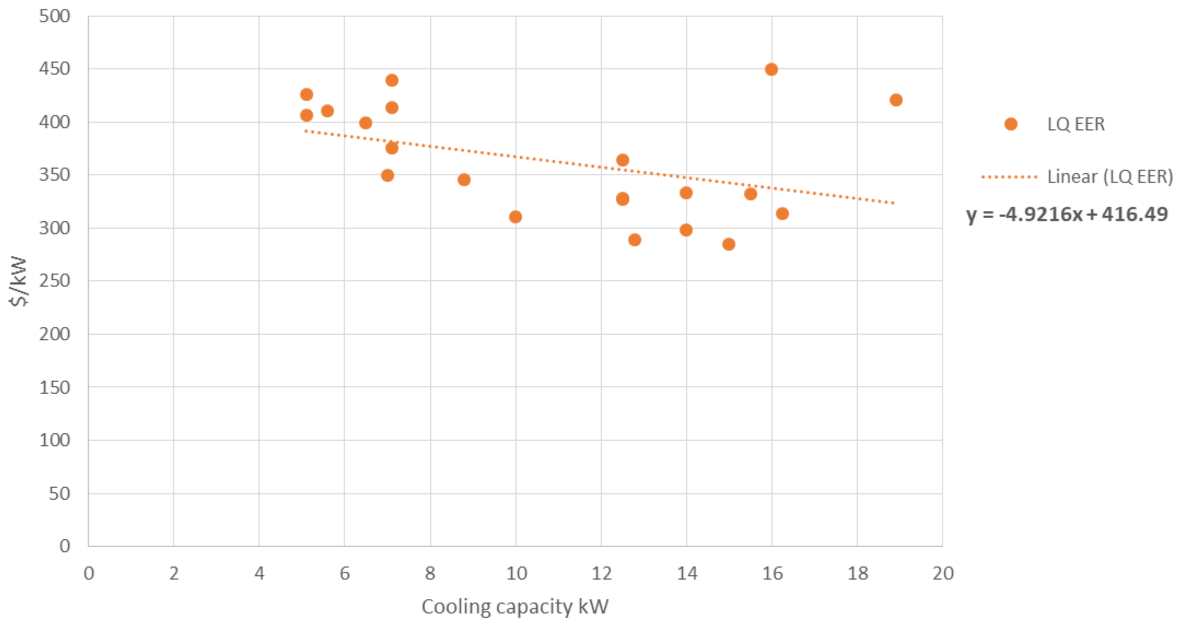

Figure 93 $/kW as a function of cooling capacity to determine base case ducted split units

The baseline cost is hence:

$$Baseline\ cost\ (\$) = -4.9216\left(\frac{\$}{kW}\right) * Cooling\ Capacity\ (kW) + 416.49\ (\$)$$

The baseline EER was taken as the average EER of the lower quartile which was 3.13.

E.15.5 Benefit Cost Analysis

All 86 units were compared with the baseline cost and those with a positive incremental cost were extracted to calculate their BCRs. The BCR is a function of both the energy savings and incremental cost. The energy savings from a unit compared to the base case depends on the reduction in annual electricity usage and demand savings from a lower peak electricity demand because of the higher EER. Both these factors depend on the 3 different archetypes (apartment, attached and detached) and 3 different climate zones (2, 5 and 6) since they determine the air conditioning loads. Therefore, this gives rise to 9 different scenarios each with different annual heating and cooling demands.

Base case construction costs were zeroed by assuming that installation costs are equal across the board so that only incremental costs were taken as the construction cost.

A technology lifecycle of 15 years was applied at a discount rate of 7%.

E.15.6 Results

The number of units with BCR>1 or negative cost across the 9 scenarios range from 45-59 and their EER distributions are shown below.

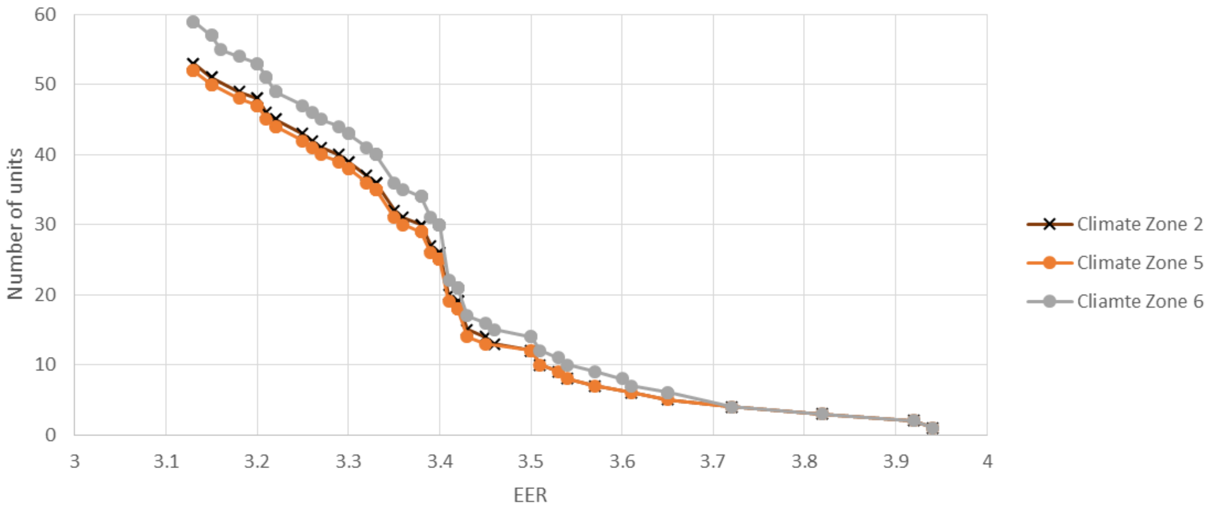

Figure 94 EER Distribution of Units with BCR>1 or having negative cost for Detached Archetype

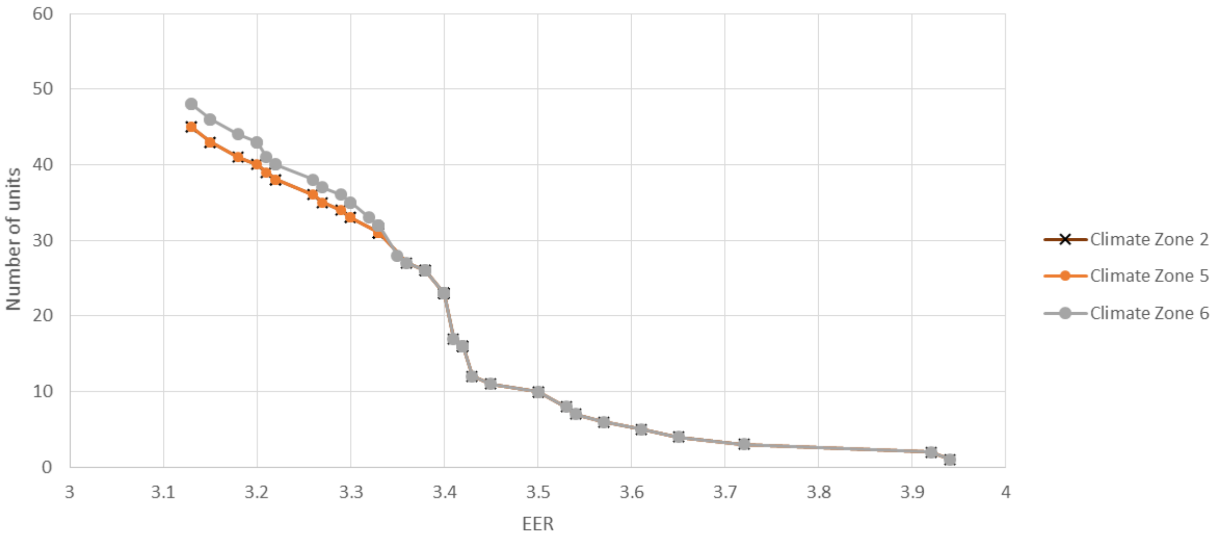

Figure 95 EER Distribution of Units with BCR>1 or having negative cost for Apartment Archetype

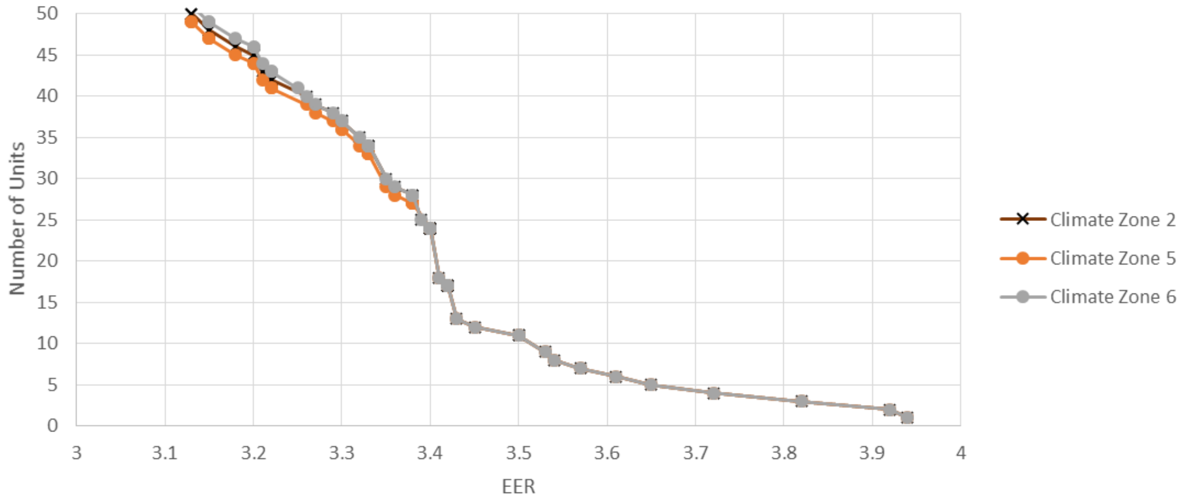

Figure 96 EER Distribution of Units with BCR>1 or having negative cost for Attached Archetype

The similarity in shape between the three curves suggest that the archetype and climate zone is not a major factor in ducted split units' EER distribution. For all three archetypes, it appears that the dividing EER between market leading units and the rest is 3.4.

Table 4-87 Proportions of units with BCR>1 or negative cost that have EER above various limits

EER Limit	Attached			Detached			Apartment		
	CZ 2	CZ 5	CZ 6	CZ 2	CZ 5	CZ 6	CZ 2	CZ 5	CZ 6
3.1	100%	100%	100%	100%	100%	100%	100%	100%	100%
3.25	80%	80%	80%	81%	81%	80%	80%	80%	79%
3.4	48%	49%	47%	49%	48%	51%	51%	51%	48%
3.5	22%	22%	22%	22.6%	23%	24%	22%	22%	21%

The large range of EERs with units that almost reach 4 indicates that 3.4 is well within the technological reach of current manufacturers. Over 20% of the sample range have EERs between 3.5 and 4. This suggests there is a potential to extend the minimum EER standard towards 4 in the near future. [53][54]

[53] E3, 2016, Air conditioners and chillers: Updated policy positions, http://www.energyrating.gov.au/sites/new.energyrating/files/documents/161123-consultation-ris-air-conditioners-and-chillers-updated-policy-proposals.pdf Accessed 19 February 2018

[54] E3, 2016, Consultation Regulatory Impact Statement – air-conditioners and chillers.http://www.energyrating.gov.au/sites/new.energyrating/files/documents/221215_Consultation_RIS_-_air_conditioners_and_chillers2_1.pdf. Accessed 19 February 2018

E.15.7 Future Economic Scenarios

The efficiency of air-conditioners has been improving at a significant rate over the past decade, as shown in Figure 97. The efficiency improvement shown in the figure from 2007-2014 is equivalent to an improvement in EER by 0.14 each year (approximately 4%). For the purposes of comparison with our data sample, which uses less efficient ducted air-conditioners as a basis, this translates to an improvement of 0.1 per year. Taking a simple extrapolation would suggest therefore that the EER for this group of air-conditioners could reach 4.9 in 15 years' time; this number seems plausible given that some small splits are already performing at this level. As a result, the projected EERs for 5, 10 and 15 years are 3.9, 4.4 and 4.9. This is in effect a technology learning rate assumption, i.e. the economics achieved at an EER of 3.4 are expected to be comparable at these higher EERs in the future.

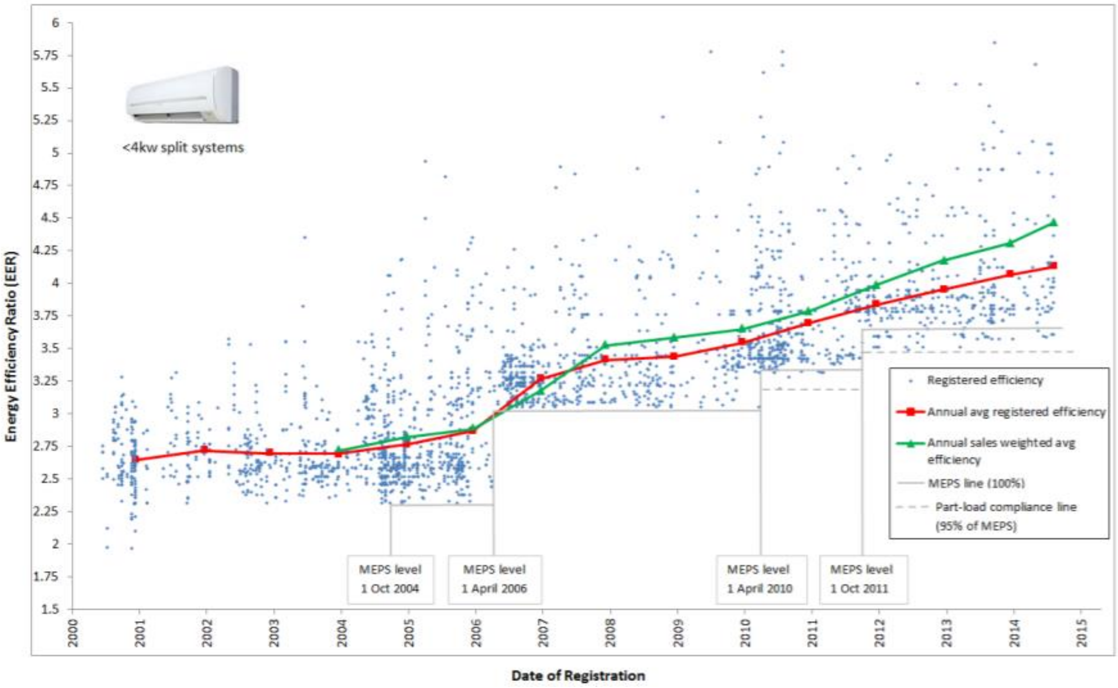

Figure 97. Cooling EERs – Split air-conditioners available in Australia 2000-2014. Source: Consultation Regulatory Impact Statement – air-conditioners and chillers, E3, February 2016. Original data sourced from Energy Rating Database www.energyrating.gov.au August 2014

Table 4-88 Modelled HVAC EER

Scenario	Base	0	5	10	15
EER	3.4	3.4	3.9	4.4	4.9

Appendix F - Commercial Methodology Details

F.1 Commercial Archetype Details

The modelling for the commercial baseline archetypes were developed 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.

F.1.1 Hotel - Class 3 Form B (3B)

The following figure shows the geometry (building form B) created for hotel building simulation. This model represents a hotel building that has 2000m², 3 storeys, 36.5m x 18.3m floor plate and 3.6m floor-floor height.

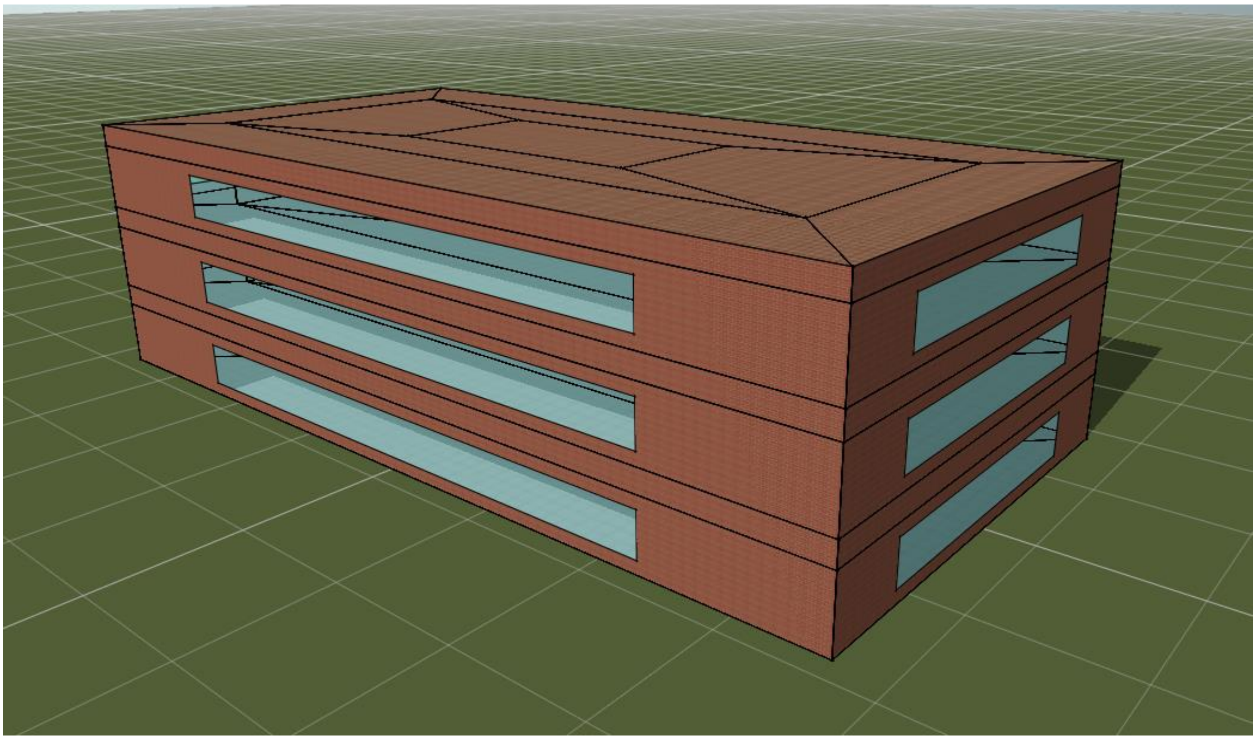

Figure 98: Building form B geometry as viewed in the IES <VE> software.

IWEC files for Brisbane, Sydney and Melbourne were used as the weather data for the simulation. 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. The internal load densities and the associated operating schedules are listed below.

Table 4-89. 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/m²
Occupants	75W sensible heat gain per person 55W latent heat gain per person Number of occupants: 17.5 m²/person
Artificial lighting	2.5 W/m² (Sole-occupancy unit of a Class 3 building)

Table 4-90. 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%

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.

F.1.2 Office - Class 5 Form A (5A)

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

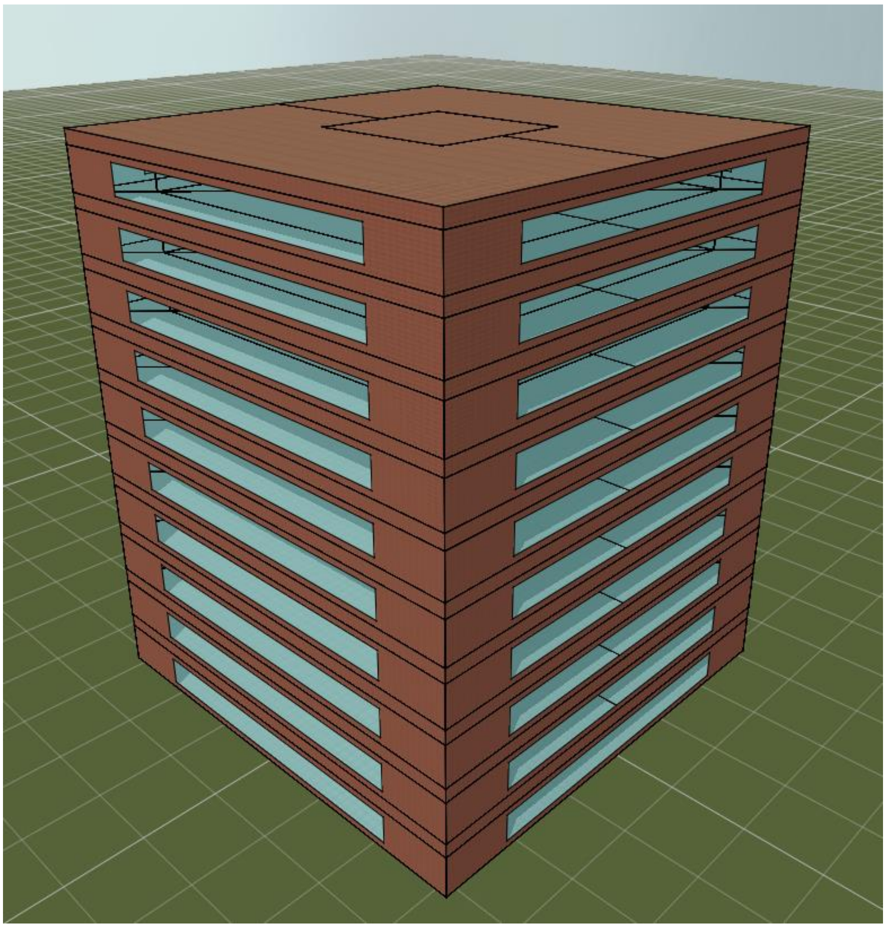

Figure 99: Building form A geometry as viewed in the IES <VE> software.

This model represents an office building that has 10,000m², 10 storeys, 31.6m x 31.6m floor plate and 3.6m floor-floor height. IWEC files for Brisbane, Sydney and Melbourne were used as the weather data for the simulation. 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. The internal load densities and the associated operating schedules are listed below.

Table 4-91. Internal loads for class 5 (office) buildings with proposed NCC 2019 lighting illumination power densities.

Type	Heat Gain
Equipment	11W/m²
Occupants	75W sensible heat gain 55W latent heat gain per person Number of occupants: 14 m²/person
Artificial lighting	4.5 W/m²

Table 4-92. 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".

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.

F.1.3 Retail - Class 6 Form C (6C)

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

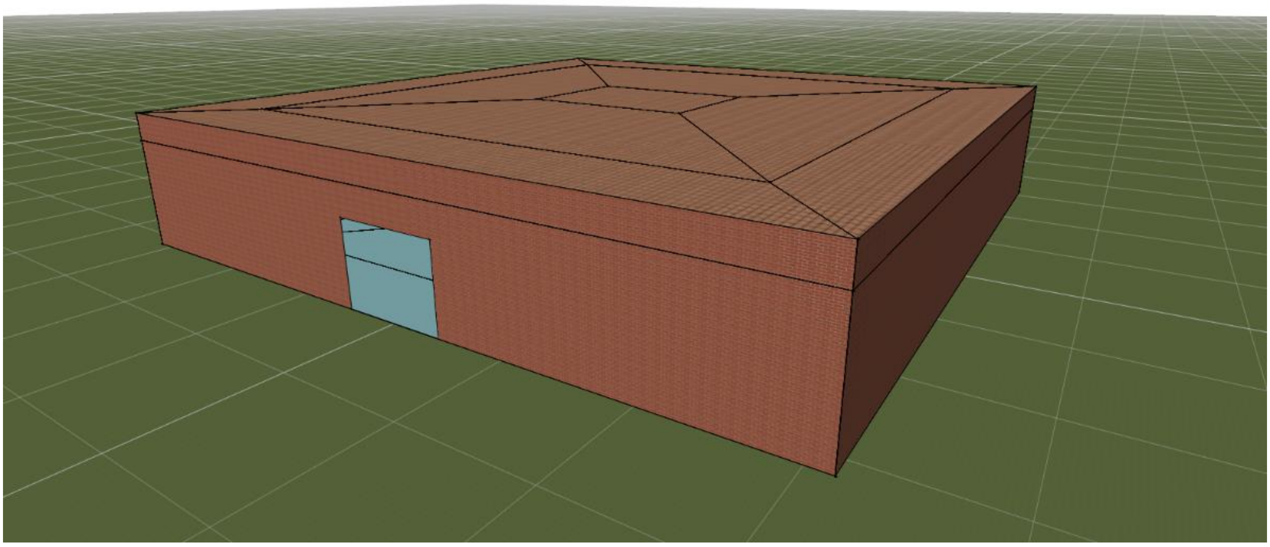

Figure 100: Building form C geometry as viewed in the IES <VE> software.

This model represents a small shop building that has 1000m², 1 storey, 31.6m x 31.6m floor plate and 6 m floor-ceiling height. IWEC files for Brisbane, Sydney and Melbourne were used as the weather data for the simulation. 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. The internal load densities and the associated operating schedules are listed below.

Table 4-93. Internal loads for class 6 (retail) buildings with proposed NCC 2019 lighting illumination power densities.

Type	Heat Gain
Equipment	5W/m²
Occupants	75W sensible heat gain per person 55W latent heat gain per person Number of occupants: 3 m²/person (at a level entered direct from the open air or any lower level)
Artificial lighting	14 W/m² (Retail space including a museum and gallery whose purpose is the sale of objects)

Table 4-94. 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

Time Period	Occupancy (Daily)	Artificial Lighting (Daily)	Appliances and Equipment (Daily)	HVAC (Daily)
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

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%.

F.1.4 Hospital Ward - Class 9a Form D (9aD)

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

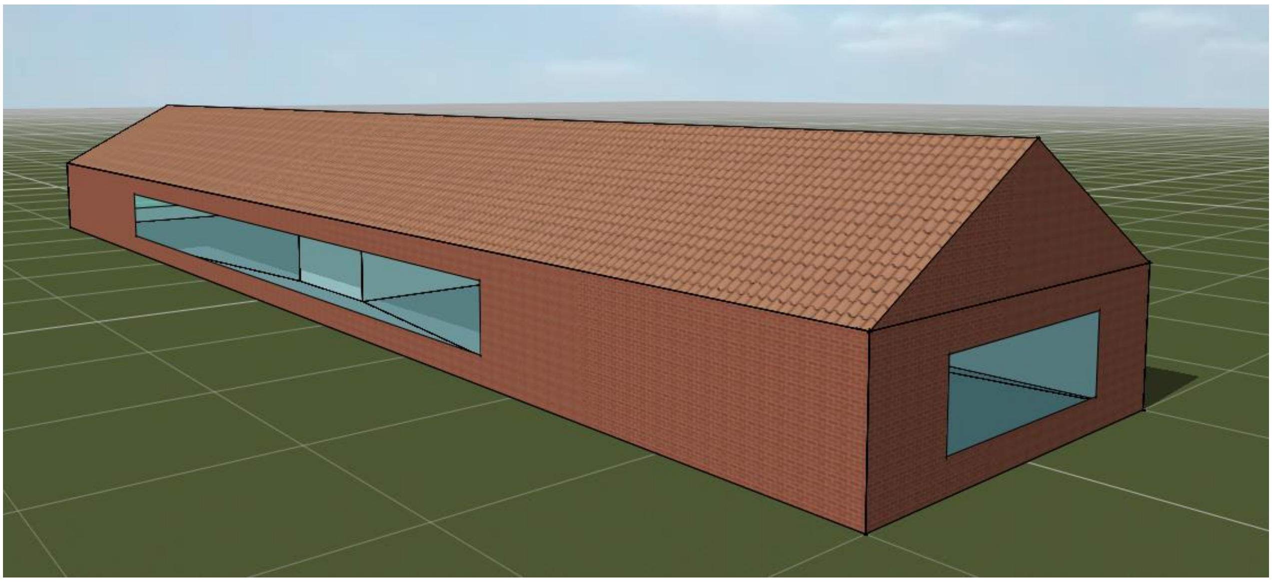

Figure 101: Building form D geometry as viewed in the IES <VE> software.

This model represents a small part of a ward building that has 500m², 1 storey, 50m x 10m floor plate and 3.3m floor-ceiling height. IWEC files for Brisbane, Sydney and Melbourne were used as the weather data for the simulation. 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. The internal load densities and the associated operating schedules are listed below.

Table 4-95. Internal loads for class 9a (ward area) buildings with proposed NCC 2019 lighting illumination power densities.

Type	Heat Gain
Equipment	5W/m²
Occupants	75W sensible heat gain per person 55W latent heat gain per person Number of occupants: 14 m²/person
Artificial lighting	2.5 W/m² (Health care – patient ward)

Table 4-96. 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
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

Time Period	Occupancy (M-F)	Occupancy (Weekend)	Artificial Lighting	HVAC (M-F)	HVAC (Weekend)
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/m².

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.

F.1.5 School - Class 9b Form E (9bE)

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

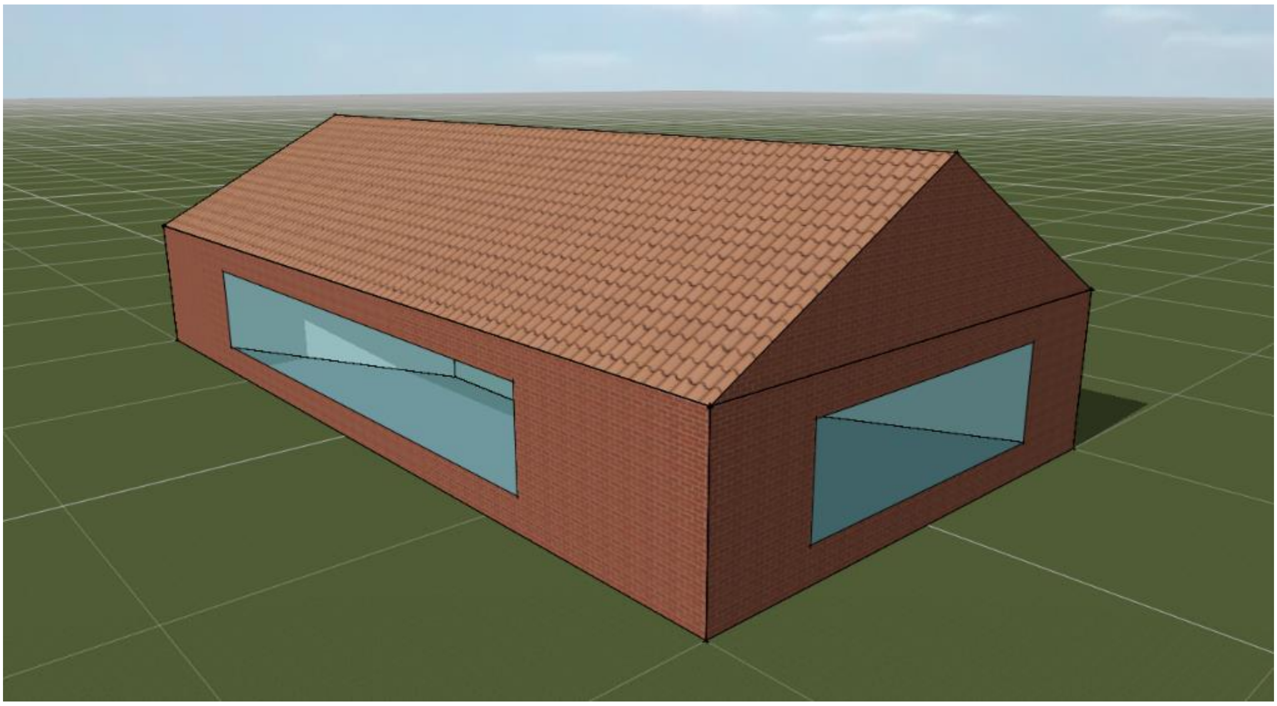

Figure 102: Building form E geometry as viewed in the IES <VE> software.

This model represents a school building that has 200m², 1 storey, 20m x 10m floor plate and 3.3m floor-ceiling height. IWEC files for Brisbane, Sydney and Melbourne were used as the weather data for the simulation. 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. The internal load densities and the associated operating schedules are listed below.

Table 4-97. Internal loads for Class 9b (school) buildings with proposed NCC 2019 lighting illumination power densities.

Type	Heat Gain
Equipment	5W/m²
Occupants	75W sensible heat gain per person 55W latent heat gain per person Number of occupants: 2 m²/person (School – general classroom)
Artificial lighting1	4.5 W/m² (School – general purpose learning areas and tutorial rooms)

Table 4-98. 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

Time Period	Occupancy (M-F)	Artificial Lighting (M-F)	Appliances and Equipment (M-F)	HVAC (M-F)
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”.

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.

F.2 Inputs from ABCB NCC2019 Analysis

The proposed building façade provisions from the NCC2019 Section J revision were included in the ASBEC modelling for the commercial archetypes. The façade provisions used in the commercial modelling were based on those produced prior to the public comment draft of the NCC Volume 1.

The HVAC systems, described above in Appendix F.1, were developed to meet the proposed NCC2019 Section J revision stringency. This included considering compliant performance targets for chillers, boilers, water loop pump powers, cooling tower fan powers in addition to economy cycle provisions and outside air treatment. The lighting illumination power density for the various archetypes were modelled from the updated figures in the public comment draft and are presented in the base case descriptions from Appendix F.1 above.

F.3 Plug-in Appliance Loads

The 'plug-in' loads used in the commercial models typically consists of equipment found in the different archetypes as specified in the NCC. These loads are presented in Appendix F.1 above using a W/m² value. The office archetype uses an average 11W/m² of appliances and equipment, the hotel uses 9.64W/m² and the remaining 3 commercial archetypes incorporate a 5W/m² component.

Appendix G - Commercial Energy Modelling Details

G.1 Single-Dimensional Energy Results

The following tables present the annual electricity and gas figures for the base and test cases for all commercial single-dimensional models.

Table 4-99: Results summary for the fabric colour measure.

	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)
Base	CZ2 3B	174,559	51	CZ2 5A	498,726	19	CZ2 9aD	34,215	37
Test 1	CZ2 3B	172,005	55	CZ2 5A	489,213	22	CZ2 9aD	32,891	38
Base	CZ5 3B	146,931	119	CZ5 5A	412,822	61	CZ5 9aD	25,281	65
Test 1	CZ5 3B	144,012	127	CZ5 5A	404,925	70	CZ5 9aD	24,158	67
Base	CZ6 3B	127,138	46	CZ6 5A	329,314	270	CZ6 9aD	17,867	90
Test 1	CZ6 3B	125,998	49	CZ6 5A	325,482	301	CZ6 9aD	17,513	92
Test 2	CZ6 3B	127,887	45	CZ6 5A	332,102	252			
	Model	Electricity Use (kWh)	Gas Use (GJ)						
Base	CZ2 9bE	15,237	-						
Test 1	CZ2 9bE	14,564	-						
Base	CZ5 9bE	11,844	-						
Test 1	CZ5 9bE	11,779	-						
Base	CZ6 9bE	12,521	-						
Test 1	CZ6 9bE	12,392	-						

Table 4-100: Results summary for the overnight ventilation, infiltration and insulation investigation.

	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)
Base	CZ2 5A	498,726	19	CZ2 6C	94,377	-
Test 1	CZ2 5A	494,537	17	CZ2 6C	93,412	-
Base	CZ5 5A	412,822	61	CZ5 6C	84,108	-
Test 1	CZ5 5A	395,932	42	CZ5 6C	80,792	-
Base	CZ6 5A	329,314	270	CZ6 6C	82,502	-
Test 1	CZ6 5A	330,120	238	CZ6 6C	76,712	-
Base	CZ7 5A	316,652	464			
Test 1	CZ7 5A	315,273	449			

Table 4-101: Results summary for the overnight ventilation and active mass investigation.

	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)
Base	CZ2 5A	498,726	19	CZ2 6C	94,377	-
Test 1	CZ2 5A	488,422	8	CZ2 6C	92,782	-

	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)
Base	CZ5 5A	412,822	61	CZ5 6C	84,108	-
Test 1	CZ5 5A	403,301	45	CZ5 6C	82,954	-
Base	CZ6 5A	329,314	270	CZ6 6C	82,502	-
Test 1	CZ6 5A	322,946	240	CZ6 6C	79,026	-
Base	CZ7 5A	316,652	464			
Test 1	CZ7 5A	307,690	429			

Table 4-102: Results summary for the passive thermal mass investigation.

	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)
Base	CZ2 3B	174,559	51	CZ2 9bE	15,237	-
Test 1	CZ2 3B	178,510	24	CZ2 9bE	13,702	-
Base	CZ5 3B	146,931	119	CZ5 9bE	11,844	-
Test 1	CZ5 3B	150,762	84	CZ5 9bE	11,187	-
Base	CZ6 3B	127,138	46	CZ6 9bE	12,521	-
Test 1	CZ6 3B	128,334	37	CZ6 9bE	12,414	-

Table 4-103: Results summary for the wall BIPV measure.

	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)
Base	CZ2 3B	174,559	51	CZ2 5A	498,726	19	CZ2 6C	94,377	-
Test 1	CZ2 3B	148,788	52	CZ2 5A	380,610	20	CZ2 6C	64,429	-
Base	CZ5 3B	146,931	119	CZ5 5A	412,822	61	CZ5 6C	84,108	-
Test 1	CZ5 3B	121,966	121	CZ5 5A	301,753	66	CZ5 6C	55,930	-
Base	CZ6 3B	127,138	46	CZ6 5A	329,314	270	CZ6 6C	82,502	-
Test 1	CZ6 3B	104,252	47	CZ6 5A	225,691	290	CZ6 6C	55,948	-
Base	CZ7 3B	119,775	57	CZ7 5A	316,652	464	CZ7 6C	84,766	-
Test 1	CZ7 3B	93,118	57	CZ7 5A	192,541	499	CZ7 6C	52,732	-
	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)			
Base	CZ2 9aD	34,215	37	CZ2 9bE	15,237	-			
Test 1	CZ2 9aD	26,176	37	CZ2 9bE	11,307	-			
Base	CZ5 9aD	25,281	65	CZ5 9bE	11,844	-			
Test 1	CZ5 9aD	17,526	65	CZ5 9bE	8,516	-			
Base	CZ6 9aD	17,867	90	CZ6 9bE	12,521	-			
Test 1	CZ6 9aD	10,738	91	CZ6 9bE	9,163	-			
Base	CZ7 9aD	17,148	108	CZ7 9bE	15,657	-			
Test 1	CZ7 9aD	6,813	109	CZ7 9bE	11,018	-			

Table 4-104: Results summary for the window BIPV measure.

	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)
Base	CZ2 3B	174,559	51	CZ2 5A	498,726	19	CZ2 9aD	34,215	37
Test 1	CZ2 3B	122,750	35	CZ2 5A	460,240	33	CZ2 9aD	28,584	43
Base	CZ5 3B	146,931	119	CZ5 5A	412,822	61	CZ5 9aD	25,281	65
Test 1	CZ5 3B	111,980	58	CZ5 5A	382,053	93	CZ5 9aD	21,156	73
Base	CZ6 3B	127,138	46	CZ6 5A	329,314	270	CZ6 9aD	17,867	90
Test 1	CZ6 3B	101,054	22	CZ6 5A	302,982	357	CZ6 9aD	14,701	96
	Model	Electricity Use (kWh)	Gas Use (GJ)						
Base	CZ2 9bE	15,237	-						
Test 1	CZ2 9bE	11,570	-						
Base	CZ5 9bE	11,844	-						
Test 1	CZ5 9bE	9,085	-						
Base	CZ6 9bE	12,521	-						
Test 1	CZ6 9bE	9,339	-						

Table 4-105: Results summary for the rooftop PV analysis.

	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)
Base	CZ2 3B	174,559	51	CZ2 5A	498,726	19	CZ2 6C	94,377	-
Test 1	CZ2 3B	131,452	51	CZ2 5A	439,404	19	CZ2 6C	34,762	-
Base	CZ5 3B	146,931	119	CZ5 5A	412,822	61	CZ5 6C	84,108	-
Test 1	CZ5 3B	104,481	120	CZ5 5A	354,452	61	CZ5 6C	25,520	-
Base	CZ6 3B	127,138	46	CZ6 5A	329,314	270	CZ6 6C	82,502	-
Test 1	CZ6 3B	86,893	47	CZ6 5A	274,216	271	CZ6 6C	27,206	-
Base	CZ7 3B	119,775	57	CZ7 5A	316,652	464	CZ7 6C	84,766	-
Test 1	CZ7 3B	72,908	57	CZ7 5A	252,414	464	CZ7 6C	20,207	-
	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)			
Base	CZ2 9aD	34,215	37	CZ2 9bE	15,237	-			
Test 1	CZ2 9aD	-906	37	CZ2 9bE	1,645	-			
Base	CZ5 9aD	25,281	65	CZ5 9bE	11,844	-			
Test 1	CZ5 9aD	-9,436	65	CZ5 9bE	-1,182	-			
Base	CZ6 9aD	17,867	90	CZ6 9bE	12,521	-			
Test 1	CZ6 9aD	-15,365	91	CZ6 9bE	-246	-			
Base	CZ7 9aD	17,148	108	CZ7 9bE	15,657	-			
Test 1	CZ7 9aD	-21,281	108	CZ7 9bE	745	-			

Table 4-106: Results summary for the external glazing efficiency measures.

	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)
Base	CZ2 3B	174,559	51	CZ2 5A	498,726	19	CZ2 9aD	34,215	37
Test 1	CZ2 3B	167,774	62	CZ2 5A	498,549	18	CZ2 9aD	31,416	42
Test 2	CZ2 3B	158,122	74	CZ2 5A	462,140	28	CZ2 9aD	27,729	46
Test 3	CZ2 3B	162,417	69	CZ2 5A	476,260	24	CZ2 9aD	29,331	45
Base	CZ5 3B	146,931	119	CZ5 5A	412,822	61	CZ5 9aD	25,281	65
Test 1	CZ5 3B	139,181	138	CZ5 5A	400,550	74	CZ5 9aD	22,827	72
Test 2	CZ5 3B	131,079	142	CZ5 5A	382,247	76	CZ5 9aD	20,144	75
Test 3	CZ5 3B	134,937	141	CZ5 5A	394,422	67	CZ5 9aD	21,572	74
Base	CZ6 3B	127,138	46	CZ6 5A	329,314	270	CZ6 9aD	17,867	90
Test 1	CZ6 3B	121,420	58	CZ6 5A	323,129	316	CZ6 9aD	16,399	100
Test 2	CZ6 3B	118,598	53	CZ6 5A	313,052	303	CZ6 9aD	14,977	97
Test 3	CZ6 3B	122,343	47	CZ6 5A	318,541	274	CZ6 9aD	16,378	92
Base	CZ7 3B	119,775	57	CZ7 5A	316,652	464	CZ7 9aD	17,148	108
Test 1	CZ7 3B	111,584	82	CZ7 5A	311,505	538	CZ7 9aD	15,432	122
Test 2	CZ7 3B	111,892	70	CZ7 5A	302,127	507	CZ7 9aD	14,258	115
Test 3	CZ7 3B	111,794	81	CZ7 5A	307,285	458	CZ7 9aD	15,372	116
	Model	Electricity Use (kWh)	Gas Use (GJ)						
Base	CZ2 9bE	15,237	-						
Test 1	CZ2 9bE	14,373	-						
Test 2	CZ2 9bE	13,988	-						
Test 3	CZ2 9bE	14,623	-						
Base	CZ5 9bE	11,844	-						
Test 1	CZ5 9bE	11,615	-						
Test 2	CZ5 9bE	11,514	-						
Test 3	CZ5 9bE	11,915	-						
Base	CZ6 9bE	12,521	-						
Test 1	CZ6 9bE	12,473	-						
Test 2	CZ6 9bE	12,361	-						
Test 3	CZ6 9bE	11,528	-						
Base	CZ7 9bE	15,657	-						
Test 1	CZ7 9bE	15,608	-						
Test 2	CZ7 9bE	15,452	-						
Test 3	CZ7 9bE	15,489	-						

Table 4-107: Results summary for the daylight harvesting efficiency measures.

	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)
Base	CZ2 5A	498,726	19	CZ2 9aD	34,215	37	CZ2 9bE	15,237	-
Test 1	CZ2 5A	452,398	20	CZ2 9aD	34,270	36	CZ2 9bE	13,340	-
Test 2	CZ2 5A	454,304	15	CZ2 9aD	33,975	34	CZ2 9bE	13,273	-
Test 3	CZ2 5A	452,892	20	CZ2 9aD	34,252	36	CZ2 9bE	13,122	-
Base	CZ5 5A	412,822	61	CZ5 9aD	25,281	65	CZ5 9bE	11,844	-
Test 1	CZ5 5A	366,323	68	CZ5 9aD	25,287	63	CZ5 9bE	10,155	-
Test 2	CZ5 5A	366,870	56	CZ5 9aD	24,899	60	CZ5 9bE	10,393	-
Test 3	CZ5 5A	368,441	67	CZ5 9aD	25,254	63	CZ5 9bE	10,623	-
Base	CZ6 5A	329,314	270	CZ6 9aD	17,867	90	CZ6 9bE	12,521	-
Test 1	CZ6 5A	285,942	299	CZ6 9aD	17,829	87	CZ6 9bE	10,907	-
Test 2	CZ6 5A	282,989	259	CZ6 9aD	17,369	83	CZ6 9bE	10,684	-
Test 3	CZ6 5A	287,585	297	CZ6 9aD	17,835	87	CZ6 9bE	11,122	-
Base	CZ7 5A	316,652	464	CZ7 9aD	17,148	108	CZ7 9bE	15,657	-
Test 1	CZ7 5A	273,892	499	CZ7 9aD	16,945	109	CZ7 9bE	14,085	-
Test 2	CZ7 5A	271,534	445	CZ7 9aD	17,291	128	CZ7 9bE	13,955	-
Test 3	CZ7 5A	270,935	554	CZ7 9aD	16,060	115	CZ7 9bE	14,371	-

Table 4-108: Results summary for the fan system efficiency measures.

	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)
Base	CZ2 5A	498,726	19	CZ2 9aD	34,215	37
Test 2	CZ2 5A	478,634	20	CZ2 9aD	31,375	39
Test 3	CZ2 5A	458,719	21	CZ2 9aD	28,027	42
Base	CZ5 5A	412,822	61	CZ5 9aD	25,281	65
Test 2	CZ5 5A	394,315	64	CZ5 9aD	22,523	68
Test 3	CZ5 5A	377,002	71	CZ5 9aD	20,084	72
Base	CZ6 5A	329,314	270	CZ6 9aD	17,867	90
Test 2	CZ6 5A	316,288	284	CZ6 9aD	15,603	94
Test 3	CZ6 5A	303,307	295	CZ6 9aD	13,301	99
Base	CZ7 5A	316,652	464	CZ7 9aD	17,148	108
Test 2	CZ7 5A	306,360	477	CZ7 9aD	14,912	113
Test 3	CZ7 5A	295,979	486	CZ7 9aD	12,652	117

Table 4-109: Results summary for the pump efficiency measures.

	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)
Base	CZ2 3B	174,559	51	CZ2 5A	498,726	19	CZ2 9aD	34,215	37

Test 1	CZ2 3B	134,711	30	CZ2 5A	494,476	24	CZ2 9aD	31,736	37
Base	CZ5 3B	146,931	119	CZ5 5A	412,822	61	CZ5 9aD	25,281	65
Test 1	CZ5 3B	121,285	53	CZ5 5A	413,693	75	CZ5 9aD	24,229	65
Base	CZ6 3B	127,138	46	CZ6 5A	329,314	270	CZ6 9aD	17,867	90
Test 1	CZ6 3B	107,976	21	CZ6 5A	329,353	316	CZ6 9aD	16,670	89

Table 4-110: Results summary for the chiller and PAC unit efficiency measures.

	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)
Base	CZ2 3B	174,559	51	CZ2 5A	498,726	19	CZ2 6C	94,377	-
Test 1	CZ2 3B	145,315	51	CZ2 5A	443,947	25	CZ2 6C	82,886	-
Test 2	CZ2 3B	137,491	51	CZ2 5A	424,920	19	CZ2 6C	81,329	-
Test 3	CZ2 3B	132,084	51	CZ2 5A	411,904	18	CZ2 6C	80,065	-
Base	CZ5 3B	146,931	119	CZ5 5A	412,822	61	CZ5 6C	84,108	-
Test 1	CZ5 3B	124,125	119	CZ5 5A	378,608	61	CZ5 6C	77,650	-
Test 2	CZ5 3B	118,512	119	CZ5 5A	367,145	61	CZ5 6C	76,731	-
Test 3	CZ5 3B	114,416	119	CZ5 5A	359,082	61	CZ5 6C	75,985	-
Base	CZ6 3B	127,138	46	CZ6 5A	329,314	270	CZ6 6C	82,502	-
Test 1	CZ6 3B	113,939	46	CZ6 5A	312,964	270	CZ6 6C	78,963	-
Test 2	CZ6 3B	110,947	46	CZ6 5A	308,134	270	CZ6 6C	78,490	-
Test 3	CZ6 3B	108,353	46	CZ6 5A	304,728	270	CZ6 6C	78,107	-
Base	CZ7 3B	119,775	57	CZ7 5A	316,652	464	CZ7 6C	84,766	-
Test 1	CZ7 3B	107,842	57	CZ7 5A	302,079	464	CZ7 6C	80,180	-
Test 2	CZ7 3B	105,149	57	CZ7 5A	297,890	464	CZ7 6C	79,515	-
Test 3	CZ7 3B	102,820	57	CZ7 5A	294,917	464	CZ7 6C	78,977	-
	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)			
Base	CZ2 9aD	34,215	37	CZ2 9bE	15,237	-			
Test 1	CZ2 9aD	28,550	37	CZ2 9bE	9,730	-			
Test 2	CZ2 9aD	26,721	37	CZ2 9bE	9,106	-			
Test 3	CZ2 9aD	25,622	37	CZ2 9bE	8,594	-			
Base	CZ5 9aD	25,281	65	CZ5 9bE	11,844	-			
Test 1	CZ5 9aD	21,582	65	CZ5 9bE	9,024	-			
Test 2	CZ5 9aD	20,586	65	CZ5 9bE	8,701	-			
Test 3	CZ5 9aD	19,996	65	CZ5 9bE	8,439	-			
Base	CZ6 9aD	17,867	90	CZ6 9bE	12,521	-			
Test 1	CZ6 9aD	16,203	90	CZ6 9bE	10,975	-			
Test 2	CZ6 9aD	15,792	90	CZ6 9bE	10,799	-			
Test 3	CZ6 9aD	15,545	90	CZ6 9bE	10,655	-			
Base	CZ7 9aD	17,148	108	CZ7 9bE	15,657	-			
Test 1	CZ7 9aD	15,544	108	CZ7 9bE	13,664	-			

Test 2	CZ7 9aD	15,158	108	CZ7 9bE	13,436	-			
Test 3	CZ7 9aD	14,928	108	CZ7 9bE	13,251	-			

Table 4-111: Results summary for the economy cycle investigation.

	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)
Base	CZ2 5A	498,726	19	CZ2 6C	94,377	-	CZ2 9aD	34,215	37
Test 1	CZ2 5A	490,521	20						
Test 2							CZ2 9aD	33,146	37
Test 3				CZ2 6C	92,462	-			
Base	CZ5 5A	412,822	61	CZ5 6C	84,108	-	CZ5 9aD	25,281	65
Test 1	CZ5 5A	408,281	62						
Test 2							CZ5 9aD	23,592	65
Test 3				CZ5 6C	80,905	-			
Base				CZ6 6C	82,502	-	CZ6 9aD	17,867	90
Test 1									
Test 2									
Test 3				CZ6 6C	79,301	-	CZ6 9aD	15,697	90
Base				CZ7 6C	84,766	-	CZ7 9aD	17,148	108
Test 1				CZ7 6C	82,117	-			
Test 2									
Test 3				CZ7 6C	79,729	-	CZ7 9aD	17,011	108

Table 4-112: Results summary for the outside air treatment efficiency measures.

	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)
Base	CZ2 3B	174,559	51	CZ2 5A	498,726	19	CZ2 6C	94,377	-
Test 1	CZ2 3B	186,810	33	CZ2 5A	510,677	17	CZ2 6C	93,909	-
Test 2	CZ2 3B			CZ2 5A	510,944	17	CZ2 6C	93,921	-
Base	CZ5 3B	146,931	119	CZ5 5A	412,822	61	CZ5 6C	84,108	-
Test 1	CZ5 3B	151,624	80	CZ5 5A	422,932	49	CZ5 6C	83,293	-
Test 2	CZ5 3B			CZ5 5A	423,174	47	CZ5 6C	83,697	-
Base	CZ6 3B	127,138	46	CZ6 5A	329,314	270	CZ6 6C	82,502	-
Test 1	CZ6 3B	128,577	39	CZ6 5A	337,660	206	CZ6 6C	78,795	-
Test 2	CZ6 3B			CZ6 5A			CZ6 6C	78,608	-
Base	CZ7 3B			CZ7 5A	316,652	464	CZ7 6C	84,766	-
Test 1	CZ7 3B			CZ7 5A	316,775	229	CZ7 6C	81,504	-
Test 2	CZ7 3B			CZ7 5A			CZ7 6C	81,605	-
	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)			

Base	CZ2 9aD	34,215	37	CZ2 9bE	15,237	-			
Test 1	CZ2 9aD	35,759	23	CZ2 9bE	14,260	-			
Test 2	CZ2 9aD	35,839	23	CZ2 9bE	14,290	-			
Base	CZ5 9aD	25,281	65	CZ5 9bE	11,844	-			
Test 1	CZ5 9aD	27,054	46	CZ5 9bE	9,976	-			
Test 2	CZ5 9aD			CZ5 9bE	9,777	-			
Base	CZ6 9aD	17,867	90	CZ6 9bE	12,521	-			
Test 1	CZ6 9aD	18,307	54	CZ6 9bE	9,006	-			
Test 2	CZ6 9aD			CZ6 9bE	8,676	-			
Base	CZ7 9aD	17,148	108	CZ7 9bE	15,657	-			
Test 1	CZ7 9aD	16,202	75	CZ7 9bE	12,106	-			
Test 2	CZ7 9aD			CZ7 9bE	11,995	-			

Table 4-113: Results summary for the commissioning investigation.

	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)
Base	CZ2 5A	498,726	19	CZ2 9aD	34,215	37			
Test 1	CZ2 5A	582,181	35	CZ2 9aD	50,188	31			
Base	CZ5 5A	412,822	61	CZ5 9aD	25,281	65			
Test 1	CZ5 5A	504,465	76	CZ5 9aD	43,265	54			
Base	CZ6 5A	329,314	270	CZ6 9aD	17,867	90			
Test 1	CZ6 5A	414,888	321	CZ6 9aD	36,579	69			
Base	CZ7 5A	316,652	464	CZ7 9aD	17,148	108			
Test 1	CZ7 5A	393,707	309	CZ7 9aD	36,989	87			

Table 4-114: Results summary for the lighting efficiency measures.

	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)
Base	CZ2 3B	174,559	51	CZ2 5A	498,726	19	CZ2 6C	94,377	-
Test 1	CZ2 3B	171,615	51	CZ2 5A	467,427	20	CZ2 6C	79,175	-
Test 2	CZ2 3B	169,260	52	CZ2 5A	435,628	21	CZ2 6C	66,775	-
Test 3	CZ2 3B	166,921	52	CZ2 5A	403,752	22	CZ2 6C	54,419	-
Base	CZ5 3B	146,931	119	CZ5 5A	412,822	61	CZ5 6C	84,108	-
Test 1	CZ5 3B	143,917	120	CZ5 5A	382,163	65	CZ5 6C	69,669	-
Test 2	CZ5 3B	141,458	121	CZ5 5A	350,946	70	CZ5 6C	58,023	-
Test 3	CZ5 3B	139,039	122	CZ5 5A	319,582	75	CZ5 6C	46,488	-
Base	CZ6 3B	127,138	46	CZ6 5A	329,314	270	CZ6 6C	82,502	-
Test 1	CZ6 3B	123,999	47	CZ6 5A	301,038	288	CZ6 6C	69,354	-
Test 2	CZ6 3B	121,492	48	CZ6 5A	271,757	307	CZ6 6C	58,711	-

Test 3	CZ6 3B	118,995	49	CZ6 5A	242,239	326	CZ6 6C	48,173	-
Base	CZ7 3B	119,775	57	CZ7 5A	316,652	464	CZ7 6C	84,766	-
Test 1	CZ7 3B	116,614	59	CZ7 5A	288,504	487	CZ7 6C	71,119	-
Test 2	CZ7 3B	114,084	60	CZ7 5A	259,395	511	CZ7 6C	60,311	-
Test 3	CZ7 3B	111,577	62	CZ7 5A	230,179	534	CZ7 6C	49,669	-
	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)			
Base	CZ2 9aD	34,215	37	CZ2 9bE	15,237	-			
Test 1	CZ2 9aD	33,494	37	CZ2 9bE	14,758	-			
Test 2	CZ2 9aD	32,877	37	CZ2 9bE	14,325	-			
Test 3	CZ2 9aD	32,307	37	CZ2 9bE	13,904	-			
Base	CZ5 9aD	25,281	65	CZ5 9bE	11,844	-			
Test 1	CZ5 9aD	24,539	65	CZ5 9bE	11,372	-			
Test 2	CZ5 9aD	23,939	65	CZ5 9bE	10,962	-			
Test 3	CZ5 9aD	23,342	66	CZ5 9bE	10,558	-			
Base	CZ6 9aD	17,867	90	CZ6 9bE	12,521	-			
Test 1	CZ6 9aD	17,142	91	CZ6 9bE	12,016	-			
Test 2	CZ6 9aD	16,562	91	CZ6 9bE	11,650	-			
Test 3	CZ6 9aD	15,987	92	CZ6 9bE	11,299	-			
Base	CZ7 9aD	17,148	108	CZ7 9bE	15,657	-			
Test 1	CZ7 9aD	16,427	110	CZ7 9bE	15,214	-			
Test 2	CZ7 9aD	15,853	110	CZ7 9bE	14,836	-			
Test 3	CZ7 9aD	15,264	111	CZ7 9bE	14,528	-			

Table 4-115: Results summary for the lift technology efficiency measures.

	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)	Model	Electricity Use (kWh)	Gas Use (GJ)
Base	CZ2 3B	174,559	51	CZ2 5A	498,726	19			
Test 1	CZ2 3B	171,933	51	CZ2 5A	465,024	19			
Base	CZ5 3B	146,931	119	CZ5 5A	412,822	61			
Test 1	CZ5 3B	144,613	119	CZ5 5A	380,119	61			
Base	CZ6 3B	127,138	46	CZ6 5A	329,314	270			
Test 1	CZ6 3B	124,560	46	CZ6 5A	301,584	270			
Base	CZ7 3B	119,775	57	CZ7 5A	316,652	464			
Test 1	CZ7 3B	117,265	57	CZ7 5A	292,446	464			

G.2 Single-Dimensional Peak Load Results

The following tables present the peak electrical demand for all commercial single-dimensional models simulated.

Table 4-116: Results summary for the fabric colour measure.

	Model	Peak Load (kW)	Model	Peak Load (kW)	Model	Peak Load (kW)	Model	Peak Load (kW)
Base	CZ2 3B	58	CZ2 5A	223	CZ2 9aD	12	CZ2 9bE	16
Test 1	CZ2 3B	57	CZ2 5A	219	CZ2 9aD	11	CZ2 9bE	15
Base	CZ5 3B	55	CZ5 5A	222	CZ5 9aD	11	CZ5 9bE	19
Test 1	CZ5 3B	53	CZ5 5A	214	CZ5 9aD	11	CZ5 9bE	18
Base	CZ6 3B	50	CZ6 5A	210	CZ6 9aD	10	CZ6 9bE	17
Test 1	CZ6 3B	50	CZ6 5A	208	CZ6 9aD	9	CZ6 9bE	17
Test 2	CZ6 3B	50	CZ6 5A	219				

Table 4-117: Results summary for the overnight ventilation, infiltration and insulation investigation.

	Model	Peak Load (kW)	Model	Peak Load (kW)
Base	CZ2 5A	223	CZ2 6C	35
Test 1	CZ2 5A	226	CZ2 6C	35
Base	CZ5 5A	222	CZ5 6C	33
Test 1	CZ5 5A	210	CZ5 6C	27
Base	CZ6 5A	210	CZ6 6C	34
Test 1	CZ6 5A	211	CZ6 6C	22
Base	CZ7 5A	199		
Test 1	CZ7 5A	196		

Table 4-118: Results summary for the overnight ventilation and active mass investigation.

	Model	Peak Load (kW)	Model	Peak Load (kW)
Base	CZ2 5A	223	CZ2 6C	35
Test 1	CZ2 5A	220	CZ2 6C	35
Base	CZ5 5A	222	CZ5 6C	33
Test 1	CZ5 5A	207	CZ5 6C	32
Base	CZ6 5A	210	CZ6 6C	34
Test 1	CZ6 5A	202	CZ6 6C	32
Base	CZ7 5A	199		
Test 1	CZ7 5A	182		

Table 4-119: Results summary for the passive thermal mass investigation.

	Model	Peak Load (kW)	Model	Peak Load (kW)
Base	CZ2 3B	58	CZ2 9bE	16
Test 1	CZ2 3B	54	CZ2 9bE	16
Base	CZ5 3B	55	CZ5 9bE	19
Test 1	CZ5 3B	50	CZ5 9bE	16
Base	CZ6 3B	50	CZ6 9bE	17
Test 1	CZ6 3B	44	CZ6 9bE	16

Table 4-120: Results summary for the wall BIPV measure.

	Model	Peak Load (kWh)	Model	Peak Load (kWh)	Model	Peak Load (kWh)	Model	Peak Load (kWh)	Model	Peak Load (kWh)
Base	CZ2 3B	58	CZ2 5A	223	CZ2 6C	35	CZ2 9aD	12	CZ2 9bE	16
Test 1	CZ2 3B	57	CZ2 5A	222	CZ2 6C	35	CZ2 9aD	12	CZ2 9bE	16
Base	CZ5 3B	55	CZ5 5A	222	CZ5 6C	33	CZ5 9aD	11	CZ5 9bE	19
Test 1	CZ5 3B	54	CZ5 5A	219	CZ5 6C	33	CZ5 9aD	11	CZ5 9bE	19
Base	CZ6 3B	50	CZ6 5A	210	CZ6 6C	34	CZ6 9aD	10	CZ6 9bE	17
Test 1	CZ6 3B	49	CZ6 5A	213	CZ6 6C	34	CZ6 9aD	9	CZ6 9bE	19
Base	CZ7 3B	40	CZ7 5A	199	CZ7 6C	32	CZ7 9aD	7	CZ7 9bE	18
Test 1	CZ7 3B	40	CZ7 5A	197	CZ7 6C	32	CZ7 9aD	7	CZ7 9bE	18

Table 4-121: Results summary for the window BIPV measure.

	Model	Peak Load (kWh)	Model	Peak Load (kWh)	Model	Peak Load (kWh)	Model	Peak Load (kWh)
Base	CZ2 3B	58	CZ2 5A	223	CZ2 9aD	12	CZ2 9bE	16
Test 1	CZ2 3B	0	CZ2 5A	0	CZ2 9aD	0	CZ2 9bE	0
Base	CZ5 3B	55	CZ5 5A	222	CZ5 9aD	11	CZ5 9bE	19
Test 1	CZ5 3B	0	CZ5 5A	0	CZ5 9aD	0	CZ5 9bE	0
Base	CZ6 3B	50	CZ6 5A	210	CZ6 9aD	10	CZ6 9bE	17
Test 1	CZ6 3B	0	CZ6 5A	0	CZ6 9aD	0	CZ6 9bE	0

Table 4-122: Results summary for the rooftop PV analysis.

	Model	Peak Load (kWh)	Model	Peak Load (kWh)	Model	Peak Load (kWh)	Model	Peak Load (kWh)	Model	Peak Load (kWh)
Base	CZ2 3B	58	CZ2 5A	223	CZ2 6C	35	CZ2 9aD	12	CZ2 9bE	16
Test 1	CZ2 3B	58	CZ2 5A	224	CZ2 6C	35	CZ2 9aD	12	CZ2 9bE	16
Base	CZ5 3B	55	CZ5 5A	222	CZ5 6C	33	CZ5 9aD	11	CZ5 9bE	19

	Model	Peak Load (kWh)	Model	Peak Load (kWh)	Model	Peak Load (kWh)	Model	Peak Load (kWh)	Model	Peak Load (kWh)
Test 1	CZ5 3B	54	CZ5 5A	221	CZ5 6C	32	CZ5 9aD	11	CZ5 9bE	19
Base	CZ6 3B	50	CZ6 5A	210	CZ6 6C	34	CZ6 9aD	10	CZ6 9bE	17
Test 1	CZ6 3B	49	CZ6 5A	214	CZ6 6C	34	CZ6 9aD	9	CZ6 9bE	18
Base	CZ7 3B	40	CZ7 5A	199	CZ7 6C	32	CZ7 9aD	7	CZ7 9bE	18
Test 1	CZ7 3B	40	CZ7 5A	199	CZ7 6C	33	CZ7 9aD	7	CZ7 9bE	18

Table 4-123: Results summary for the external glazing efficiency measures.

	Model	Peak Load (kWh)	Model	Peak Load (kWh)	Model	Peak Load (kWh)	Model	Peak Load (kWh)
Base	CZ2 3B	58	CZ2 5A	223	CZ2 9aD	12	CZ2 9bE	16
Test 1	CZ2 3B	56	CZ2 5A	224	CZ2 9aD	11	CZ2 9bE	15
Test 2	CZ2 3B	51	CZ2 5A	203	CZ2 9aD	10	CZ2 9bE	15
Test 3	CZ2 3B	53	CZ2 5A	211	CZ2 9aD	10	CZ2 9bE	15
Base	CZ5 3B	55	CZ5 5A	222	CZ5 9aD	11	CZ5 9bE	19
Test 1	CZ5 3B	52	CZ5 5A	214	CZ5 9aD	11	CZ5 9bE	19
Test 2	CZ5 3B	49	CZ5 5A	197	CZ5 9aD	10	CZ5 9bE	18
Test 3	CZ5 3B	51	CZ5 5A	206	CZ5 9aD	10	CZ5 9bE	19
Base	CZ6 3B	50	CZ6 5A	210	CZ6 9aD	10	CZ6 9bE	17
Test 1	CZ6 3B	47	CZ6 5A	211	CZ6 9aD	9	CZ6 9bE	18
Test 2	CZ6 3B	44	CZ6 5A	197	CZ6 9aD	8	CZ6 9bE	17
Test 3	CZ6 3B	46	CZ6 5A	204	CZ6 9aD	9	CZ6 9bE	17
Base	CZ7 3B	40	CZ7 5A	199	CZ7 9aD	7	CZ7 9bE	18
Test 1	CZ7 3B	35	CZ7 5A	193	CZ7 9aD	7	CZ7 9bE	18
Test 2	CZ7 3B	39	CZ7 5A	177	CZ7 9aD	6	CZ7 9bE	18
Test 3	CZ7 3B	35	CZ7 5A	185	CZ7 9aD	6	CZ7 9bE	18

Table 4-124: Results summary for the daylight harvesting efficiency measures.

	Model	Peak Load (kW)	Model	Peak Load (kW)	Model	Peak Load (kW)
Base	CZ2 5A	223	CZ2 9aD	12	CZ2 9bE	16
Test 1	CZ2 5A	205	CZ2 9aD	12	CZ2 9bE	16
Test 2	CZ2 5A	205	CZ2 9aD	11	CZ2 9bE	16
Test 3	CZ2 5A	205	CZ2 9aD	12	CZ2 9bE	15
Base	CZ5 5A	222	CZ5 9aD	11	CZ5 9bE	19
Test 1	CZ5 5A	202	CZ5 9aD	11	CZ5 9bE	18
Test 2	CZ5 5A	197	CZ5 9aD	11	CZ5 9bE	19
Test 3	CZ5 5A	206	CZ5 9aD	11	CZ5 9bE	19
Base	CZ6 5A	210	CZ6 9aD	10	CZ6 9bE	17

	Model	Peak Load (kW)	Model	Peak Load (kW)	Model	Peak Load (kW)
Test 1	CZ6 5A	196	CZ6 9aD	9	CZ6 9bE	18
Test 2	CZ6 5A	193	CZ6 9aD	9	CZ6 9bE	17
Test 3	CZ6 5A	194	CZ6 9aD	9	CZ6 9bE	19
Base	CZ7 5A	199	CZ7 9aD	7	CZ7 9bE	18
Test 1	CZ7 5A	186	CZ7 9aD	7	CZ7 9bE	18
Test 2	CZ7 5A	183	CZ7 9aD	8	CZ7 9bE	18
Test 3	CZ7 5A	184	CZ7 9aD	7	CZ7 9bE	18

Table 4-125: Results summary for the fan system efficiency measures.

	Model	Peak Load (kW)	Model	Peak Load (kW)
Base	CZ2 5A	223	CZ2 9aD	12
Test 2	CZ2 5A	221	CZ2 9aD	11
Test 3	CZ2 5A	212	CZ2 9aD	10
Base	CZ5 5A	222	CZ5 9aD	11
Test 2	CZ5 5A	213	CZ5 9aD	11
Test 3	CZ5 5A	203	CZ5 9aD	10
Base	CZ6 5A	210	CZ6 9aD	10
Test 2	CZ6 5A	207	CZ6 9aD	9
Test 3	CZ6 5A	201	CZ6 9aD	8
Base	CZ7 5A	199	CZ7 9aD	7
Test 2	CZ7 5A	189	CZ7 9aD	7
Test 3	CZ7 5A	182	CZ7 9aD	6

Table 4-126: Results summary for the chiller and PAC unit efficiency measures.

	Model	Peak Load (kWh)	Model	Peak Load (kWh)	Model	Peak Load (kWh)	Model	Peak Load (kWh)	Model	Peak Load (kWh)
Base	CZ2 3B	58	CZ2 5A	223	CZ2 6C	35	CZ2 9aD	12	CZ2 9bE	16
Test 1	CZ2 3B	47	CZ2 5A	206	CZ2 6C	26	CZ2 9aD	10	CZ2 9bE	9
Test 2	CZ2 3B	42	CZ2 5A	183	CZ2 6C	25	CZ2 9aD	9	CZ2 9bE	8
Test 3	CZ2 3B	39	CZ2 5A	170	CZ2 6C	24	CZ2 9aD	8	CZ2 9bE	8
Base	CZ5 3B	55	CZ5 5A	222	CZ5 6C	33	CZ5 9aD	11	CZ5 9bE	19
Test 1	CZ5 3B	44	CZ5 5A	201	CZ5 6C	25	CZ5 9aD	9	CZ5 9bE	10
Test 2	CZ5 3B	39	CZ5 5A	179	CZ5 6C	24	CZ5 9aD	8	CZ5 9bE	9
Test 3	CZ5 3B	36	CZ5 5A	167	CZ5 6C	23	CZ5 9aD	8	CZ5 9bE	9
Base	CZ6 3B	50	CZ6 5A	210	CZ6 6C	34	CZ6 9aD	10	CZ6 9bE	17
Test 1	CZ6 3B	40	CZ6 5A	185	CZ6 6C	26	CZ6 9aD	8	CZ6 9bE	13
Test 2	CZ6 3B	37	CZ6 5A	166	CZ6 6C	25	CZ6 9aD	7	CZ6 9bE	13

	Model	Peak Load (kWh)	Model	Peak Load (kWh)	Model	Peak Load (kWh)	Model	Peak Load (kWh)	Model	Peak Load (kWh)
Test 3	CZ6 3B	34	CZ6 5A	153	CZ6 6C	24	CZ6 9aD	7	CZ6 9bE	13
Base	CZ7 3B	40	CZ7 5A	199	CZ7 6C	32	CZ7 9aD	7	CZ7 9bE	18
Test 1	CZ7 3B	31	CZ7 5A	169	CZ7 6C	25	CZ7 9aD	6	CZ7 9bE	18
Test 2	CZ7 3B	28	CZ7 5A	154	CZ7 6C	24	CZ7 9aD	5	CZ7 9bE	18
Test 3	CZ7 3B	27	CZ7 5A	144	CZ7 6C	24	CZ7 9aD	5	CZ7 9bE	18

Table 4-127: Results summary for the economy cycle investigation.

	Model	Peak Load (kW)	Model	Peak Load (kW)	Model	Peak Load (kW)
Base	CZ2 5A	223	CZ2 6C	35	CZ2 9aD	12
Test 1	CZ2 5A	225				
Test 2					CZ2 9aD	12
Test 3			CZ2 6C	35		
Base	CZ5 5A	222	CZ5 6C	33	CZ5 9aD	11
Test 1	CZ5 5A	220				
Test 2					CZ5 9aD	12
Test 3			CZ5 6C	34		
Base			CZ6 6C	34	CZ6 9aD	10
Test 1						
Test 2						
Test 3			CZ6 6C	34	CZ6 9aD	9
Base			CZ7 6C	32	CZ7 9aD	7
Test 1			CZ7 6C	33		
Test 2						
Test 3			CZ7 6C	33	CZ7 9aD	7

Table 4-128: Results summary for the outside air treatment efficiency measures.

	Model	Peak Load (kWh)	Model	Peak Load (kWh)	Model	Peak Load (kWh)	Model	Peak Load (kWh)	Model	Peak Load (kWh)
Base	CZ2 3B	58	CZ2 5A	223	CZ2 6C	35	CZ2 9aD	12	CZ2 9bE	16
Test 1	CZ2 3B	58	CZ2 5A	227	CZ2 6C	35	CZ2 9aD	12	CZ2 9bE	15
Test 2	CZ2 3B		CZ2 5A	228	CZ2 6C	35	CZ2 9aD	12	CZ2 9bE	15
Base	CZ5 3B	55	CZ5 5A	222	CZ5 6C	33	CZ5 9aD	11	CZ5 9bE	19
Test 1	CZ5 3B	54	CZ5 5A	224	CZ5 6C	31	CZ5 9aD	11	CZ5 9bE	14
Test 2	CZ5 3B		CZ5 5A	222	CZ5 6C	31	CZ6 9aD		CZ5 9bE	14
Base	CZ6 3B	50	CZ6 5A	210	CZ6 6C	34	CZ6 9aD	10	CZ6 9bE	17
Test 1	CZ6 3B	50	CZ6 5A	211	CZ6 6C	32	CZ7 9aD	9	CZ6 9bE	14
Test 2	CZ6 3B		CZ6 5A		CZ6 6C	32	CZ7 9aD		CZ6 9bE	15

	Model	Peak Load (kWh)	Model	Peak Load (kWh)	Model	Peak Load (kWh)	Model	Peak Load (kWh)	Model	Peak Load (kWh)
Base	CZ7 3B		CZ7 5A	199	CZ7 6C	32	CZ2 9aD	7	CZ7 9bE	18
Test 1	CZ7 3B		CZ7 5A	190	CZ7 6C	31	CZ2 9aD	7	CZ7 9bE	15
Test 2	CZ7 3B		CZ7 5A		CZ7 6C	31	CZ2 9aD		CZ7 9bE	14

Table 4-129: Results summary for the commissioning investigation.

	Model	Peak Load (kWh)
Base	CZ2 5A	223
Test 1	CZ2 5A	0
Base	CZ5 5A	222
Test 1	CZ5 5A	0
Base	CZ6 5A	210
Test 1	CZ6 5A	0
Base	CZ7 5A	199
Test 1	CZ7 5A	0

Table 4-130: Results summary for the lighting efficiency measures.

	Model	Peak Load (kWh)	Model	Peak Load (kWh)	Model	Peak Load (kWh)	Model	Peak Load (kWh)	Model	Peak Load (kWh)
Base	CZ2 3B	58	CZ2 5A	223	CZ2 6C	35	CZ2 9aD	12	CZ2 9bE	16
Test 1	CZ2 3B	58	CZ2 5A	212	CZ2 6C	32	CZ2 9aD	12	CZ2 9bE	17
Test 2	CZ2 3B	58	CZ2 5A	203	CZ2 6C	31	CZ2 9aD	12	CZ2 9bE	16
Test 3	CZ2 3B	58	CZ2 5A	196	CZ2 6C	29	CZ2 9aD	12	CZ2 9bE	16
Base	CZ5 3B	55	CZ5 5A	222	CZ5 6C	33	CZ5 9aD	11	CZ5 9bE	19
Test 1	CZ5 3B	55	CZ5 5A	210	CZ5 6C	31	CZ5 9aD	11	CZ5 9bE	19
Test 2	CZ5 3B	54	CZ5 5A	199	CZ5 6C	30	CZ5 9aD	11	CZ5 9bE	19
Test 3	CZ5 3B	54	CZ5 5A	190	CZ5 6C	27	CZ5 9aD	11	CZ5 9bE	19
Base	CZ6 3B	50	CZ6 5A	210	CZ6 6C	34	CZ6 9aD	10	CZ6 9bE	17
Test 1	CZ6 3B	50	CZ6 5A	206	CZ6 6C	32	CZ6 9aD	9	CZ6 9bE	17
Test 2	CZ6 3B	49	CZ6 5A	194	CZ6 6C	30	CZ6 9aD	9	CZ6 9bE	17
Test 3	CZ6 3B	49	CZ6 5A	182	CZ6 6C	28	CZ6 9aD	9	CZ6 9bE	18
Base	CZ7 3B	40	CZ7 5A	199	CZ7 6C	32	CZ7 9aD	7	CZ7 9bE	18
Test 1	CZ7 3B	39	CZ7 5A	189	CZ7 6C	30	CZ7 9aD	7	CZ7 9bE	18
Test 2	CZ7 3B	39	CZ7 5A	181	CZ7 6C	26	CZ7 9aD	7	CZ7 9bE	18
Test 3	CZ7 3B	39	CZ7 5A	172	CZ7 6C	23	CZ7 9aD	7	CZ7 9bE	17

Table 4-131: Results summary for the lift technology efficiency measures.

	Model	Peak Load (kWh)	Model	Peak Load (kWh)
Base	CZ2 3B	58	CZ2 5A	223
Test 1	CZ2 3B	58	CZ2 5A	223
Base	CZ5 3B	55	CZ5 5A	222
Test 1	CZ5 3B	55	CZ5 5A	222
Base	CZ6 3B	50	CZ6 5A	210
Test 1	CZ6 3B	50	CZ6 5A	210
Base	CZ7 3B	40	CZ7 5A	199
Test 1	CZ7 3B	40	CZ7 5A	199

Appendix H - Commercial Multi-Dimensional Economic Details

H.1 Benefit Cost Analysis

The benefit cost ratio is calculated by dividing the incremental lifecycle operational cost divided by the incremental lifecycle construction cost. The incremental capital cost is found by subtracting the scenario capital cost from the base case capital cost which includes any variation in HVAC capex. For example, an incremental operational cost of $200,000, an incremental capital cost of $150,000 and a HVAC plant capex variation of $50,000 results in a benefit cost ratio of ($200,000 / ($150,000-$50,000)) = 2.0. The previous calculation assumes the inclusion of a contribution from network cost reduction. Ignoring this contribution, the benefit cost ratio is calculated similarly; ($200,000 / $150,000) = 1.33.

The energy and economic figures presented in the results table below takes data from the whole building energy analysis. The benefit cost ratios presented are based on regulated building energy only and were tuned to the range of 1 - 1.5.

The lifecycle costs are calculated based on the economic modelling methodology described in Appendix A - Economic Analysis Assumptions.

The area assumptions for the archetypes are as follows:

Hotel – 2,000 m^2

Office Building – 10,000 m^2

Retail Building – 1,000 m^2

Hospital Ward – 500 m^2

School – 200 m^2

The tables in the sub sections below represent the following information:

- **Model –** refers to the modelling scenario for the particular archetype for the particular year.
- **Base Construction Cost –** refers to the assumed absolute construction cost of relevant works (not accounting for HVAC variation).
- **HVAC sizing capital cost adjustment -** refers to the change in capital cost of (assumed) split HVAC system, due to variation in peak demand, relative to base case.
- **Capital Cost (not inc. network adjustments) –** refers to base construction cost + HVAC adjustments.
- **Energy Use (kWh) –** refers to entire building yearly energy use.
- **Peak Demand (kW) –** refers to peak HVAC electricity demand for the year.
- **Network adjustments to capital cost –** refers to incremental variation in capital cost due to change in peak demand relative to the base case.
- **Lifecycle energy cost savings (today) –** refers to energy cost savings accrued over the lifetime of the technology (40 years) for measures implemented at 0 years (2019) into the future. Calculated in $ (dollars).
- **Lifecycle energy cost savings (5 yrs) -** refers to energy cost savings accrued over the lifetime of the technology (40 years) for measures implemented at 5 years (2024) into the future. Calculated in $ (dollars).
- **Lifecycle energy cost savings (10 yrs) -** refers to energy cost savings accrued over the lifetime of the technology (40 years) for measures implemented at 10 years (2029) into the future. Calculated in $ (dollars).
- **Lifecycle energy cost savings (15 yrs) -** refers to energy cost savings accrued over the lifetime of the technology (40 years) for measures implemented at 15 years (2034) into the future. Calculated in $ (dollars).
- **BC Ratio – Today -** refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost of measures implemented at 0 years (2019) into the future.
- **BC Ratio - 5 yrs -** refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost of measures implemented at 5 years (2024) into the future.
- **BC Ratio - 10 yrs** - refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost of measures implemented at 10 years (2029) into the future.

- **BC Ratio - 15 yrs -** refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost of measures implemented at 15 years (2034) into the future.
- **BC Ratio (without network adjustment) – Today -** refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost less network adjustments implemented at 0 years (2019) into the future.
- **BC Ratio (without network adjustment) – 5 yrs -** refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost less network adjustments implemented at 5 years (2024) into the future.
- **BC Ratio (without network adjustment) – 10 yrs -** refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost less network adjustments implemented at 10 years (2029) into the future.
- **BC Ratio (without network adjustment) – 15 yrs –** refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost less network adjustments implemented at 15 years (2034) into the future.

The tables presented below contain the full breakdown of all the inputs which made up the benefit cost calculation. Results are given for both archetype orientations that were used in the multi- dimensional tuning, those with the highest and lowest yearly energy consumption. The construction costs are fixed and implemented by years for scenarios given in Table 2-8 to Table 2-13.

H.1.1 Conservative Trajectory

Presented in the table below are the benefit cost ratio results for the package of measures included in the multidimensional conservative energy efficiency trajectories/scenarios.

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
CZ2 3B	Base case		234,572	217,934	60	61.49													
	0 yrs	$151,037	148,615	142,556	22	36.81	-$23,785	180,713				1.43				1.20			
	5 yrs	$293,914	130,373	125,054	19	32.57	-$27,598		274,596				1.04				0.93		
	10 yrs	$308,881	111,545	107,170	16	29.95	-$29,821			338,570				1.23				1.10	
	15 yrs	$325,483	106,010	101,954	15	28.68	-$30,717				392,935				1.35				1.21
CZ5 3B	Base case		228,984	191,999	133	58.81													
	0 yrs	$145,662	140,476	128,025	45	33.48	-$24,403	165,365				1.41				1.14			
	5 yrs	$199,237	124,939	114,542	37	29.67	-$27,799		241,264				1.44				1.21		
	10 yrs	$283,681	109,587	99,925	35	27.23	-$29,850			296,481				1.19				1.05	
	15 yrs	$283,227	105,596	95,651	36	26.26	-$30,468				340,482				1.37				1.20
CZ6 3B	Base case		178,590	169,240	34	52.93													
	0 yrs	$87,787	127,467	121,493	22	33.28	-$18,936	90,539				1.25				1.03			
	5 yrs	$153,188	115,940	108,429	27	29.31	-$22,537		149,668				1.14				0.98		
	10 yrs	$176,765	103,322	96,263	25	27.33	-$24,195			185,973				1.22				1.05	
	15 yrs	$194,406	99,271	92,411	25	26.35	-$24,884				220,043				1.30				1.13
CZ7 3B	Base case		183,647	167,935	57	45.55													
	0 yrs	$109,093	135,192	113,095	80	30.70	-$14,309	98,220				1.04				0.90			
	5 yrs	$148,395	122,913	105,089	64	27.44	-$17,277		147,130				1.14				0.99		
	10 yrs	$184,267	108,636	91,817	61	25.86	-$18,607			182,871				1.12				0.99	
	15 yrs	$220,842	105,639	88,292	62	25.03	-$19,208				214,939				1.08				0.97
CZ2 5A	Base case		896,381	891,241	19	322.17													
	0 yrs	$412,680	730,955	726,611	16	281.58	-$39,112	400,573				1.08				0.97			
	5 yrs	$607,623	687,383	687,285	0	256.91	-$62,277		605,414				1.12				1.00		
	10 yrs	$900,060	471,405	471,295	0	213.85	-$102,390			851,446				1.05				0.95	

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	15 yrs	$890,715	419,340	419,215	0	201.26	-$113,196				1,092,519				1.38				1.23
CZ5 5A	Base case		822,332	805,338	61	320.83													
	0 yrs	$361,918	683,359	663,131	73	269.76	-$49,205	326,199				1.02				0.90			
	5 yrs	$484,813	639,251	638,893	1	248.57	-$68,958		478,385				1.12				0.99		
	10 yrs	$595,769	439,897	439,724	1	191.45	-$122,300			678,284				1.32				1.14	
	15 yrs	$923,088	391,288	391,096	1	179.75	-$132,086				881,612				1.07				0.96
CZ6 5A	Base case		796,870	721,830	270	348.59													
	0 yrs	$324,798	621,968	620,181	6	265.12	-$80,419	286,138				1.02				0.88			
	5 yrs	$324,557	601,260	599,473	6	239.70	-$103,918		384,622				1.48				1.19		
	10 yrs	$633,329	409,242	407,078	8	165.60	-$172,964			554,642				1.02				0.88	
	15 yrs	$624,459	360,414	357,602	10	156.79	-$179,569				744,197				1.41				1.19
CZ7 5A	Base case		837,921	709,168	464	463.97													
	0 yrs	$222,183	705,846	603,520	368	270.09	-$186,786	227,544				1.17				1.02			
	5 yrs	$367,901	597,556	579,764	64	221.84	-$231,056		426,838				1.43				1.16		
	10 yrs	$630,235	379,644	361,635	65	154.12	-$292,872			595,620				1.07				0.95	
	15 yrs	$700,084	329,790	312,301	63	145.95	-$297,732				774,643				1.29				1.11
CZ2 6C	Base case		122,602	122,602	-	41.12													
	0 yrs	$54,850	62,263	62,263	-	32.28	-$8,516	65,537				1.32				1.19			
	5 yrs	$118,371	44,670	44,670	-	21.67	-$18,560		124,989				1.20				1.06		
	10 yrs	$216,022	19,822	19,822	-	15.17	-$24,524			201,659				1.02				0.93	
	15 yrs	$273,268	14,989	14,989	-	12.07	-$27,190				283,080				1.12				1.04
CZ5 6C	Base case		111,095	111,095	-	41.06													
	0 yrs	$57,503	53,696	53,696	-	27.53	-$13,036	60,322				1.19				1.05			
	5 yrs	$87,501	42,760	42,760	-	20.68	-$19,445		100,518				1.40				1.15		

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	10 yrs	$176,416	20,968	20,968	-	16.20	-$23,492			168,705				1.07				0.96	
	15 yrs	$243,823	15,907	15,907	-	13.48	-$25,812				243,470				1.10				1.00
CZ6 6C	Base case		103,571	103,571	-	39.11													
	0 yrs	$48,884	48,305	48,305	-	28.95	-$9,779	60,320				1.43				1.23			
	5 yrs	$85,559	40,650	40,650	-	21.21	-$17,078		88,327				1.23				1.03		
	10 yrs	$161,979	20,257	20,257	-	15.20	-$22,591			151,424				1.05				0.93	
	15 yrs	$211,266	16,297	16,297	-	13.09	-$24,354				214,824				1.12				1.02
CZ7 6C	Base case		104,531	104,531	-	35.76													
	0 yrs	$71,236	43,124	43,124	-	20.90	-$14,319	68,783				1.10				0.97			
	5 yrs	$102,133	37,176	37,176	-	17.40	-$17,524		94,767				1.06				0.93		
	10 yrs	$160,374	18,273	18,273	-	13.97	-$20,599			156,784				1.09				0.98	
	15 yrs	$202,928	14,756	14,756	-	12.80	-$21,503				219,978				1.19				1.08
CZ2 9aD	Base case		65,768	55,655	36	13.70													
	0 yrs	$68,263	25,053	19,627	20	6.82	-$6,634	64,970				1.04				0.95			
	5 yrs	$68,263	23,427	18,001	20	6.18	-$7,176		87,012				1.40				1.27		
	10 yrs	$82,736	21,822	16,627	19	5.68	-$7,586			103,786				1.37				1.25	
	15 yrs	$97,132	21,133	16,006	18	5.42	-$7,753				118,457				1.31				1.22
CZ2 9aD	Base case		66,639	47,000	71	13.92													
	0 yrs	$54,805	29,373	19,326	36	7.15	-$6,527	53,343				1.09				0.97			
	5 yrs	$59,728	27,589	17,838	35	6.45	-$7,130		69,758				1.32				1.17		
	10 yrs	$68,179	26,473	16,805	35	5.80	-$7,676			81,283				1.33				1.19	
	15 yrs	$81,578	25,760	16,238	34	5.57	-$7,823				92,196				1.24				1.13
CZ6 9aD	Base case		61,232	38,326	82	11.20													
	0 yrs	$18,694	44,258	18,494	93	6.94	-$4,100	18,854				1.16				1.01			

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	5 yrs	$34,643	30,641	16,750	50	5.93	-$5,026		43,769				1.42				1.26		
	10 yrs	$41,593	30,214	15,913	51	5.49	-$5,398			50,689				1.35				1.22	
	15 yrs	$47,800	28,753	15,201	49	5.27	-$5,552				60,044				1.39				1.26
CZ7 9aD	Base case		68,458	38,458	108	10.11													
	0 yrs	$34,670	37,542	17,143	73	6.47	-$3,512	35,348				1.09				1.02			
	5 yrs	$37,962	36,806	16,648	73	5.81	-$4,108		44,067				1.27				1.16		
	10 yrs	$41,154	35,893	15,686	73	5.44	-$4,422			51,675				1.38				1.26	
	15 yrs	$44,468	35,455	15,186	73	5.23	-$4,570				58,917				1.45				1.32
CZ2 9bE	Base case		17,758	17,758	-	14.47													
	0 yrs	$13,252	4,534	4,534	-	10.01	-$4,301	12,217				1.20				0.92			
	5 yrs	$38,354	1,276	1,276	-	4.19	-$9,806		33,461				1.15				0.87		
	10 yrs	$38,334	663	663	-	3.07	-$10,777			40,852				1.44				1.07	
	15 yrs	$43,986	526	526	-	2.75	-$10,972				47,173				1.39				1.07
CZ5 9bE	Base case		14,570	14,570	-	14.20													
	0 yrs	$16,705	2,393	2,393	-	6.85	-$7,078	13,834				1.29				0.83			
	5 yrs	$39,053	877	877	-	2.73	-$10,941		31,443				1.21				0.81		
	10 yrs	$38,827	644	644	-	2.25	-$11,294			37,094				1.47				0.96	
	15 yrs	$45,730	557	557	-	2.17	-$11,255				42,042				1.27				0.92
CZ6 9bE	Base case		14,806	14,806	-	15.22													
	0 yrs	$19,311	3,150	3,150	-	8.11	-$6,850	16,484				1.03				0.85			
	5 yrs	$34,282	1,422	1,422	-	4.73	-$10,007		32,799				1.45				0.96		
	10 yrs	$41,001	1,049	1,049	-	4.38	-$10,249			38,687				1.33				0.94	
	15 yrs	$47,420	831	831	-	3.33	-$11,136				44,991				1.28				0.95
CZ7 9bE	Base case		17,144	17,144	-	16.38													

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	0 yrs	$21,618	3,551	3,551	-	10.13	-$6,015	17,694				1.03				0.82			
	5 yrs	$38,593	1,837	1,837	-	6.75	-$9,184		33,652				1.12				0.87		
	10 yrs	$38,312	1,176	1,176	-	5.88	-$9,927			40,704				1.40				1.06	
	15 yrs	$46,388	1,018	1,018	-	5.89	-$9,818				46,152				1.24				0.99

H.1.2 Accelerated Deployment Trajectory

Presented in the table below are the benefit cost ratio results for the package of measures included in the multidimensional Accelerated Deployment energy efficiency trajectories/scenarios.

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
CZ2 3B	Base case		234,572	217,934	60	61.49													
	0 yrs	$164,672	149,126	149,126	-	31.84	-$28,574	$241,890				1.78				1.45			
	5 yrs	$306,350	144,686	144,686	-	30.31	-$29,756		$296,472				1.09				0.98		
	10 yrs	$320,526	139,605	139,605	-	28.75	-$30,947			$360,924				1.24				1.11	
	15 yrs	$336,539	135,765	135,765	-	27.61	-$31,720				$425,685				1.36				1.21
CZ5 3B	Base case		228,984	191,999	133	58.81													
	0 yrs	$159,829	141,616	141,616	-	29.76	-$27,983	$207,111				1.59				1.27			
	5 yrs	$212,101	137,055	137,055	-	28.13	-$29,274		$253,791				1.42				1.19		
	10 yrs	$296,906	132,522	132,522	-	26.42	-$30,608			$305,704				1.14				1.00	
	15 yrs	$296,813	123,953	123,953	-	25.61	-$31,080				$382,675				1.40				1.23
CZ6 3B	Base case		178,590	169,240	34	52.93													
	0 yrs	$96,481	132,257	132,257	-	30.28	-$21,819	$130,502				1.73				1.34			
	5 yrs	$162,900	129,591	129,591	-	28.62	-$23,197		$160,919				1.16				1.00		
	10 yrs	$186,012	126,637	126,637	-	27.15	-$24,372			$196,698				1.20				1.04	
	15 yrs	$203,399	123,796	123,796	-	26.24	-$24,988				$235,619				1.27				1.11
CZ7 3B	Base case		183,647	167,935	57	45.55													
	0 yrs	$120,979	134,568	134,568	-	27.70	-$17,200	$126,544				1.22				1.03			
	5 yrs	$159,788	129,671	129,671	-	26.40	-$18,278		$163,872				1.18				1.03		
	10 yrs	$195,488	126,432	126,432	-	25.64	-$18,819			$200,199				1.13				1.00	
	15 yrs	$231,386	123,652	123,652	-	24.86	-$19,372				$238,179				1.09				0.99
CZ2 5A	Base case		896,381	891,241	19	322.17													
	0 yrs	$2,647,292	667,550	667,550	-	249.31	-$70,199	$727,179				0.28				0.27			

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 year s	BC Ratio - 15 year s	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustme nt) - 15 yrs
	5 yrs	$2,847,695	641,585	641,585	-	229.23	-$88,696		$944,396				0.35				0.34		
	10 yrs	$2,830,133	629,798	629,798	-	215.41	-$100,912			$1,139,199				0.41				0.40	
	15 yrs	$2,845,203	607,021	607,021	-	209.18	-$105,781				$1,404,322				0.49				0.48
CZ5 5A	Base case		822,332	805,338	61	320.83													
	0 yrs	$4,551,684	622,549	622,549	-	233.37	-$84,269	$609,684				0.14				0.13			
	5 yrs	$4,620,952	604,031	604,031	-	213.30	-$102,623		$777,970				0.17				0.17		
	10 yrs	$4,721,188	598,636	598,636	-	199.05	-$115,113			$917,474				0.20				0.19	
	15 yrs	$4,722,943	576,158	576,158	-	191.52	-$121,067				$1,149,069				0.24				0.23
CZ6 5A	Base case		796,870	721,830	270	348.59													
	0 yrs	$4,640,470	560,726	560,726	-	219.27	-$124,595	$609,984				0.13				0.13			
	5 yrs	$4,633,002	544,682	544,682	-	209.57	-$132,671		$761,612				0.17				0.16		
	10 yrs	$4,626,449	530,411	530,411	-	197.17	-$143,124			$926,698				0.20				0.20	
	15 yrs	$4,616,776	513,166	513,166	-	189.13	-$149,293				$1,123,616				0.24				0.23
CZ7 5A	Base case		837,921	709,168	464	463.97													
	0 yrs	$4,205,082	551,393	551,393	-	180.23	-$273,362	$664,211				0.16				0.15			
	5 yrs	$4,398,229	533,434	533,434	-	151.54	-$298,147		$825,138				0.19				0.19		
	10 yrs	$4,395,943	515,784	515,784	-	148.22	-$298,442			$1,005,007				0.23				0.22	
	15 yrs	$4,485,562	499,911	499,911	-	144.63	-$298,972				$1,196,334				0.26				0.25
CZ2 6C	Base case		122,602	122,602	-	41.12													
	0 yrs	$66,784	90,105	90,105	-	26.94	-$13,655	$104,737				1.97				1.56			
	5 yrs	$128,790	80,854	80,854	-	24.50	-$15,857		$156,820				1.41				1.24		
	10 yrs	$227,760	71,935	71,935	-	22.07	-$17,999			$219,480				1.04				0.95	

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	15 yrs	$285,551	62,707	62,707	-	19.20	-$20,518				$294,534				1.07				0.99
CZ5 6C	Base case		111,095	111,095	-	41.06													
	0 yrs	$117,338	82,350	82,350	-	26.51	-$14,012	$92,648				0.89				0.79			
	5 yrs	$146,634	74,258	74,258	-	23.82	-$16,446		$138,376				1.08				0.96		
	10 yrs	$235,046	66,053	66,053	-	20.73	-$19,210			$195,115				0.89				0.82	
	15 yrs	$300,066	58,094	58,094	-	18.01	-$21,571				$260,633				0.90				0.84
CZ6 6C	Base case		103,571	103,571	-	39.11													
	0 yrs	$330,431	79,028	79,028	-	24.37	-$14,193	$79,103				0.25				0.24			
	5 yrs	$550,684	71,926	71,926	-	22.18	-$16,154		$118,872				0.23				0.22		
	10 yrs	$623,872	64,223	64,223	-	19.59	-$18,444			$170,448				0.28				0.27	
	15 yrs	$449,839	57,369	57,369	-	17.08	-$20,618				$227,194				0.51				0.49
CZ7 6C	Base case		104,531	104,531	-	35.76													
	0 yrs	$249,148	79,367	79,367	-	21.73	-$13,525	$81,104				0.34				0.32			
	5 yrs	$457,334	72,114	72,114	-	19.55	-$15,472		$121,770				0.28				0.27		
	10 yrs	$517,041	64,616	64,616	-	17.23	-$17,519			$172,905				0.34				0.33	
	15 yrs	$356,537	57,661	57,661	-	15.17	-$19,282				$230,481				0.66				0.62
CZ2 9aD	Base case		65,768	55,655	36	13.70													
	0 yrs	$78,382	33,864	33,864	-	7.22	-$6,245	$82,463				1.12				1.03			
	5 yrs	$78,400	32,973	32,973	-	6.80	-$6,587		$98,165				1.37				1.25		
	10 yrs	$92,816	32,002	32,002	-	6.37	-$6,928			$115,602				1.32				1.22	
	15 yrs	$107,207	31,194	31,194	-	6.04	-$7,178				$133,426				1.28				1.19
CZ2 9aD	Base case		66,639	47,000	71	13.92													

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	0 yrs	$61,967	32,146	32,146	-	7.30	-$6,381	$71,623				1.24				1.12			
	5 yrs	$69,720	31,271	31,271	-	6.83	-$6,772		$84,255				1.32				1.19		
	10 yrs	$75,029	30,392	30,392	-	6.43	-$7,083			$97,464				1.39				1.25	
	15 yrs	$89,671	29,655	29,655	-	6.07	-$7,351				$110,817				1.28				1.17
CZ6 9aD	Base case		61,232	38,326	82	11.20													
	0 yrs	$135,363	37,809	37,809	-	8.90	-$2,216	$29,364				0.20				0.20			
	5 yrs	$148,152	35,585	35,585	-	8.05	-$3,003		$39,651				0.25				0.25		
	10 yrs	$154,123	34,356	34,356	-	7.54	-$3,459			$46,961				0.29				0.28	
	15 yrs	$161,031	33,351	33,351	-	7.11	-$3,822				$54,228				0.32				0.31
CZ7 9aD	Base case		68,458	38,458	108	10.11													
	0 yrs	$43,285	36,409	36,409	-	9.45	-$643	$42,881				0.92				0.91			
	5 yrs	$46,512	35,027	35,027	-	8.76	-$1,292		$51,339				1.05				1.03		
	10 yrs	$49,751	33,834	33,834	-	8.19	-$1,819			$59,014				1.15				1.10	
	15 yrs	$53,046	32,803	32,803	-	7.69	-$2,266				$66,792				1.22				1.17
CZ2 9bE	Base case		17,758	17,758	-	14.47													
	0 yrs	$179,334	8,223	8,223	-	7.94	-$6,294	$30,732				0.18				0.17			
	5 yrs	$179,204	7,811	7,811	-	7.48	-$6,672		$37,364				0.22				0.21		
	10 yrs	$178,635	7,479	7,479	-	7.02	-$7,040			$44,527				0.26				0.25	
	15 yrs	$183,626	7,122	7,122	-	6.71	-$7,261				$52,299				0.29				0.27
CZ5 9bE	Base case		14,570	14,570	-	14.20													
	0 yrs	$99,490	6,739	6,739	-	7.27	-$6,670	$25,238				0.29				0.25			
	5 yrs	$122,821	6,090	6,090	-	6.18	-$7,651		$31,854				0.30				0.26		

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	10 yrs	$123,401	6,003	6,003	-	6.01	-$7,733			$37,111				0.33				0.30	
	15 yrs	$130,022	5,615	5,615	-	5.76	-$7,899				$44,037				0.36				0.33
CZ6 9bE	Base case		14,806	14,806	-	15.22													
	0 yrs	$96,480	5,446	5,446	-	7.23	-$7,699	$30,168				0.35				0.31			
	5 yrs	$114,457	5,148	5,148	-	6.14	-$8,663		$36,280				0.36				0.32		
	10 yrs	$121,678	4,783	4,783	-	6.15	-$8,571			$43,419				0.39				0.35	
	15 yrs	$127,560	4,664	4,664	-	5.91	-$8,712				$49,876				0.42				0.38
CZ7 9bE	Base case		17,144	17,144	-	16.38													
	0 yrs	$100,452	7,973	7,973	-	8.34	-$7,743	$29,559				0.32				0.29			
	5 yrs	$116,103	7,343	7,343	-	7.66	-$8,315		$36,814				0.35				0.32		
	10 yrs	$116,388	7,032	7,032	-	7.24	-$8,633			$43,801				0.40				0.37	
	15 yrs	$122,495	6,796	6,796	-	6.98	-$8,796				$50,885				0.43				0.40

Appendix I - Commercial Economic Modelling Details

The single-dimensional analysis benefit cost results are presented in the following tables for each of the energy efficiency measures respectively. Cells with “n.c.” equate to “negative cost” results from the benefit cost analysis; meaning the construction cost of the test case is lower than the base case.

I.1 Benefit Cost Analysis

The benefit cost ratio is calculated by dividing the lifecycle energy cost savings over the differential capital cost less network adjustments.

For example, from the table for conservative trajectory numbers Table 4-71, for Climate Zone 2, 180°, 0 year scenario, the BCR value would be:

$$\frac{2{,}342}{[(66{,}538-61{,}206)-1{,}240]} = \frac{2{,}342}{4{,}092} = 0.57$$

The lifecycle costs are calculated based on the economic modelling methodology described in Appendix A -

The tables in the sub sections below represent the following information:

- **Model –** refers to the modelling scenario for the particular archetype for the particular year.
- **Base Construction Cost –** refers to the assumed absolute construction cost of relevant works (not accounting for HVAC variation).
- **HVAC sizing capital cost adjustment -** refers to the change in capital cost of (assumed) split HVAC system, due to variation in peak demand, relative to base case.
- **Capital Cost (not inc. network adjustments) –** refers to base construction cost + HVAC adjustments.
- **Energy Use (kWh) –** refers to entire building yearly energy use.
- **Peak Demand (kW) –** refers to peak HVAC electricity demand for the year.
- **Network adjustments to capital cost –** refers to incremental variation in capital cost due to change in peak demand relative to the base case.
- **Lifecycle energy cost savings (today) –** refers to energy cost savings accrued over the lifetime of the technology (40 years) for measures implemented at 0 years (2019) into the future. Calculated in $ (dollars).
- **Lifecycle energy cost savings (5 yrs) -** refers to energy cost savings accrued over the lifetime of the technology (40 years) for measures implemented at 5 years (2024) into the future. Calculated in $ (dollars).
- **Lifecycle energy cost savings (10 yrs) -** refers to energy cost savings accrued over the lifetime of the technology (40 years) for measures implemented at 10 years (2029) into the future. Calculated in $ (dollars).
- **Lifecycle energy cost savings (15 yrs) -** refers to energy cost savings accrued over the lifetime of the technology (40 years) for measures implemented at 15 years (2034) into the future. Calculated in $ (dollars).
- **BC Ratio – Today -** refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost of measures implemented at 0 years (2019) into the future.
- **BC Ratio - 5 yrs -** refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost of measures implemented at 5 years (2024) into the future.
- **BC Ratio - 10 yrs** - refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost of measures implemented at 10 years (2029) into the future.
- **BC Ratio - 15 yrs -** refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost of measures implemented at 15 years (2034) into the future.
- **BC Ratio (without network adjustment) – Today -** refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost less network adjustments implemented at 0 years (2019) into the future.
- **BC Ratio (without network adjustment) – 5 yrs -** refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost less network adjustments implemented at 5 years (2024) into the future.

- **BC Ratio (without network adjustment) – 10 yrs -** refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost less network adjustments implemented at 10 years (2029) into the future.
- **BC Ratio (without network adjustment) – 15 yrs –** refers to the benefit cost ratio defined as the ratio of the lifecycle energy cost savings over the differential capital cost less network adjustments implemented at 15 years (2034) into the future.

The tables presented below contain the full breakdown of all the inputs which made up the benefit cost calculation. Results are given for both archetype orientations that were used in the multi- dimensional tuning, those with the highest and lowest yearly energy consumption. The construction costs are fixed and implemented by years for scenarios given in Table 2-8 to Table 2-13.

I.2 Fabric Colour

The fabric colour measure compares an external wall absorptivity of 0.7 (base) with 0.4 (test 1) and 0.9 (test 2). The benefit cost analysis results are presented in Table 4-132 below. No capex has been associated with this measure.

Table 4-132: Results summary for the fabric colour measure.

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
CZ23B	Base case		188,716	174,559	51	58.17													
	Level 1	-$5,087	187,302	172,005	55	56.80	-$1,323	$6,967	$8,446	$9,612	$10,758	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
CZ53B	Base case		179,993	146,931	119	54.68													
	Level 1	-$3,278	179,267	144,012	127	53.45	-$1,179	$6,991	$8,627	$9,945	$11,254	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
CZ63B	Base case		140,010	127,138	46	49.71													
	Level 1	$0	139,625	125,998	49	49.71	$0	$2,840	$3,485	$4,002	$4,513	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
CZ25A	Base case		503,866	498,726	19	223.17													
	Level 1	-$16,862	495,208	489,213	22	218.84	-$4,171	$29,652	$35,364	$39,767	$44,033	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
CZ55A	Base case		429,817	412,822	61	221.83													
	Level 1	-$22,874	424,253	404,925	70	213.90	-$7,643	$22,844	$27,488	$31,115	$34,657	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
CZ65A	Base case		404,355	329,314	270	210.09													
	Level 1	-$2,998	409,132	325,482	301	208.20	-$1,820	$2,918	$4,719	$6,350	$8,068	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
CZ29aD	Base case		44,399	34,215	37	11.69													

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	Level 1	-$1,084	43,470	32,891	38	11.09	-$577	$3,824	$4,602	$5,209	$5,803	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
CZ5 9aD	Base case		43,235	25,281	65	11.27													
	Level 1	-$704	42,811	24,158	67	10.73	-$521	$2,847	$3,486	$3,995	$4,499	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
CZ6 9aD	Base case		42,806	17,867	90	9.54													
	Level 1	-$1,283	43,064	17,513	92	9.01	-$511	$469	$647	$801	$959	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
CZ2 9bE	Base case		15,237	15,237	-	16.33													
	Level 1	-$1,560	14,564	14,564	-	15.34	-$961	$2,163	$2,571	$2,884	$3,185	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
CZ5 9bE	Base case		11,844	11,844	-	18.84													
	Level 1	-$437	11,779	11,779	-	18.48	-$347	$209	$248	$278	$307	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
CZ6 9bE	Base case		12,521	12,521	-	17.38													
	Level 1	$0	12,392	12,392	-	17.36	-$19	$414	$492	$552	$609	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost

I.3 Overnight Ventilation, Infiltration and Insulation Measure

The overnight ventilation, infiltration and insulation measure identifies the optimal combination for the office and retail archetypes. The test case for each of the models uses a combination of the measures and the results are presented in Table 4-133 below. Pricing for the measures were built up with available retail costs for insulation, contractor's estimated cost for control work and infiltration test.

- Expanded polystyrene insulation framing board (price for coverage at required thicknesses estimated at $1.025/m²/mm based average costs of 8 products with differing thickness and batt coverage).
  - Cost of infiltration test is varied based on type of archetype and priced as $5,000 for 3B, 6C & 9bE and $7,500 for 5A model.
  - Costing for control work is obtained as $500 for 3B & 5A archetype models and $400 for 6C & 9bE archetype models.

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

Table 4-133: Results summary for the overnight ventilation, infiltration and insulation investigation.

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
CZ2 6C	Base case		94,377	94,377	-	35.14													
	Level 1	$53,443	93,412	93,412	-	35.14	-$2	$3,100	$3,684	$4,132	$4,564	0.06	0.07	0.08	0.09	0.06	0.07	0.08	0.09
CZ5 6C	Base case		84,108	84,108	-	32.90													
	Level 1	$39,537	80,792	80,792	-	27.15	-$5,543	$10,661	$12,671	$14,210	$15,698	0.31	0.37	0.42	0.46	0.27	0.32	0.36	0.40
CZ6 6C	Base case		82,502	82,502	-	33.51													
	Level 1	$32,312	76,712	76,712	-	22.38	-$10,724	$18,617	$22,126	$24,814	$27,412	0.86	1.02	1.14	1.25	0.58	0.68	0.77	0.85
CZ2 5A	Base case		503,866	498,726	19	223.17													
	Level 1	$16,985	499,154	494,537	17	226.10	$2,822	$14,039	$16,609	$18,563	$20,442	0.71	0.84	0.94	1.04	0.83	0.98	1.09	1.20
CZ5 5A	Base case		429,817	412,822	61	221.83													
	Level 1	$5,396	407,701	395,932	42	210.04	-$11,363	$60,011	$70,560	$78,492	$86,068	negative cost	negative cost	negative cost	negative cost	11.12	13.08	14.55	15.95
CZ6 5A	Base case		404,355	329,314	270	210.09													
	Level 1	$12,300	396,237	330,120	238	210.98	$858	$7,154	$7,205	$6,985	$6,624	0.54	0.55	0.53	0.50	0.58	0.59	0.57	0.54
CZ7 5A	Base case		445,406	316,652	464	198.97													

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	Level 1	-$7,267	439,868	315,273	449	196.12	-$2,745	$8,977	$10,064	$10,776	$11,395	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost

I.4 Overnight Ventilation and Active Thermal Mass

The optimal overnight ventilation conditions from the above investigation was used in combination with increased thermal mass. A 150mm concrete slab are used as Active mass and control work is involved for the ventilation component. Costing for control work is obtained as $500 for 3B & 5A archetype models and $400 for 6C & 9bE archetype models. The capital costs for the concrete slab were obtained from Building Cost Index March 2018 and can be found as follows:

Table 4-134: Normalised construction cost for the active mass component.

Scenarios	Performance Value	Climate Zone 2	Climate Zone 5	Climate Zone 6	Climate Zone 7
All cases	150 mm concrete including form work and reinforcing to walls 150 mm	$221	$253	$245	$210

Table 4-135: Results summary for the active mass and overnight ventilation measures.

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
CZ2 6C	Base case		94,377	94,377	-	35.14													
	Level 1	$202,128	92,782	92,782	-	35.34	$192	$5,125	$6,091	$6,831	$7,546	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.04
CZ5 6C	Base case		84,108	84,108	-	32.90													
	Level 1	$224,799	82,954	82,954	-	31.83	-$1,031	$3,710	$4,409	$4,944	$5,462	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
CZ6 6C	Base case		82,502	82,502	-	33.51													
	Level 1	$224,062	79,026	79,026	-	31.87	-$1,578	$11,179	$13,285	$14,900	$16,459	0.05	0.06	0.07	0.07	0.05	0.06	0.07	0.07
CZ2 5A	Base case		503,866	498,726	19	223.17													
	Level 1	$962,834	490,601	488,422	8	219.80	-$3,249	$36,362	$42,785	$47,620	$52,242	0.04	0.04	0.05	0.05	0.04	0.04	0.05	0.05
CZ5 5A	Base case		429,817	412,822	61	221.83													
	Level 1	$1,080,153	415,723	403,301	45	206.87	-$14,413	$35,606	$41,651	$46,151	$50,421	0.03	0.04	0.04	0.05	0.03	0.04	0.04	0.05
CZ6 5A	Base case		404,355	329,314	270	210.09													
	Level 1	$1,055,593	389,702	322,946	240	201.59	-$8,189	$29,521	$33,880	$36,980	$39,836	0.03	0.03	0.04	0.04	0.03	0.03	0.04	0.04
CZ7 5A	Base case		445,406	316,652	464	198.97													
	Level 1	$865,598	426,948	307,690	429	182.19	-$16,171	$39,185	$45,190	$49,515	$53,535	0.05	0.05	0.06	0.06	0.05	0.05	0.06	0.06

I.5 Passive Thermal Mass

Thermal mass, in the form of concrete external walls and internal core walls, is investigated for this measure with the results presented below in Table 4-137. The capital costs for the concrete slab were obtained from Building Cost Index March 2018 and can be found as follows:

Table 4-136: Normalised construction cost for the passive mass component.

Scenarios	Performance Value	Climate Zone 2 Construction cost (per unit)	Climate Zone 5 Construction cost (per unit)	Climate Zone 6 Construction cost (per unit)
All cases	150 mm concrete including form work and reinforcing to walls 150 mm	$221	$253	$245

Table 4-137: Results summary for the passive mass efficiency measures.

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
CZ2 3B	Base case		143,391	135,171	30	43.06													
	Level 1	$68,131	142,369	137,116	19	42.61	-$435	-$3,013	-$4,012	-$4,864	-$5,736	-0.04	-0.06	-0.07	-0.08	-0.04	-0.06	-0.07	-0.08
CZ5 3B	Base case		136,388	121,652	53	45.87													
	Level 1	$72,790	135,664	123,414	44	41.38	-$4,319	-$2,950	-$3,867	-$4,643	-$5,433	-0.04	-0.06	-0.07	-0.08	-0.04	-0.05	-0.06	-0.07
CZ6 3B	Base case		114,260	108,347	21	33.38													
	Level 1	$73,655	113,862	108,656	19	31.84	-$1,483	-$221	-$365	-$497	-$635	0.00	-0.01	-0.01	-0.01	0.00	0.00	-0.01	-0.01
CZ2 9bE	Base case		13,452	13,452	-	11.27													
	Level 1	$43,220	12,073	12,073	-	11.22	-$47	$4,433	$5,268	$5,909	$6,527	0.10	0.12	0.14	0.15	0.10	0.12	0.14	0.15
CZ5 9bE	Base case		11,145	11,145	-	13.71													
	Level 1	$47,848	10,231	10,231	-	13.57	-$135	$2,937	$3,490	$3,914	$4,324	0.06	0.07	0.08	0.09	0.06	0.07	0.08	0.09
CZ6 9bE	Base case		11,039	11,039	-	12.35													
	Level 1	$49,115	11,146	11,146	-	12.26	-$86	-$342	-$407	-$456	-$504	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01

I.6 BIPV

Building integrated solar photovoltaics (BIPV) for northern, western and eastern façades were implemented for all archetypes, to cover as much of the external wall as possible using a standard sized panel. The capital costs for BIPV was based on the estimation cost of a European company, Metsolar, and the price per square meter was $882. The results of the energy benefit from this technology is presented in Table 4-138.

Table 4-138: Wall BIPV results summary for all archetypes.

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
CZ2 3B	Base case		188,716	174,559	51	58.17													
	Level 1	$302,547	163,274	148,788	52	57.48	-$664	$82,498	$260,530	$365,098	$403,350	0.27	0.88	1.25	1.40	0.27	0.87	1.24	1.40
CZ5 3B	Base case		179,993	146,931	119	54.68													
	Level 1	$304,356	155,700	121,966	121	54.24	-$418	$79,532	$227,772	$315,266	$348,344	0.26	0.76	1.07	1.20	0.26	0.76	1.07	1.20
CZ6 3B	Base case		140,010	127,138	46	49.71													
	Level 1	$304,066	117,366	104,252	47	49.47	-$230	$73,319	$200,986	$276,496	$305,464	0.24	0.67	0.94	1.05	0.24	0.67	0.94	1.05
CZ7 3B	Base case		135,487	119,775	57	39.65													
	Level 1	$304,404	109,080	93,118	57	39.54	-$101	$85,434	$203,230	$273,561	$302,223	0.28	0.68	0.93	1.04	0.28	0.68	0.93	1.04
CZ2 5A	Base case		503,866	498,726	19	223.17													
	Level 1	$1,513,896	386,259	380,610	20	221.52	-$1,590	$379,206	$866,266	$1,157,996	$1,279,257	0.25	0.58	0.79	0.89	0.25	0.58	0.79	0.88
CZ5 5A	Base case		429,817	412,822	61	221.83													
	Level 1	$1,512,302	319,971	301,753	66	218.87	-$2,860	$355,771	$752,427	$991,791	$1,095,744	0.24	0.51	0.68	0.76	0.24	0.51	0.68	0.76
CZ6 5A	Base case		404,355	329,314	270	210.09													
	Level 1	$1,529,710	306,130	225,691	290	212.68	$2,494	$327,270	$636,123	$824,616	$911,583	0.21	0.42	0.55	0.62	0.21	0.42	0.56	0.62
CZ7 5A	Base case		445,406	316,652	464	198.97													
	Level 1	$1,512,533	331,216	192,541	499	197.23	-$1,680	$388,202	$673,005	$850,300	$940,508	0.26	0.45	0.58	0.65	0.26	0.45	0.58	0.65
CZ2 6C	Base case		94,377	94,377	-	35.14													
	Level 1	$393,253	64,429	64,429	-	34.90	-$233	$96,287	$184,771	$238,777	$263,768	0.24	0.48	0.63	0.70	0.24	0.48	0.63	0.70
CZ5 6C	Base case		84,108	84,108	-	32.90													
	Level 1	$393,559	55,930	55,930	-	33.04	$130	$90,597	$168,730	$216,625	$239,298	0.23	0.44	0.57	0.64	0.23	0.44	0.57	0.64

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
CZ6 6C	Base case		82,502	82,502	-	33.51													
	Level 1	$393,333	55,948	55,948	-	33.65	$132	$85,378	$162,547	$209,699	$231,647	0.22	0.42	0.55	0.62	0.22	0.42	0.55	0.62
CZ7 6C	Base case		84,766	84,766	-	32.44													
	Level 1	$393,265	52,732	52,732	-	32.28	-$150	$102,997	$179,976	$227,671	$251,499	0.26	0.46	0.60	0.67	0.26	0.46	0.60	0.67
CZ2 9aD	Base case		44,399	34,215	37	11.69													
	Level 1	$84,527	36,433	26,176	37	11.59	-$95	$25,765	$59,209	$79,232	$87,534	0.31	0.71	0.97	1.09	0.30	0.71	0.97	1.08
CZ5 9aD	Base case		43,235	25,281	65	11.27													
	Level 1	$84,724	35,606	17,526	65	11.30	$27	$24,796	$48,621	$63,128	$69,750	0.29	0.58	0.77	0.86	0.29	0.58	0.77	0.86
CZ6 9aD	Base case		42,806	17,867	90	9.54													
	Level 1	$83,649	35,900	10,738	91	9.07	-$450	$22,678	$38,706	$48,696	$53,820	0.27	0.47	0.60	0.68	0.27	0.47	0.60	0.67
CZ7 9aD	Base case		47,242	17,148	108	7.40													
CZ7 9aD	Base case		47,242	17,148	108	7.40													
	Level 1	$84,780	37,137	6,813	109	7.22	-$168	$32,976	$46,662	$55,697	$61,555	0.39	0.56	0.68	0.76	0.39	0.56	0.68	0.76
CZ2 9bE	Base case		15,237	15,237	-	16.33													
	Level 1	$43,876	11,307	11,307	-	15.89	-$429	$12,637	$27,362	$36,224	$40,015	0.29	0.64	0.86	0.96	0.29	0.63	0.85	0.95
CZ5 9bE	Base case		11,844	11,844	-	18.84													
	Level 1	$45,494	8,516	8,516	-	19.02	$173	$10,700	$22,014	$28,859	$31,880	0.23	0.49	0.65	0.73	0.24	0.49	0.65	0.73
CZ6 9bE	Base case		12,521	12,521	-	17.38													
	Level 1	$45,158	9,163	9,163	-	18.69	$1,260	$10,795	$22,833	$30,095	$33,245	0.23	0.50	0.67	0.75	0.24	0.51	0.69	0.77
CZ7 9bE	Base case		15,657	15,657	-	17.61													
	Level 1	$45,158	11,018	11,018	-	17.61	$0	$14,915	$29,754	$38,766	$42,823	0.33	0.67	0.88	0.99	0.33	0.67	0.88	0.99

Transparent PV cells were used to model window BIPV. The transparent PV cells have a lower efficiency than the opaque examples used in the wall BIPV analysis.

I.7 Rooftop PV

The rooftop PV analysis implemented tilt frames for the flat rooftops of the hotel, office and retail archetypes. The angle of tilt was adjusted to the latitude of the location and the spacing was determined so there was no shading between 9am and 3pm. The same number of panels were used for all climate zones. Archetypes 9aD and 9bE, the hospital ward and school, respectively, were mounted flush to their 30° pitched rooftops. The capital costs for PV was based on the industrial expert estimated cost and the price per square meter was $280 per square meter.

Table 4-139: Rooftop PV analysis results and corresponding benefit cost ratios.

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
CZ2 3B	Base case		143,391	135,171	30	43.06													
	Level 1	$80,600	100,332	92,075	30	38.97	-$3,937	$138,520	$265,151	$342,469	$378,317	1.81	3.51	4.61	5.17	1.72	3.34	4.38	4.91
CZ5 3B	Base case		136,388	121,652	53	45.87													
	Level 1	$78,924	94,037	79,255	53	34.26	-$11,181	$136,264	$248,475	$317,489	$350,723	2.01	3.73	4.84	5.44	1.73	3.20	4.15	4.65
CZ6 3B	Base case		114,260	108,347	21	33.38													
	Level 1	$79,178	74,106	68,155	21	27.45	-$5,710	$129,183	$227,941	$289,022	$319,276	1.76	3.15	4.06	4.56	1.63	2.92	3.76	4.22
CZ7 3B	Base case		135,472	119,759	57	39.41													
	Level 1	$79,609	88,643	72,923	57	29.24	-$9,798	$150,578	$258,568	$325,703	$359,792	2.16	3.77	4.82	5.41	1.89	3.30	4.22	4.73
CZ2 5A	Base case		558,097	551,364	24	229.27													
	Level 1	$110,570	443,288	436,541	24	215.52	-$13,248	$369,160	$915,317	$1,240,339	$1,370,157	3.79	9.57	13.16	14.78	3.34	8.40	11.56	12.98
CZ5 5A	Base case		491,120	470,313	75	223.18													
	Level 1	$106,556	377,327	356,492	75	193.14	-$28,946	$365,922	$824,078	$1,098,811	$1,213,818	4.71	10.84	14.66	16.48	3.43	7.85	10.63	11.93
CZ6 5A	Base case		472,890	385,346	315	212.95													
	Level 1	$109,608	362,357	274,650	316	187.57	-$24,445	$355,729	$722,635	$944,975	$1,043,898	4.18	8.65	11.48	12.90	3.25	6.69	8.89	9.97
CZ7 5A	Base case		450,047	377,137	262	199.18													
	Level 1	$111,077	330,117	257,153	263	181.95	-$16,603	$385,709	$739,147	$954,911	$1,054,861	4.08	7.96	10.44	11.73	3.47	6.76	8.86	9.94
CZ2 6C	Base case		89,637	89,637	-	26.05													
	Level 1	$110,763	30,025	30,025	-	22.74	-$3,188	$191,662	$260,560	$306,926	$339,049	1.78	2.46	2.94	3.30	1.73	2.39	2.86	3.21
CZ5 6C	Base case		81,661	81,661	-	27.56													
	Level 1	$110,964	23,108	23,108	-	23.28	-$4,127	$188,257	$248,962	$290,531	$320,939	1.76	2.37	2.80	3.15	1.70	2.28	2.70	3.03

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
CZ6 6C	Base case		78,679	78,679	-	22.99													
	Level 1	$111,267	23,475	23,475	-	21.88	-$1,070	$177,489	$236,566	$276,808	$305,780	1.61	2.18	2.59	2.91	1.60	2.16	2.56	2.88
CZ7 6C	Base case		82,631	82,631	-	33.63													
	Level 1	$110,356	18,069	18,069	-	24.51	-$8,790	$207,577	$266,422	$307,645	$339,843	2.04	2.67	3.13	3.51	1.88	2.45	2.87	3.22
CZ2 9aD	Base case		42,061	31,915	37	10.35													
	Level 1	$65,590	6,914	-3,298	37	7.79	-$2,461	$113,142	$130,874	$145,169	$160,371	1.79	2.11	2.37	2.66	1.73	2.03	2.28	2.56
CZ5 9aD	Base case		42,261	24,357	64	10.43													
	Level 1	$65,380	7,604	-10,387	65	8.35	-$2,007	$111,612	$121,318	$130,983	$144,703	1.76	1.94	2.13	2.39	1.71	1.88	2.07	2.32
CZ6 9aD	Base case		41,580	16,762	89	7.47													
	Level 1	$64,993	8,598	-16,492	90	7.35	-$116	$106,619	$108,747	$113,917	$125,873	1.64	1.70	1.81	2.03	1.64	1.70	1.81	2.03
CZ7 9aD	Base case		47,247	17,153	108	7.33													
	Level 1	$65,813	8,772	-21,280	108	5.45	-$1,810	$123,612	$123,669	$128,269	$141,689	1.93	1.96	2.07	2.32	1.88	1.91	2.01	2.25
CZ2 9bE	Base case		13,452	13,452	-	11.27													
	Level 1	$25,167	-131	-131	-	9.61	-$1,603	$43,670	$51,757	$57,982	$64,051	1.85	2.23	2.54	2.85	1.74	2.09	2.38	2.66
CZ5 9bE	Base case		11,145	11,145	-	13.71													
	Level 1	$26,348	-2,267	-2,267	-	10.06	-$3,515	$43,121	$48,772	$53,588	$59,197	1.89	2.17	2.42	2.72	1.64	1.88	2.10	2.35
CZ6 9bE	Base case		11,039	11,039	-	12.35													
	Level 1	$25,536	-1,798	-1,798	-	9.15	-$3,083	$41,273	$47,089	$51,930	$57,365	1.84	2.13	2.39	2.68	1.62	1.87	2.10	2.35
CZ7 9bE	Base case		10,392	10,392	-	14.22													
	Level 1	$25,536	-4,528	-4,528	-	8.87	-$5,154	$47,968	$52,064	$56,173	$62,052	2.35	2.60	2.85	3.20	1.88	2.07	2.27	2.54

I.8 Glazing Measures

There were three different external glazing measures modelled: NCC2019 glazing with an external overhang (test 1), NCC2019 glazing with exterior operated shutters (test 2) and electrochromic glazing (test 3). The capital costs for glazing was based on various industrial experts' estimation and supplier's retail prices provided upon inquiry. As the prices change depending on the materials and type, it was difficult to get exact pricing for all items and therefore, the expert's estimation was preferred. The pricing information can be found as follows:

- For overhang of 0.5P/H, the type was chosen as aluminium awning and it was priced at $837.37 per square meter including arm support and installation cost.

- For exterior operated shutters scenario, aluminium shutters from Shutterkits were chosen and it was priced at $92.11 per square meter. The motor for shutters was priced at $325/unit from Blindsonthenet for the model number of Automate E6 ARC & Wirefree motor.

- For electrochromic glazing, the prices obtained were 421$/m² for SC08, 435 $/m² for SC09, 597 $/m² for SC12 and 394 $/m² for SC04.

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

Table 4-140: External glazing efficiency measure results.

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
CZ2 3B	Base case		188,716	174,559	51	58.17													
	Level 1	$184,662	184,878	167,774	62	56.29	-$1,808	$18,598	$22,531	$25,631	$28,674	0.10	0.12	0.14	0.16	0.10	0.12	0.14	0.16
	Level 2	$7,031	178,753	158,122	74	51.25	-$6,670	$45,778	$55,346	$62,866	$70,238	126.82	0.12	0.14	0.16	0.10	7.87	8.94	9.99
	Level 3	$278,786	181,673	162,417	69	53.13	-$4,853	$33,471	$40,519	$46,069	$51,515	0.12	0.12	0.14	0.16	0.10	0.15	0.17	0.18
CZ5 3B	Base case		179,993	146,931	119	54.68													
	Level 1	$185,000	177,572	139,181	138	52.06	-$2,521	$19,098	$23,472	$26,978	$30,454	0.10	0.13	0.15	0.17	0.10	0.13	0.15	0.16
	Level 2	$17,114	170,398	131,079	142	48.94	-$5,523	$44,134	$53,360	$60,613	$67,722	3.81	0.13	0.15	0.17	0.10	3.12	3.54	3.96
	Level 3	$287,136	174,061	134,937	141	50.52	-$4,006	$31,942	$38,842	$44,306	$49,685	0.11	0.13	0.15	0.17	0.10	0.14	0.15	0.17
CZ6 3B	Base case		140,010	127,138	46	49.71													
	Level 1	$168,569	137,514	121,420	58	46.67	-$2,929	$14,866	$18,136	$20,736	$23,301	0.09	0.11	0.13	0.14	0.09	0.11	0.12	0.14
	Level 2	$14,264	133,392	118,598	53	43.86	-$5,641	$25,359	$30,417	$34,349	$38,180	2.94	0.11	0.13	0.14	0.09	2.13	2.41	2.68
	Level 3	$372,827	135,272	122,343	47	45.52	-$4,038	$15,354	$18,256	$20,481	$22,632	0.04	0.11	0.13	0.14	0.09	0.05	0.05	0.06
CZ7 3B	Base case		135,487	119,775	57	39.65													
	Level 1	$136,638	134,260	111,584	82	35.00	-$4,480	$18,732	$23,274	$26,957	$30,631	0.14	0.18	0.20	0.23	0.14	0.17	0.20	0.22
	Level 2	$4,835	131,244	111,892	70	39.35	-$286	$21,369	$25,925	$29,522	$33,058	4.70	0.18	0.20	0.23	0.14	5.36	6.11	6.84
	Level 3	$225,490	134,227	111,794	81	34.97	-$4,508	$18,321	$22,750	$26,341	$29,920	0.08	0.18	0.20	0.23	0.14	0.10	0.12	0.13
CZ2 5A	Base case		503,866	498,726	19	223.17													
	Level 1	$821,839	503,682	498,549	18	223.73	$540	$575	$682	$764	$843	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Level 2	$80,379	469,914	462,140	28	203.14	-$19,301	$114,753	$136,761	$153,703	$170,112	1.88	0.00	0.00	0.00	0.00	1.70	1.91	2.12
	Level 3	$1,843,352	482,884	476,260	24	211.33	-$11,406	$70,610	$84,132	$94,537	$104,613	0.04	0.00	0.00	0.00	0.00	0.05	0.05	0.06

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
CZ5 5A	Base case		429,817	412,822	61	221.83													
	Level 1	$802,653	420,984	400,550	74	213.86	-$7,687	$35,702	$42,930	$48,569	$54,074	0.04	0.05	0.06	0.07	0.04	0.05	0.06	0.07
	Level 2	$97,991	403,444	382,247	76	196.90	-$24,019	$93,716	$111,988	$126,112	$139,825	1.27	0.05	0.06	0.07	0.04	1.14	1.29	1.43
	Level 3	$1,864,503	413,096	394,422	67	205.96	-$15,295	$57,326	$68,373	$76,887	$85,140	0.03	0.05	0.06	0.07	0.04	0.04	0.04	0.05
CZ6 5A	Base case		404,355	329,314	270	210.09													
	Level 1	$815,708	410,912	323,129	316	210.64	$527	$5,970	$8,947	$11,599	$14,372	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.02
	Level 2	$116,111	397,131	313,052	303	196.63	-$12,963	$42,415	$51,721	$59,116	$66,410	0.41	0.01	0.01	0.02	0.01	0.45	0.51	0.57
	Level 3	$1,886,634	394,756	318,541	274	204.32	-$5,558	$33,355	$39,811	$44,793	$49,625	0.02	0.01	0.01	0.02	0.01	0.02	0.02	0.03
CZ7 5A	Base case		445,406	316,652	464	198.97													
	Level 1	$798,837	460,887	311,505	538	192.56	-$6,183	-$5,977	-$4,106	-$2,071	$236	-0.01	-0.01	0.00	0.00	-0.01	-0.01	0.00	0.00
	Level 2	$94,904	442,952	302,127	507	176.87	-$21,299	$33,519	$41,590	$48,127	$54,641	0.46	-0.01	0.00	0.00	-0.01	0.44	0.51	0.58
	Level 3	$1,857,293	434,519	307,285	458	184.53	-$13,911	$31,776	$37,543	$41,918	$46,119	0.02	-0.01	0.00	0.00	-0.01	0.02	0.02	0.02
CZ2 6C	Base case		-	-	-	0.00													
	Level 1	$0	-	-	-	0.00	Sc2	$0	$0	$0	$0	0.00	0.00	0.00	negative cost	0.00	0.00	0.00	negative cost
	Level 2	$0	-	-	-	0.00	Sc3	$0	$0	$0	$0	0.00	0.00	0.00	negative cost	0.00	0.00	0.00	negative cost
	Level 3	$0	-	-	-	0.00	Sc4	$0	$0	$0	$0	0.00	0.00	0.00	negative cost	0.00	0.00	0.00	negative cost
CZ5 6C	Base case		-	-	-	0.00													
	Level 1	$0	-	-	-	0.00	Sc2	$0	$0	$0	$0	0.00	0.00	0.00	negative cost	0.00	0.00	0.00	negative cost
	Level 2	$0	-	-	-	0.00	Sc3	$0	$0	$0	$0	0.00	0.00	0.00	negative cost	0.00	0.00	0.00	negative cost
	Level 3	$0	-	-	-	0.00	Sc4	$0	$0	$0	$0	0.00	0.00	0.00	negative cost	0.00	0.00	0.00	negative cost

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
CZ6 6C	Base case		-	-	-	0.00													
	Level 1	$0	-	-	-	0.00	Sc2	$0	$0	$0	$0	0.00	0.00	0.00	negative cost	0.00	0.00	0.00	negative cost
	Level 2	$0	-	-	-	0.00	Sc3	$0	$0	$0	$0	0.00	0.00	0.00	negative cost	0.00	0.00	0.00	negative cost
	Level 3	$0	-	-	-	0.00	Sc4	$0	$0	$0	$0	0.00	0.00	0.00	negative cost	0.00	0.00	0.00	negative cost
CZ7 6C	Base case		-	-	-	0.00													
	Level 1	$0	-	-	-	0.00	Sc2	$0	$0	$0	$0	0.00	0.00	0.00	negative cost	0.00	0.00	0.00	negative cost
	Level 2	$0	-	-	-	0.00	Sc3	$0	$0	$0	$0	0.00	0.00	0.00	negative cost	0.00	0.00	0.00	negative cost
	Level 3	$0	-	-	-	0.00	Sc4	$0	$0	$0	$0	0.00	0.00	0.00	negative cost	0.00	0.00	0.00	negative cost
CZ2 9aD	Base case		44,399	34,215	37	11.69													
	Level 1	$66,868	42,977	31,416	42	10.82	-$843	$7,494	$9,106	$10,382	$11,637	0.11	0.14	0.16	0.18	0.11	0.14	0.16	0.17
	Level 2	$6,979	40,564	27,729	46	9.54	-$2,069	$17,957	$21,726	$24,691	$27,600	3.66	0.14	0.16	0.18	0.11	3.11	3.54	3.95
	Level 3	$96,311	41,880	29,331	45	10.20	-$1,434	$13,119	$15,935	$18,161	$20,351	0.14	0.14	0.16	0.18	0.11	0.17	0.19	0.21
CZ5 9aD	Base case		43,235	25,281	65	11.27													
	Level 1	$67,968	42,956	22,827	72	10.82	-$431	$5,515	$6,870	$7,972	$9,072	0.08	0.10	0.12	0.13	0.08	0.10	0.12	0.13
	Level 2	$3,056	40,898	20,144	75	9.90	-$1,317	$13,459	$16,402	$18,739	$21,043	7.74	0.10	0.12	0.13	0.08	5.37	6.13	6.89
	Level 3	$97,805	42,263	21,572	74	10.16	-$1,068	$8,936	$11,018	$12,693	$14,356	0.09	0.10	0.12	0.13	0.08	0.11	0.13	0.15
CZ6 9aD	Base case		42,806	17,867	90	9.54													
	Level 1	$63,412	44,261	16,399	100	8.67	-$836	$1,527	$2,240	$2,871	$3,529	0.02	0.04	0.05	0.06	0.02	0.04	0.05	0.06
	Level 2	$9,248	41,874	14,977	97	8.44	-$1,058	$7,153	$8,785	$10,093	$11,389	0.87	0.04	0.05	0.06	0.02	0.95	1.09	1.23
	Level 3	$125,239	41,863	16,378	92	8.53	-$970	$4,191	$5,061	$5,742	$6,410	0.03	0.04	0.05	0.06	0.02	0.04	0.05	0.05
CZ7 9aD	Base case		47,242	17,148	108	7.40													
	Level 1	$48,834	49,432	15,432	122	6.93	-$449	$1,252	$2,055	$2,784	$3,554	0.03	0.04	0.06	0.07	0.03	0.04	0.06	0.07

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	Level 2	$6,505	46,136	14,258	115	5.68	-$1,653	$7,343	$8,985	$10,296	$11,592	1.51	0.04	0.06	0.07	0.03	1.38	1.58	1.78
	Level 3	$79,633	47,572	15,372	116	6.36	-$1,002	$3,411	$4,360	$5,148	$5,945	0.04	0.04	0.06	0.07	0.03	0.05	0.06	0.07
CZ2 9bE	Base case		15,237	15,237	-	16.33													
	Level 1	$31,237	14,373	14,373	-	15.50	-$809	$2,776	$3,299	$3,700	$4,088	0.09	0.11	0.12	0.13	0.09	0.11	0.12	0.13
	Level 2	$5,819	13,988	13,988	-	15.19	-$1,107	$4,015	$4,772	$5,352	$5,912	0.85	0.11	0.12	0.13	0.09	0.82	0.92	1.02
	Level 3	$80,513	14,623	14,623	-	15.27	-$1,026	$1,973	$2,345	$2,630	$2,905	0.02	0.11	0.12	0.13	0.09	0.03	0.03	0.04
CZ5 9bE	Base case		11,844	11,844	-	18.84													
	Level 1	$38,987	11,615	11,615	-	18.71	-$133	$735	$873	$979	$1,082	0.02	0.02	0.03	0.03	0.02	0.02	0.03	0.03
	Level 2	$6,872	11,514	11,514	-	18.01	-$806	$1,059	$1,259	$1,412	$1,559	0.17	0.02	0.03	0.03	0.02	0.18	0.21	0.23
	Level 3	$82,993	11,915	11,915	-	18.79	-$51	-$230	-$273	-$306	-$338	0.00	0.02	0.03	0.03	0.02	0.00	0.00	0.00
CZ6 9bE	Base case		12,521	12,521	-	17.38													
	Level 1	$39,001	12,473	12,473	-	17.96	$556	$154	$183	$206	$227	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01
	Level 2	$8,309	12,361	12,361	-	17.34	-$41	$514	$611	$685	$757	0.06	0.00	0.01	0.01	0.00	0.07	0.08	0.09
	Level 3	$82,744	11,528	11,528	-	17.19	-$179	$3,190	$3,791	$4,252	$4,696	0.04	0.00	0.01	0.01	0.00	0.05	0.05	0.06
CZ7 9bE	Base case		15,657	15,657	-	17.61													
	Level 1	$39,001	15,608	15,608	-	17.61	$0	$157	$186	$209	$231	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01
	Level 2	$7,683	15,452	15,452	-	17.61	$0	$658	$781	$876	$968	0.09	0.00	0.01	0.01	0.00	0.10	0.11	0.13
	Level 3	$82,744	15,489	15,489	-	17.61	$0	$539	$641	$719	$794	0.01	0.00	0.01	0.01	0.00	0.01	0.01	0.01

I.9 Daylight Harvesting

The final building fabric measure investigated relates to daylight harvesting. Daylight harvesting incorporates daylight sensors in building perimeter zones. When there is sufficient natural light in the space, the artificial lighting is turned down increasing the energy performance.

The capital costs involved for daylighting scenarios were based on daylighting sensors and light shelves. The prices were based on various industrial experts' estimation and supplier's retail prices. As the prices change depending on the materials and type, it was difficult to get exact pricing for some items and therefore, the expert's estimation was preferred for those.

- Daylighting sensor price was based on Little Cherry price list as of April 2018 and it was priced at $288.20/unit. The total cost obtained for sensors were by multiplying of the number of sensors with the price of sensor.
- For light shelves, Aluminium light shelves were chosen and it was priced at $837.37 per square meter including arm support and installation cost.
- The labour cost for installation of sensor was estimated as $120/hour and 3 sensor would be installed per hour.

No learning rate has been applied to either performance or cost. The results for archetypes 5A, 9aD and 9bE are presented below in Table 4-141.

Table 4-141: Daylighting results – the hotel (3B) and retail (6C) archetype were not simulated as there was marginal benefit.

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
CZ2 5A	Base case		503,866	498,726	19	223.17													
	Level 1	$34,599	457,961	452,398	20	204.88	-$17,625	$148,488	$176,532	$198,035	$218,813	8.75	10.40	11.44	12.52	4.29	5.10	5.72	6.32
	Level 2	$843,752	458,523	454,304	15	205.10	-$17,408	$143,829	$170,800	$191,441	$211,365	0.17	10.40	11.44	12.52	4.29	0.20	0.23	0.25
	Level 3	$401,205	458,423	452,892	20	205.29	-$17,231	$146,935	$174,682	$195,956	$216,513	0.38	10.40	11.44	12.52	4.29	0.44	0.49	0.54
CZ5 5A	Base case		429,817	412,822	61	221.83													
	Level 1	$24,524	420,984	400,550	74	213.86	-$7,687	$35,702	$42,930	$48,569	$54,074	2.12	2.55	2.86	3.17	1.46	1.75	1.98	2.20
	Level 2	$813,980	403,444	382,247	76	196.90	-$24,019	$93,716	$111,988	$126,112	$139,825	0.12	2.55	2.86	3.17	1.46	0.14	0.15	0.17
	Level 3	$966,497	413,096	394,422	67	205.96	-$15,295	$57,326	$68,373	$76,887	$85,140	0.06	2.55	2.86	3.17	1.46	0.07	0.08	0.09
CZ6 5A	Base case		404,355	329,314	270	210.09													
	Level 1	$35,497	410,912	323,129	316	210.64	$527	$5,970	$8,947	$11,599	$14,372	0.17	0.25	0.32	0.40	0.17	0.25	0.33	0.40
	Level 2	$823,075	397,131	313,052	303	196.63	-$12,963	$42,415	$51,721	$59,116	$66,410	0.05	0.25	0.32	0.40	0.17	0.06	0.07	0.08
	Level 3	$974,628	394,756	318,541	274	204.32	-$5,558	$33,355	$39,811	$44,793	$49,625	0.03	0.25	0.32	0.40	0.17	0.04	0.05	0.05
CZ7 5A	Base case		445,406	316,652	464	198.97													
	Level 1	$28,820	460,887	311,505	538	192.56	-$6,183	-$5,977	-$4,106	-$2,071	$236	-0.26	-0.18	-0.09	0.01	-0.21	-0.14	-0.07	0.01
	Level 2	$831,898	442,952	302,127	507	176.87	-$21,299	$33,519	$41,590	$48,127	$54,641	0.04	-0.18	-0.09	0.01	-0.21	0.05	0.06	0.07
	Level 3	$954,167	434,519	307,285	458	184.53	-$13,911	$31,776	$37,543	$41,918	$46,119	0.03	-0.18	-0.09	0.01	-0.21	0.04	0.04	0.05
CZ2 9aD	Base case		44,399	34,215	37	11.69													
	Level 1	$1,684	44,135	34,270	36	11.77	$76	$171	$156	$136	$112	0.10	0.09	0.08	0.06	0.10	0.09	0.08	0.07

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	Level 2	$68,964	43,285	33,975	34	11.42	-$260	$1,725	$1,923	$2,049	$2,157	0.03	0.09	0.08	0.06	0.10	0.03	0.03	0.03
	Level 3	$52,665	44,115	34,252	36	11.78	$88	$230	$227	$215	$198	0.00	0.09	0.08	0.06	0.10	0.00	0.00	0.00
CZ5 9aD	Base case		43,235	25,281	65	11.27													
	Level 1	$1,717	42,697	25,287	63	11.36	$86	$575	$604	$611	$608	0.32	0.34	0.34	0.34	0.33	0.35	0.36	0.35
	Level 2	$69,320	41,464	24,899	60	11.17	-$101	$2,746	$3,061	$3,263	$3,435	0.04	0.34	0.34	0.34	0.33	0.04	0.05	0.05
	Level 3	$52,668	42,659	25,254	63	11.37	$91	$686	$736	$758	$770	0.01	0.34	0.34	0.34	0.33	0.01	0.01	0.01
CZ6 9aD	Base case		42,806	17,867	90	9.54													
	Level 1	$1,314	42,014	17,829	87	9.45	-$82	$945	$1,014	$1,044	$1,061	0.77	0.82	0.85	0.86	0.72	0.77	0.79	0.81
	Level 2	$64,067	40,412	17,369	83	8.88	-$631	$3,671	$4,087	$4,351	$4,574	0.06	0.82	0.85	0.86	0.72	0.06	0.07	0.07
	Level 3	$50,974	42,018	17,835	87	9.28	-$248	$928	$993	$1,021	$1,035	0.02	0.82	0.85	0.86	0.72	0.02	0.02	0.02
CZ7 9aD	Base case		47,242	17,148	108	7.40													
	Level 1	$2,307	47,111	16,945	109	7.38	-$17	$574	$693	$786	$877	0.25	0.30	0.34	0.38	0.25	0.30	0.34	0.38
	Level 2	$65,519	52,894	17,291	128	7.75	$339	-$6,476	-$6,896	-$7,057	-$7,122	-0.10	0.30	0.34	0.38	0.25	-0.11	-0.11	-0.11
	Level 3	$45,809	48,007	16,060	115	6.99	-$394	$1,474	$2,021	$2,494	$2,981	0.03	0.30	0.34	0.38	0.25	0.04	0.05	0.07
CZ2 9bE	Base case		15,237	15,237	-	16.33													
	Level 1	$3,397	13,340	13,340	-	16.33	-$9	$6,098	$7,247	$8,128	$8,979	1.80	2.14	2.40	2.65	1.80	2.13	2.39	2.64
	Level 2	$40,550	13,273	13,273	-	15.84	-$474	$6,316	$7,506	$8,418	$9,299	0.16	2.14	2.40	2.65	1.80	0.19	0.21	0.23
	Level 3	$36,079	13,122	13,122	-	15.10	-$1,191	$6,800	$8,082	$9,064	$10,013	0.19	2.14	2.40	2.65	1.80	0.22	0.25	0.28
CZ5 9bE	Base case		11,844	11,844	-	18.84													
	Level 1	$2,704	10,155	10,155	-	18.17	-$650	$5,428	$6,451	$7,235	$7,992	2.64	3.14	3.50	3.86	2.01	2.39	2.68	2.96
	Level 2	$42,050	10,393	10,393	-	19.17	$315	$4,663	$5,542	$6,215	$6,866	0.11	3.14	3.50	3.86	2.01	0.13	0.15	0.16
	Level 3	$36,079	10,623	10,623	-	19.15	$299	$3,925	$4,665	$5,232	$5,780	0.11	3.14	3.50	3.86	2.01	0.13	0.15	0.16

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
CZ6 9bE	Base case		12,521	12,521	-	17.38													
	Level 1	$3,458	10,907	10,907	-	17.64	$248	$5,187	$6,165	$6,914	$7,638	1.40	1.66	1.87	2.06	1.50	1.78	2.00	2.21
	Level 2	$41,323	10,684	10,684	-	17.36	-$13	$5,903	$7,016	$7,868	$8,692	0.14	1.66	1.87	2.06	1.50	0.17	0.19	0.21
	Level 3	$35,854	11,122	11,122	-	18.51	$1,085	$4,496	$5,344	$5,993	$6,620	0.12	1.66	1.87	2.06	1.50	0.15	0.17	0.18
CZ7 9bE	Base case		15,657	15,657	-	17.61													
	Level 1	$3,458	14,085	14,085	-	17.52	-$92	$5,055	$6,008	$6,738	$7,443	1.50	1.78	2.00	2.21	1.46	1.74	1.95	2.15
	Level 2	$41,323	13,955	13,955	-	17.51	-$101	$5,473	$6,504	$7,295	$8,058	0.13	1.78	2.00	2.21	1.46	0.16	0.18	0.20
	Level 3	$35,854	14,371	14,371	-	17.53	-$79	$4,133	$4,912	$5,509	$6,085	0.12	1.78	2.00	2.21	1.46	0.14	0.15	0.17

I.10 Fan

The supply and return air fan pressure drop was varied to quantify the energy savings regarding air handling systems. A 25% pressure drop reduction (test 2) and 50% pressure drop reduction (test 3) were modelled with the results presented in Table 4-142. There was no test 1 case modelled as the maximum available fan efficiency was already incorporated in the base case models.

The fan system pricing was based on pressure changes through different scenarios. It was assumed that the fan sizes would remain the same while design pressure would be reduced to meet the improved energy in the future. Therefore, the prices were obtained from the changes of duct work according to the scenarios design pressure. The construction cost involved new duct work and insulation to meet the targeted delivery pressure and was based on the Rawlinson handbook 2018.

- The construction cost shown at below table represent the variation from the base case scenarios only and therefore only the base case pricing is present.

Table 4-142: Fan system efficiency investigation energy savings and benefit cost analysis results.

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
CZ2 5A	Base case		503,866	498,726	19	223.17													
	Level 1	$0	-	-	-	0.00	-$215,014	$1,609,096	$1,911,587	$2,143,235	$2,366,922	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	$171,438	484,111	478,634	20	221.41	-$1,702	$64,231	$76,384	$85,707	$94,719	0.38	negative cost	negative cost	negative cost	negative cost	0.45	0.50	0.55
	Level 3	$421,291	464,447	458,719	21	212.14	-$10,630	$127,987	$152,192	$170,757	$188,701	0.31	negative cost	negative cost	negative cost	negative cost	0.36	0.41	0.45
CZ5 5A	Base case		429,817	412,822	61	221.83													
	Level 1	$0	-	-	-	0.00	-$213,726	$1,345,848	$1,597,006	$1,788,974	$1,974,132	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	$118,551	412,061	394,315	64	212.90	-$8,605	$58,682	$69,850	$78,430	$86,730	0.53	negative cost	negative cost	negative cost	negative cost	0.59	0.66	0.73
	Level 3	$419,091	396,624	377,002	71	203.17	-$17,983	$112,299	$133,844	$150,430	$166,496	0.28	negative cost	negative cost	negative cost	negative cost	0.32	0.36	0.40
CZ6 5A	Base case		404,355	329,314	270	210.09													
	Level 1	$0	-	-	-	0.00	-$202,409	$1,140,744	$1,344,816	$1,499,009	$1,646,716	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	$112,903	395,043	316,288	284	207.02	-$2,960	$37,824	$45,492	$51,476	$57,318	0.34	negative cost	negative cost	negative cost	negative cost	0.40	0.46	0.51
	Level 3	$358,781	385,199	303,307	295	200.69	-$9,056	$76,136	$91,479	$103,436	$115,101	0.22	negative cost	negative cost	negative cost	negative cost	0.25	0.29	0.32
CZ7 5A	Base case		445,406	316,652	464	198.97													
	Level 1	$0	-	-	-	0.00	-$191,700	$1,158,690	$1,358,339	$1,507,578	$1,649,609	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	$95,414	438,956	306,360	477	189.35	-$9,267	$28,896	$34,900	$39,613	$44,229	0.34	negative cost	negative cost	negative cost	negative cost	0.37	0.42	0.46
	Level 3	$397,838	431,037	295,979	486	181.62	-$16,717	$59,583	$71,728	$81,218	$90,489	0.16	negative cost	negative cost	negative cost	negative cost	0.18	0.20	0.23

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
CZ2 9aD	Base case		44,399	34,215	37	11.69													
	Level 1	$0	-	-	-	0.00	-$11,264	$121,127	$142,474	$158,535	$173,881	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	$180	42,246	31,375	39	10.96	-$708	$8,380	$10,059	$11,366	$12,640	negative cost	negative cost	negative cost	negative cost	negative cost	55.78	63.03	70.09
	Level 3	$2,843	39,607	28,027	42	10.20	-$1,439	$18,371	$22,036	$24,885	$27,660	13.08	negative cost	negative cost	negative cost	negative cost	7.75	8.75	9.73
CZ5 9aD	Base case		43,235	25,281	65	11.27													
	Level 1	$0	-	-	-	0.00	-$10,859	$100,888	$117,292	$129,339	$140,679	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	$663	41,426	22,523	68	10.67	-$583	$7,831	$9,445	$10,709	$11,946	98.64	negative cost	negative cost	negative cost	negative cost	14.25	16.16	18.03
	Level 3	$5,332	40,052	20,084	72	10.08	-$1,147	$14,508	$17,535	$19,913	$22,244	3.47	negative cost	negative cost	negative cost	negative cost	3.29	3.73	4.17
CZ6 9aD	Base case		42,806	17,867	90	9.54													
	Level 1	$0	-	-	-	0.00	-$9,188	$84,678	$97,013	$105,737	$113,752	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	$1,240	41,816	15,603	94	8.66	-$844	$5,887	$7,181	$8,210	$9,225	14.86	negative cost	negative cost	negative cost	negative cost	5.79	6.62	7.44
	Level 3	$1,906	40,836	13,301	99	7.95	-$1,527	$11,845	$14,455	$16,530	$18,578	31.30	negative cost	negative cost	negative cost	negative cost	7.59	8.67	9.75
CZ7 9aD	Base case		47,242	17,148	108	7.40													
	Level 1	$0	-	-	-	0.00	-$7,126	$87,996	$100,207	$108,687	$116,379	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	$2,080	46,228	14,912	113	6.98	-$406	$5,854	$7,135	$8,152	$9,154	3.50	negative cost	negative cost	negative cost	negative cost	3.43	3.92	4.40
	Level 3	$2,893	45,224	12,652	117	6.25	-$1,107	$11,749	$14,323	$16,367	$18,384	6.58	negative cost	negative cost	negative cost	negative cost	4.95	5.66	6.35

I.11 Pump

A 7% increase in pump efficiency for chilled water, condenser water and heating hot water pumps were modelled to gauge the energy performance benefit for models 3B, 5A and 9aD. Pump efficiency measure results excluding the capex estimates and benefit cost ratios due to a lack of data.

I.12 Chiller and PAC

Three levels of chiller and packaged air conditioning (PAC) unit performance were modelled to find their impact on annual building energy consumption. The current NCC stringency (base case) was compared with best practice (test 1) examples of chillers and PAC units, the expected best practice performance in 10 years' time (test 2) and the expected best practice performance in 20 years' time (test 3). No incremental capital cost was included for the chiller and PAC unit single-dimensional measures. The capex results are presented in Table 4-143 below.

Table 4-143: Chiller and PAC efficiency increases for all model archetypes.

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
CZ2 3B	Base case		188,716	174,559	51	58.17													
	Level 1	$104	159,471	145,315	51	47.43	-$10,345	$94,025	$111,744	$125,321	$138,438	negative cost	negative cost	negative cost	negative cost	902.13	1072.13	1202.40	1328.25
	Level 2	$18	151,649	137,491	51	41.98	-$15,595	$119,179	$141,638	$158,849	$175,474	negative cost	negative cost	negative cost	negative cost	902.13	7670.03	8602.03	9502.33
	Level 3	$253	146,242	132,084	51	38.74	-$18,716	$136,564	$162,299	$182,021	$201,071	negative cost	negative cost	negative cost	negative cost	902.13	641.45	719.39	794.68
CZ5 3B	Base case		179,993	146,931	119	54.68													
	Level 1	$321	157,185	124,125	119	44.17	-$10,125	$73,327	$87,146	$97,735	$107,964	negative cost	negative cost	negative cost	negative cost	228.12	271.11	304.05	335.87
	Level 2	-$598	151,571	118,512	119	39.20	-$14,908	$91,376	$108,595	$121,790	$134,537	negative cost	negative cost	negative cost	negative cost	228.12	negative cost	negative cost	negative cost
	Level 3	-$617	147,478	114,416	119	36.42	-$17,589	$104,540	$124,241	$139,338	$153,921	negative cost	negative cost	negative cost	negative cost	228.12	negative cost	negative cost	negative cost
CZ6 3B	Base case		140,010	127,138	46	49.71													
	Level 1	-$698	126,810	113,939	46	40.46	-$8,910	$42,437	$50,434	$56,563	$62,483	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	-$327	123,818	110,947	46	36.74	-$12,495	$52,057	$61,867	$69,384	$76,646	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 3	-$148	121,224	108,353	46	34.33	-$14,822	$60,399	$71,781	$80,503	$88,928	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
CZ7 3B	Base case		135,487	119,775	57	39.65													
	Level 1	-$209	123,554	107,842	57	30.62	-$8,699	$38,367	$45,598	$51,139	$56,491	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	-$313	120,861	105,149	57	28.34	-$10,890	$47,024	$55,886	$62,676	$69,236	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	Level 3	-$342	118,532	102,820	57	27.16	-$12,027	$54,513	$64,787	$72,659	$80,264	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
CZ25A	Base case		503,866	498,726	19	223.17													
	Level 1	$16,945	450,906	443,947	25	205.91	-$16,630	$174,136	$207,217	$232,619	$257,189	552.28	657.20	369.17	327.51	10.28	12.23	13.73	15.18
	Level 2	$776	430,071	424,920	19	183.32	-$38,400	$237,287	$282,005	$316,274	$349,377	negative cost	657.20	369.17	327.51	10.28	363.43	407.59	450.25
	Level 3	$780	417,024	411,904	18	170.22	-$51,014	$279,168	$331,774	$372,087	$411,027	negative cost	657.20	369.17	327.51	10.28	425.13	476.78	526.68
CZ55A	Base case		429,817	412,822	61	221.83													
	Level 1	-$2,818	395,606	378,608	61	201.26	-$19,826	$110,000	$130,730	$146,616	$161,961	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	-$7,899	384,139	367,145	61	179.17	-$41,101	$146,862	$174,538	$195,746	$216,233	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 3	-$1,697	376,064	359,082	61	167.23	-$52,611	$172,797	$205,360	$230,312	$254,415	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
CZ65A	Base case		404,355	329,314	270	210.09													
	Level 1	$8,144	388,008	312,964	270	185.25	-$23,934	$52,565	$62,472	$70,063	$77,397	negative cost	negative cost	negative cost	negative cost	6.45	7.67	8.60	9.50
	Level 2	$6,458	383,182	308,134	270	166.01	-$42,467	$68,088	$80,921	$90,754	$100,254	negative cost	negative cost	negative cost	negative cost	6.45	12.53	14.05	15.52
	Level 3	-$2,301	379,769	304,728	270	152.82	-$55,174	$79,047	$93,944	$105,359	$116,387	negative cost	negative cost	negative cost	negative cost	6.45	negative cost	negative cost	negative cost
CZ75A	Base case		445,406	316,652	464	198.97													
	Level 1	$24	430,858	302,079	464	168.75	-$29,119	$46,828	$55,657	$62,423	$68,960	negative cost	negative cost	negative cost	negative cost	1968.64	2339.79	2624.23	2899.02
	Level 2	$55	426,645	297,890	464	154.12	-$43,210	$60,322	$71,690	$80,401	$88,816	negative cost	negative cost	negative cost	negative cost	1968.64	1307.35	1466.21	1619.68

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	Level 3	$65	423,715	294,917	464	144.20	-$52,769	$69,833	$83,000	$93,091	$102,840	negative cost	negative cost	negative cost	negative cost	1968.64	1271.26	1425.82	1575.13
CZ2 6C	Base case		94,377	94,377	-	35.14													
	Level 1	$0	82,886	82,886	-	25.94	-$8,865	$36,943	$43,904	$49,239	$54,393	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	$0	81,329	81,329	-	24.69	-$10,065	$41,950	$49,856	$55,914	$61,766	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 3	$0	80,065	80,065	-	23.68	-$11,038	$46,013	$54,684	$61,329	$67,748	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
CZ5 6C	Base case		84,108	84,108	-	32.90													
	Level 1	$0	77,650	77,650	-	24.85	-$7,760	$20,764	$24,676	$27,675	$30,571	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	$0	76,731	76,731	-	23.72	-$8,850	$23,719	$28,188	$31,614	$34,922	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 3	$0	75,985	75,985	-	22.80	-$9,735	$26,116	$31,038	$34,810	$38,453	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
CZ6 6C	Base case		82,502	82,502	-	33.51													
	Level 1	$1,434	78,963	78,963	-	26.20	-$7,045	$11,380	$13,524	$15,168	$16,755	negative cost	negative cost	negative cost	negative cost	7.94	9.43	10.58	11.69
	Level 2	$1,434	78,490	78,490	-	24.92	-$8,271	$12,899	$15,330	$17,193	$18,992	negative cost	negative cost	negative cost	negative cost	7.94	10.69	11.99	13.25
	Level 3	$1,434	78,107	78,107	-	23.89	-$9,265	$14,132	$16,795	$18,836	$20,807	negative cost	negative cost	negative cost	negative cost	7.94	11.71	13.14	14.51
CZ7 6C	Base case		84,766	84,766	-	32.44													
	Level 1	$0	80,180	80,180	-	24.67	-$7,481	$14,747	$17,526	$19,656	$21,713	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	$0	79,515	79,515	-	24.38	-$7,761	$16,883	$20,064	$22,502	$24,858	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 3	$0	78,977	78,977	-	24.38	-$7,761	$18,615	$22,123	$24,811	$27,408	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
CZ2 9aD	Base case		44,399	34,215	37	11.69													
	Level 1	$21	38,733	28,550	37	10.18	-$1,460	$18,214	$21,646	$24,276	$26,817	negative cost	negative cost	negative cost	negative cost	865.98	1029.16	1154.21	1275.00
	Level 2	-$114	36,903	26,721	37	8.98	-$2,610	$24,096	$28,637	$32,116	$35,478	negative cost	negative cost	negative cost	negative cost	865.98	negative cost	negative cost	negative cost

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	Level 3	-$172	35,805	25,622	37	8.20	-$3,362	$27,627	$32,833	$36,823	$40,676	negative cost	negative cost	negative cost	negative cost	865.98	negative cost	negative cost	negative cost
CZ5 9aD	Base case		43,235	25,281	65	11.27													
	Level 1	-$12	39,533	21,582	65	9.26	-$1,941	$11,895	$14,136	$15,854	$17,513	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	$6	38,540	20,586	65	8.33	-$2,831	$15,094	$17,938	$20,118	$22,224	negative cost	negative cost	negative cost	negative cost	negative cost	3048.57	3419.01	3776.85
	Level 3	$2	37,949	19,996	65	7.73	-$3,410	$16,994	$20,196	$22,650	$25,021	negative cost	negative cost	negative cost	negative cost	negative cost	13442.90	15076.36	16654.28
CZ6 9aD	Base case		42,806	17,867	90	9.54													
	Level 1	-$501	41,142	16,203	90	8.00	-$1,476	$5,349	$6,357	$7,130	$7,876	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	-$762	40,732	15,792	90	7.12	-$2,325	$6,669	$7,926	$8,889	$9,819	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 3	-$694	40,485	15,545	90	6.65	-$2,777	$7,464	$8,871	$9,948	$10,990	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
CZ7 9aD	Base case		47,242	17,148	108	7.40													
	Level 1	$238	45,638	15,544	108	6.04	-$1,309	$5,156	$6,128	$6,873	$7,592	negative cost	negative cost	negative cost	negative cost	21.63	25.70	28.82	31.84
	Level 2	$44	45,252	15,158	108	5.46	-$1,863	$6,398	$7,604	$8,528	$9,420	negative cost	negative cost	negative cost	negative cost	21.63	172.55	193.51	213.77
	Level 3	$327	45,022	14,928	108	5.14	-$2,174	$7,138	$8,484	$9,514	$10,510	negative cost	negative cost	negative cost	negative cost	21.63	25.93	29.08	32.13
CZ2 9bE	Base case		15,237	15,237	-	16.33													
	Level 1	-$168	9,730	9,730	-	8.96	-$7,110	$17,705	$21,041	$23,598	$26,068	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	$0	9,106	9,106	-	8.14	-$7,897	$19,713	$23,428	$26,275	$29,025	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 3	$0	8,594	8,594	-	8.14	-$7,897	$21,357	$25,382	$28,466	$31,445	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
CZ5 9bE	Base case		11,844	11,844	-	18.84													
	Level 1	$0	9,024	9,024	-	10.27	-$8,262	$9,067	$10,776	$12,086	$13,350	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	$0	8,701	8,701	-	9.29	-$9,207	$10,104	$12,008	$13,468	$14,877	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 3	$0	8,439	8,439	-	8.70	-$9,771	$10,945	$13,008	$14,589	$16,116	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
CZ6 9bE	Base case		12,521	12,521	-	17.38													

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	Level 1	$0	10,975	10,975	-	13.09	-$4,130	$4,968	$5,904	$6,622	$7,315	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	$0	10,799	10,799	-	13.09	-$4,130	$5,536	$6,579	$7,379	$8,151	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 3	$0	10,655	10,655	-	13.09	-$4,130	$5,997	$7,127	$7,993	$8,830	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
CZ79bE	Base case		15,657	15,657	-	17.61													
	Level 1	$0	13,664	13,664	-	17.61	$0	$6,408	$7,616	$8,541	$9,435	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	$0	13,436	13,436	-	17.61	$0	$7,141	$8,487	$9,518	$10,514	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 3	$0	13,251	13,251	-	17.61	$0	$7,735	$9,193	$10,310	$11,389	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost

I.13 Economy Cycle

Three economy cycle stringency levels were investigated relative to the NCC2019 base case; reverting back to the NCC2016 stringency (test 1), using a lower system limit of 20kW cooling capacity (test 2) and having no lower limit to the system size where an economy cycle operation can be implemented. The results are presented in Table 4-145 in addition to the respective BCRs.

The capital costs for Economy cycle were based on various industrial manufacturers and experts for estimation. The pricing items involved damper, motorized actuators, louvers, ducting, sensors and controls. The details for costing can be found as follows:

- For dampers, the prices were obtained from Riley damper and the prices ranged from $450 to $3,266.7 per square meter depending on the size.
- For actuators, the price was obtained from Belimo and it was priced at $155/unit.
- For base case, it was assumed that there were existing duct work and louvers for fresh air intake. For economy cycle, these duct work and louvers would be enlarged to suit to the new application and the pricing was obtained from the differences. For the pricing of enlarged duct work and louver, it was based on Rawlinson handbook 2018. The new louver was costed from $200 to $580 per unit. It was also considered that insulation was required to partial duct work only.
- For sensors, combined dew point and dry bulb temperature sensor was selected and the cost for it was $315/unit.
- For wiring and control including software implementation, it was estimated to be costed as $1,500 for each sensor. In actual application, these cost can be reduced for multiple sensors, however, for this practice, it was assumed as $1,500 for each sensor implementation.

No learning rate has been applied to performance or cost.

Table 4-144: Economy cycle capital costing.

Archetype	Scenarios	Climate Zone 2 Construction cost (per unit)	Climate Zone 5 Construction cost (per unit)	Climate Zone 6 Construction cost (per unit)
5A	Best case	$13,529	$13,529	$13,529
9aD	Best case	$2,330	$2,330	$2,330
6C	Best case	$5,146	$5,146	$5,146

Table 4-145: Economy cycle energy savings and benefit cost analysis results

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
CZ2 3B	Base case		503,866	498,726	19	223.17													
	Level 1	$27,059	496,030	490,521	20	225.40	$2,150	$25,975	$30,924	$34,727	$38,407	0.89	1.06	1.19	1.32	0.96	1.14	1.28	1.42
	Level 2	$0	-	-	-	0.00	-$215,014	$1,609,096	$1,911,587	$2,143,235	$2,366,922	negative cost	1.06	1.19	1.32	0.96	negative cost	negative cost	negative cost
	Level 3	$0	-	-	-	0.00	-$215,014	$1,609,096	$1,911,587	$2,143,235	$2,366,922	negative cost	1.06	1.19	1.32	0.96	negative cost	negative cost	negative cost
CZ5 3B	Base case		429,817	412,822	61	221.83													
	Level 1	$27,059	425,631	408,281	62	220.45	-$1,334	$14,213	$16,944	$19,046	$21,083	0.55	0.66	0.74	0.82	0.53	0.63	0.70	0.78
	Level 2	$0	-	-	-	0.00	-$213,726	$1,345,848	$1,597,006	$1,788,974	$1,974,132	negative cost	0.66	0.74	0.82	0.53	negative cost	negative cost	negative cost
	Level 3	$0	-	-	-	0.00	-$213,726	$1,345,848	$1,597,006	$1,788,974	$1,974,132	negative cost	0.66	0.74	0.82	0.53	negative cost	negative cost	negative cost
CZ6 3B	Base case		404,355	329,314	270	210.09													
	Level 1	$0	-	-	-	0.00	-$202,409	$1,140,744	$1,344,816	$1,499,009	$1,646,716	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	$0	-	-	-	0.00	-$202,409	$1,140,744	$1,344,816	$1,499,009	$1,646,716	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 3	$0	-	-	-	0.00	-$202,409	$1,140,744	$1,344,816	$1,499,009	$1,646,716	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
CZ7 3B	Base case		94,377	94,377	-	35.14													
	Level 1	$0	-	-	-	0.00	-$33,853	$303,436	$360,619	$404,438	$446,767	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	$0	-	-	-	0.00	-$33,853	$303,436	$360,619	$404,438	$446,767	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	Level 3	$10,292	92,462	92,462	-	35.10	-$40	$6,155	$7,315	$8,203	$9,062	0.60	negative cost	negative cost	negative cost	negative cost	0.71	0.80	0.88
CZ2 5A	Base case		84,108	84,108	-	32.90													
	Level 1	$0	-	-	-	0.00	-$31,699	$270,420	$321,381	$360,432	$398,156	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	$0	-	-	-	0.00	-$31,699	$270,420	$321,381	$360,432	$398,156	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 3	$10,292	80,905	80,905	-	33.59	$666	$10,297	$12,237	$13,724	$15,160	0.94	negative cost	negative cost	negative cost	negative cost	1.19	1.33	1.47
CZ5 5A	Base case		82,502	82,502	-	33.51													
	Level 1	$0	-	-	-	0.00	-$32,284	$265,259	$315,247	$353,553	$390,557	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	$0	-	-	-	0.00	-$32,284	$265,259	$315,247	$353,553	$390,557	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 3	$10,292	79,301	79,301	-	34.50	$954	$10,294	$12,234	$13,721	$15,157	0.92	negative cost	negative cost	negative cost	negative cost	1.19	1.33	1.47
CZ6 5A	Base case		84,766	84,766	-	32.44													
	Level 1	$4,660	82,117	82,117	-	33.03	$569	$8,519	$10,124	$11,355	$12,543	1.63	1.94	2.18	2.41	1.83	2.17	2.44	2.69
	Level 2	$0	-	-	-	0.00	-$31,253	$272,538	$323,898	$363,255	$401,274	negative cost	1.94	2.18	2.41	1.83	negative cost	negative cost	negative cost
	Level 3	$10,292	79,729	79,729	-	32.98	$524	$16,197	$19,250	$21,589	$23,848	1.50	1.94	2.18	2.41	1.83	1.87	2.10	2.32
CZ7 5A	Base case		44,399	34,215	37	11.69													
	Level 1	$0	-	-	-	0.00	-$11,264	$121,127	$142,474	$158,535	$173,881	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	$4,660	43,447	33,146	37	11.58	-$105	$3,308	$3,949	$4,443	$4,922	0.73	negative cost	negative cost	negative cost	negative cost	0.85	0.95	1.06
	Level 3	$0	-	-	-	0.00	-$11,264	$121,127	$142,474	$158,535	$173,881	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
CZ2 6C	Base case		43,235	25,281	65	11.27													

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	Level 1	$0	-	-	-	0.00	-$10,859	$100,888	$117,292	$129,339	$140,679	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	$4,660	41,517	23,592	65	11.56	$275	$5,462	$6,487	$7,272	$8,030	1.11	negative cost	negative cost	negative cost	negative cost	1.39	1.56	1.72
	Level 3	$0	-	-	-	0.00	-$10,859	$100,888	$117,292	$129,339	$140,679	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
CZ5 6C	Base case		42,806	17,867	90	9.54													
	Level 1	$0	-	-	-	0.00	-$9,188	$84,678	$97,013	$105,737	$113,752	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	$0	-	-	-	0.00	-$9,188	$84,678	$97,013	$105,737	$113,752	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 3	$4,660	40,672	15,697	90	9.30	-$224	$6,937	$8,249	$9,256	$10,230	1.56	negative cost	negative cost	negative cost	negative cost	1.77	1.99	2.20
CZ6 6C	Base case		47,242	17,148	108	7.40													
	Level 1	$0	-	-	-	0.00	-$7,126	$87,996	$100,207	$108,687	$116,379	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	$0	-	-	-	0.00	-$7,126	$87,996	$100,207	$108,687	$116,379	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 3	$4,660	47,113	17,011	108	7.46	$58	$431	$513	$576	$637	0.09	negative cost	negative cost	negative cost	negative cost	0.11	0.12	0.14

I.14 Outside Air Treatment

Two levels of outside air (OA) treatment were investigated. A heat exchanger was installed (test 1) to the base HVAC system if one was not already present. If there already was, then the efficiency was increased. Test 2 incorporated CO2 control in addition to the heat exchanger.

The capital costs for OA treatment was based on the requirement of heat exchanger size for heat recovery and the manufacturer, Air Change, was selected for the based pricing. The pricing details can be found as follows:

- For CO2 sensor, the prices included control wiring, BMS connection and labour cost. The breakdown for the inclusions are $215/unit for CO2 sensor, $120 for wiring per unit, $1000 for BMS connection and $500 for labour cost.
- For heat recovery heat exchangers and CO2, the construction cost for each archetype are shown at below.

No learning rate has been applied to performance or cost.

Table 4-146: Heat exchanger and CO2 control capex pricing.

Archetype	Scenarios	Climate Zone 2 Construction cost (per unit)	Climate Zone 5 Construction cost (per unit)	Climate Zone 6 Construction cost (per unit)
3B	Base case	$5,084	-	-
	Heat recovery	$5,084	$5,084	$5,084
	HR + CO2	-	-	-
5A	Base case	-	-	-
	Heat recovery	$45,500	$45,500	$45,500
	HR + CO2	$54,675	$54,675	$54,675
9aD	Base case	-	-	-
	Heat recovery	$2,110	$2,110	$2,110
	HR + CO2	$3,945	$3,945	$3,945
6C	Base case	-	-	-
	Heat recovery	$7,870	$7,870	$7,870
	HR + CO2	$17,045	$17,045	$17,045
9bE	Base case	-	-	-
	Heat recovery	$2,080	$2,080	$2,080
	HR + CO2	$3,915	$3,915	$3,915

Table 4-147: Outside air treatment via the use of heat exchangers and CO2 control methods.

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
CZ2 3B	Base case		188,716	174,559	51	58.17													
	Level 1	$9,597	195,970	186,810	33	57.78	-$373	-$33,931	-$41,052	-$46,654	-$52,148	-3.68	-4.45	-5.05	-5.65	-3.54	-4.28	-4.86	-5.43
	Level 2	$0	-	-	-	0.00	-$56,043	$576,695	$683,317	$764,609	$842,902	negative cost	-4.45	-5.05	-5.65	-3.54	negative cost	negative cost	negative cost
CZ5 3B	Base case		179,993	146,931	119	54.68													
	Level 1	$7,750	173,827	151,624	80	54.48	-$188	-$3,231	-$5,417	-$7,409	-$9,514	-0.43	-0.72	-0.98	-1.26	-0.42	-0.70	-0.96	-1.23
	Level 2	$0	-	-	-	0.00	-$52,676	$508,511	$599,537	$668,327	$734,230	negative cost	-0.72	-0.98	-1.26	-0.42	negative cost	negative cost	negative cost
CZ6 3B	Base case		140,010	127,138	46	49.71													
	Level 1	-$261	139,288	128,577	39	49.77	$57	-$2,267	-$3,009	-$3,640	-$4,285	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
	Level 2	$0	-	-	-	0.00	-$47,895	$422,826	$500,638	$559,890	$616,914	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost	negative cost
CZ2 5A	Base case		503,866	498,726	19	223.17													
	Level 1	$91,322	515,296	510,677	17	227.49	$4,164	-$37,856	-$45,065	-$50,605	-$55,965	-0.40	-0.47	-0.53	-0.59	-0.41	-0.49	-0.55	-0.61
	Level 2	$202,846	515,543	510,944	17	228.49	$5,120	-$38,693	-$46,063	-$51,727	-$57,207	-0.19	-0.47	-0.53	-0.59	-0.41	-0.23	-0.26	-0.28
CZ5 5A	Base case		429,817	412,822	61	221.83													
	Level 1	$82,155	436,537	422,932	49	223.66	$1,758	-$28,802	-$34,722	-$39,358	-$43,892	-0.34	-0.41	-0.47	-0.52	-0.35	-0.42	-0.48	-0.53
	Level 2	$77,079	436,151	423,174	47	222.28	$427	-$28,896	-$34,925	-$39,663	-$44,305	-0.37	-0.41	-0.47	-0.52	-0.35	-0.45	-0.51	-0.57
CZ6 5A	Base case		404,355	329,314	270	210.09													

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	Level 1	$77,795	394,830	337,660	206	210.88	$759	-$7,318	-$11,293	-$14,860	-$18,602	-0.09	-0.14	-0.19	-0.24	-0.09	-0.15	-0.19	-0.24
	Level 2	$0	-	-	-	0.00	-$202,409	$1,140,744	$1,344,816	$1,499,009	$1,646,716	negative cost	-0.14	-0.19	-0.24	-0.09	negative cost	negative cost	negative cost
CZ7 5A	Base case		445,406	316,652	464	198.97													
	Level 1	$60,713	380,377	316,775	229	190.01	-$8,635	$70,752	$74,619	$75,684	$75,633	1.36	1.43	1.45	1.45	1.17	1.23	1.25	1.25
	Level 2	$0	-	-	-	0.00	-$191,700	$1,158,690	$1,358,339	$1,507,578	$1,649,609	negative cost	1.43	1.45	1.45	1.17	negative cost	negative cost	negative cost
CZ2 6C	Base case		94,377	94,377	-	35.14													
	Level 1	$15,604	93,909	93,909	-	35.10	-$39	$1,502	$1,785	$2,002	$2,212	0.10	0.11	0.13	0.14	0.10	0.11	0.13	0.14
	Level 2	$24,391	93,921	93,921	-	35.10	-$39	$1,465	$1,741	$1,952	$2,157	0.06	0.11	0.13	0.14	0.10	0.07	0.08	0.09
CZ5 6C	Base case		84,108	84,108	-	32.90													
	Level 1	$14,392	83,293	83,293	-	31.09	-$1,746	$2,619	$3,113	$3,491	$3,857	0.21	0.25	0.28	0.30	0.18	0.22	0.24	0.27
	Level 2	$25,287	83,697	83,697	-	30.57	-$2,245	$1,322	$1,571	$1,762	$1,947	0.06	0.25	0.28	0.30	0.18	0.06	0.07	0.08
CZ6 6C	Base case		82,502	82,502	-	33.51													
	Level 1	$14,037	78,795	78,795	-	32.32	-$1,144	$11,919	$14,165	$15,886	$17,549	0.92	1.10	1.23	1.36	0.85	1.01	1.13	1.25
	Level 2	$26,170	78,608	78,608	-	32.48	-$990	$12,520	$14,880	$16,688	$18,434	0.50	1.10	1.23	1.36	0.85	0.57	0.64	0.70
CZ7 6C	Base case		84,766	84,766	-	32.44													
	Level 1	$12,022	81,504	81,504	-	31.04	-$1,348	$10,491	$12,468	$13,983	$15,446	0.98	1.17	1.31	1.44	0.87	1.04	1.16	1.28
	Level 2	$22,634	81,605	81,605	-	30.56	-$1,806	$10,165	$12,081	$13,549	$14,967	0.49	1.17	1.31	1.44	0.87	0.53	0.60	0.66
CZ2 9aD	Base case		44,399	34,215	37	11.69													
	Level 1	$3,379	42,111	35,759	23	11.72	$32	-$781	-$1,485	-$2,136	-$2,828	-0.23	-0.44	-0.63	-0.83	-0.23	-0.44	-0.63	-0.84
	Level 2	$8,697	42,187	35,839	23	11.64	-$53	-$1,033	-$1,785	-$2,473	-$3,201	-0.12	-0.44	-0.63	-0.83	-0.23	-0.21	-0.28	-0.37

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
CZ5 9aD	Base case		43,235	25,281	65	11.27													
	Level 1	$3,684	39,793	27,054	46	11.37	$100	-$5	-$764	-$1,497	-$2,292	0.00	-0.20	-0.40	-0.61	0.00	-0.21	-0.41	-0.62
	Level 2	$0	-	-	-	0.00	-$10,859	$100,888	$117,292	$129,339	$140,679	negative cost	-0.20	-0.40	-0.61	0.00	negative cost	negative cost	negative cost
CZ6 9aD	Base case		42,806	17,867	90	9.54													
	Level 1	$2,806	33,427	18,307	54	9.19	-$338	$9,308	$9,635	$9,600	$9,403	3.77	3.90	3.88	3.80	3.32	3.43	3.42	3.35
	Level 2	$0	-	-	-	0.00	-$9,188	$84,678	$97,013	$105,737	$113,752	negative cost	3.90	3.88	3.80	3.32	negative cost	negative cost	negative cost
CZ7 9aD	Base case		47,242	17,148	108	7.40													
	Level 1	$4,471	37,031	16,202	75	7.23	-$159	$13,160	$14,293	$14,892	$15,317	3.05	3.31	3.45	3.55	2.94	3.20	3.33	3.43
	Level 2	$0	-	-	-	0.00	-$7,126	$87,996	$100,207	$108,687	$116,379	negative cost	3.31	3.45	3.55	2.94	negative cost	negative cost	negative cost
CZ2 9bE	Base case		15,237	15,237	-	16.33													
	Level 1	$14,379	14,260	14,260	-	14.99	-$1,291	$3,141	$3,733	$4,187	$4,625	0.24	0.29	0.32	0.35	0.22	0.26	0.29	0.32
	Level 2	$35,847	14,290	14,290	-	14.87	-$1,409	$3,045	$3,619	$4,058	$4,483	0.09	0.29	0.32	0.35	0.22	0.10	0.11	0.13
CZ5 9bE	Base case		11,844	11,844	-	18.84													
	Level 1	$14,431	9,976	9,976	-	14.42	-$4,260	$6,006	$7,138	$8,005	$8,843	0.59	0.70	0.78	0.86	0.42	0.49	0.55	0.61
	Level 2	$35,284	9,777	9,777	-	13.98	-$4,686	$6,644	$7,896	$8,856	$9,783	0.22	0.70	0.78	0.86	0.42	0.22	0.25	0.28
CZ6 9bE	Base case		12,521	12,521	-	17.38													
	Level 1	$10,683	9,006	9,006	-	14.36	-$2,908	$11,300	$13,429	$15,061	$16,637	1.45	1.73	1.92	2.12	1.06	1.26	1.41	1.56
	Level 2	$33,285	8,676	8,676	-	15.38	-$1,928	$12,360	$14,690	$16,475	$18,199	0.39	1.73	1.92	2.12	1.06	0.44	0.49	0.55
CZ7 9bE	Base case		15,657	15,657	-	17.61													
	Level 1	$1,331	12,106	12,106	-	14.54	-$2,963	$11,417	$13,569	$15,218	$16,810	negative cost	negative cost	negative cost	negative cost	8.58	10.19	11.43	12.63
	Level 2	$23,533	11,995	11,995	-	14.46	-$3,036	$11,772	$13,991	$15,691	$17,333	0.57	negative cost	negative cost	negative cost	8.58	0.59	0.67	0.74

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	Level 2	$0	-	-	-	0.00	-$7,126	$87,996	$100,207	$108,687	$116,379	negative cost	3.31	3.45	3.55	2.94	negative cost	negative cost	negative cost

I.15 Commissioning

A comparison between good commissioning practice (base) and poor commissioning practice (test 1) provides insight into the magnitude of energy improvement available through this process. No capital cost pricing was obtained for this section of the single-dimensional analysis.

I.16 Lighting

Three levels of lighting efficiency measures were modelled for comparison with the NCC2019 base case. Occupancy sensors (test 1) were implemented in addition to a decrease in lighting power density of 20% (test 2) and 40% (test 3) to complete the analysis. Lighting design for each of the archetypes assumed that current LED technology was used in the base case line scenarios, and that assumed that lumens will improve in the future while the price remains unchanged. The prices obtained were based on industrial supplier and industrial expert's estimation.

Lamp pricing was referenced from the Little Cherry price list as of April 2018:

Table 4-148: Pricing methodology used for the lighting analysis.

Luminaire	Cost
Troffer Viva Air 30W 5x5 4K	$ 256.25
Highbay ZETTA 200W 5K DIM 120	$ 371.78
RDL OPTIMA Classic 10W 4K	$ 11.55
RDL OPTIMA Classic 13W 4K	$ 16.25
Retail Display Array II 40W 4K	$ 78.44

An additional 15% of the total cost was added to lighting pricing for control and commissioning of the system.

Similarly, daylighting and occupancy sensor price was based on Little Cherry price list as of April 2018 and a model PD4-M-1C-FC-T was selected for all building archetypes and the price for it was $238.2. The effective area of the sensor is 38 m² and therefore, the number of sensors required for each archetype also varied. The total cost obtained for sensors were by multiplying of the number of sensors with the price of sensor. The labour cost for installation of sensor was estimated as $120/hour and 3 sensor would be installed per hour.

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

Table 4-149: Lighting efficiency and controls measures energy savings and benefit cost ratios for all archetypes.

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
CZ2 3B	Base case		188,716	174,559	51	58.17													
	Level 1	$41,479	185,910	171,615	51	58.08	-$86	$9,314	$11,090	$12,454	$13,774	0.23	0.27	0.30	0.33	0.22	0.27	0.30	0.33
	Level 2	$41,212	183,667	169,260	52	57.94	-$217	$16,764	$19,959	$22,415	$24,791	0.41	0.27	0.30	0.33	0.22	0.48	0.54	0.60
	Level 3	$40,616	181,439	166,921	52	57.59	-$561	$24,163	$28,769	$32,309	$35,734	0.60	0.27	0.30	0.33	0.22	0.71	0.80	0.88
CZ5 3B	Base case		179,993	146,931	119	54.68													
	Level 1	$40,717	177,302	143,917	120	54.52	-$154	$9,338	$11,145	$12,539	$13,891	0.23	0.27	0.31	0.34	0.23	0.27	0.31	0.34
	Level 2	$40,336	175,102	141,458	121	54.28	-$385	$16,960	$20,241	$22,772	$25,226	0.42	0.27	0.31	0.34	0.23	0.50	0.56	0.63
	Level 3	$40,795	172,952	139,039	122	54.50	-$171	$24,445	$29,175	$32,824	$36,364	0.60	0.27	0.31	0.34	0.23	0.72	0.80	0.89
CZ6 3B	Base case		140,010	127,138	46	49.71													
	Level 1	$41,437	137,183	123,999	47	49.62	-$86	$9,751	$11,634	$13,086	$14,493	0.24	0.28	0.32	0.35	0.24	0.28	0.32	0.35
	Level 2	$41,544	134,933	121,492	48	49.46	-$243	$17,532	$20,918	$23,530	$26,062	0.42	0.28	0.32	0.35	0.24	0.50	0.57	0.63
	Level 3	$41,278	132,695	118,995	49	49.32	-$383	$25,276	$30,160	$33,926	$37,579	0.62	0.28	0.32	0.35	0.24	0.73	0.82	0.91
CZ7 3B	Base case		135,487	119,775	57	39.65													
	Level 1	$40,938	132,909	116,614	59	39.47	-$171	$9,527	$11,407	$12,864	$14,282	0.23	0.28	0.32	0.35	0.23	0.28	0.31	0.35
	Level 2	$40,472	130,871	114,084	60	39.19	-$440	$17,123	$20,506	$23,130	$25,683	0.43	0.28	0.32	0.35	0.23	0.51	0.57	0.63
	Level 3	$40,765	128,867	111,577	62	38.75	-$861	$24,635	$29,506	$33,286	$36,962	0.62	0.28	0.32	0.35	0.23	0.72	0.82	0.91
CZ2 5A	Base case		503,866	498,726	19	223.17													
	Level 1	$204,527	472,870	467,427	20	212.46	-$10,320	$100,300	$119,246	$133,773	$147,811	0.52	0.61	0.69	0.76	0.49	0.58	0.65	0.72
	Level 2	$205,768	441,438	435,628	21	203.38	-$19,072	$202,137	$240,328	$269,613	$297,913	1.08	0.61	0.69	0.76	0.49	1.17	1.31	1.45
	Level 3	$199,338	409,982	403,752	22	195.57	-$26,592	$304,166	$361,645	$405,724	$448,321	1.76	0.61	0.69	0.76	0.49	1.81	2.04	2.25

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
CZ5 5A	Base case		429,817	412,822	61	221.83													
	Level 1	$198,459	400,301	382,163	65	210.38	-$11,040	$97,326	$115,833	$130,048	$143,800	0.52	0.62	0.69	0.77	0.49	0.58	0.66	0.72
	Level 2	$189,406	370,416	350,946	70	199.07	-$21,934	$196,240	$233,581	$262,268	$290,021	1.17	0.62	0.69	0.77	0.49	1.23	1.38	1.53
	Level 3	$183,811	340,482	319,582	75	190.11	-$30,560	$295,517	$351,775	$394,999	$436,818	1.93	0.62	0.69	0.77	0.49	1.91	2.15	2.38
CZ6 5A	Base case		404,355	329,314	270	210.09													
	Level 1	$222,251	381,071	301,038	288	205.54	-$4,386	$85,459	$102,290	$115,333	$128,014	0.39	0.47	0.53	0.59	0.38	0.46	0.52	0.58
	Level 2	$203,673	356,919	271,757	307	194.11	-$15,397	$174,002	$208,263	$234,813	$260,628	0.92	0.47	0.53	0.59	0.38	1.02	1.15	1.28
	Level 3	$195,631	332,693	242,239	326	182.22	-$26,851	$263,128	$314,954	$355,118	$394,171	1.56	0.47	0.53	0.59	0.38	1.61	1.82	2.01
CZ7 5A	Base case		445,406	316,652	464	198.97													
	Level 1	$202,642	423,894	288,504	487	188.69	-$9,905	$83,254	$99,907	$112,862	$125,487	0.43	0.52	0.59	0.65	0.41	0.49	0.56	0.62
	Level 2	$198,740	401,249	259,395	511	180.87	-$17,443	$169,784	$203,684	$230,043	$255,723	0.94	0.52	0.59	0.65	0.41	1.02	1.16	1.29
	Level 3	$193,401	378,619	230,179	534	172.30	-$25,694	$256,528	$307,731	$347,542	$386,326	1.53	0.52	0.59	0.65	0.41	1.59	1.80	2.00
CZ2 6C	Base case		94,377	94,377	-	35.14													
	Level 1	$19,313	79,175	79,175	-	32.39	-$2,644	$48,875	$58,086	$65,144	$71,962	2.93	3.48	3.90	4.30	2.53	3.01	3.37	3.73
	Level 2	$17,622	66,775	66,775	-	30.55	-$4,424	$88,745	$105,469	$118,284	$130,664	6.72	3.48	3.90	4.30	2.53	5.99	6.71	7.41
	Level 3	$16,895	54,419	54,419	-	29.35	-$5,573	$128,469	$152,679	$171,232	$189,153	11.35	3.48	3.90	4.30	2.53	9.04	10.14	11.20
CZ5 6C	Base case		84,108	84,108	-	32.90													
	Level 1	$20,093	69,669	69,669	-	31.22	-$1,622	$46,422	$55,171	$61,875	$68,351	2.51	2.99	3.34	3.69	2.31	2.75	3.08	3.40
	Level 2	$20,696	58,023	58,023	-	30.06	-$2,735	$83,865	$99,670	$111,781	$123,480	4.67	2.99	3.34	3.69	2.31	4.82	5.40	5.97
	Level 3	$19,127	46,488	46,488	-	27.32	-$5,382	$120,954	$143,748	$161,215	$178,088	8.80	2.99	3.34	3.69	2.31	7.52	8.43	9.31
CZ6 6C	Base case		82,502	82,502	-	33.51													
	Level 1	$21,448	69,354	69,354	-	32.46	-$1,009	$42,273	$50,239	$56,344	$62,241	2.07	2.46	2.75	3.04	1.97	2.34	2.63	2.90

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
	Level 2	$20,060	58,711	58,711	-	29.92	-$3,457	$76,492	$90,907	$101,954	$112,624	4.61	2.46	2.75	3.04	1.97	4.53	5.08	5.61
	Level 3	$18,354	48,173	48,173	-	28.32	-$4,995	$110,375	$131,175	$147,114	$162,511	8.26	2.46	2.75	3.04	1.97	7.15	8.02	8.85
CZ7 6C	Base case		84,766	84,766	-	32.44													
	Level 1	$20,604	71,119	71,119	-	29.53	-$2,798	$43,879	$52,148	$58,485	$64,606	2.46	2.93	3.27	3.61	2.13	2.53	2.84	3.14
	Level 2	$17,638	60,311	60,311	-	25.67	-$6,520	$78,629	$93,446	$104,801	$115,770	7.07	2.93	3.27	3.61	2.13	5.30	5.94	6.56
	Level 3	$15,605	49,669	49,669	-	22.70	-$9,378	$112,844	$134,110	$150,406	$166,148	18.12	2.93	3.27	3.61	2.13	8.59	9.64	10.65
CZ2 9aD	Base case		44,399	34,215	37	11.69													
	Level 1	$11,172	43,753	33,494	37	11.63	-$57	$2,235	$2,667	$3,000	$3,324	0.20	0.24	0.27	0.30	0.20	0.24	0.27	0.30
	Level 2	$11,205	43,189	32,877	37	11.63	-$63	$4,161	$4,964	$5,583	$6,183	0.37	0.24	0.27	0.30	0.20	0.44	0.50	0.55
	Level 3	$11,162	42,678	32,307	37	11.59	-$98	$5,930	$7,074	$7,957	$8,812	0.54	0.24	0.27	0.30	0.20	0.63	0.71	0.79
CZ5 9aD	Base case		43,235	25,281	65	11.27													
	Level 1	$11,240	42,620	24,539	65	11.25	-$23	$2,247	$2,690	$3,032	$3,365	0.20	0.24	0.27	0.30	0.20	0.24	0.27	0.30
	Level 2	$11,220	42,111	23,939	65	11.21	-$56	$4,077	$4,877	$5,497	$6,099	0.37	0.24	0.27	0.30	0.20	0.43	0.49	0.54
	Level 3	$11,209	41,612	23,342	66	11.19	-$81	$5,889	$7,044	$7,939	$8,809	0.53	0.24	0.27	0.30	0.20	0.63	0.71	0.79
CZ6 9aD	Base case		42,806	17,867	90	9.54													
	Level 1	$10,750	42,282	17,142	91	9.34	-$189	$2,112	$2,539	$2,872	$3,197	0.20	0.24	0.27	0.30	0.20	0.24	0.27	0.30
	Level 2	$10,343	41,861	16,562	91	9.17	-$352	$3,802	$4,571	$5,170	$5,755	0.38	0.24	0.27	0.30	0.20	0.44	0.50	0.56
	Level 3	$10,463	41,441	15,987	92	9.20	-$325	$5,482	$6,590	$7,454	$8,297	0.54	0.24	0.27	0.30	0.20	0.63	0.71	0.79
CZ7 9aD	Base case		47,242	17,148	108	7.40													
	Level 1	$11,802	46,850	16,427	110	7.35	-$48	$1,959	$2,376	$2,705	$3,029	0.17	0.20	0.23	0.26	0.17	0.20	0.23	0.26
	Level 2	$11,572	46,542	15,853	110	7.32	-$75	$3,515	$4,263	$4,854	$5,435	0.31	0.20	0.23	0.26	0.17	0.37	0.42	0.47
	Level 3	$11,458	46,219	15,264	111	7.23	-$164	$5,117	$6,207	$7,067	$7,911	0.45	0.20	0.23	0.26	0.17	0.54	0.62	0.69

		Base Construction Cost (inc HVAC capital cost adjustment)	Energy Use (kWh)	Electricity Use (kWh)	Gas Use (GJ)	Peak Demand (kW)	Network adjustments to capital cost	Lifecycle energy cost savings (today)	Lifecycle energy cost savings (5 yrs)	Lifecycle energy cost savings (10 yrs)	Lifecycle energy cost savings (15 yrs)	BC Ratio - Today	BC Ratio - 5 yrs	BC Ratio - 10 years	BC Ratio - 15 years	BC Ratio (without network adjustment) - Today	BC Ratio (without network adjustment) - 5 yrs	BC Ratio (without network adjustment) - 10 yrs	BC Ratio (without network adjustment) - 15 yrs
CZ2 9bE	Base case		15,237	15,237	-	16.33													
	Level 1	$4,394	14,758	14,758	-	16.57	$229	$1,540	$1,830	$2,052	$2,267	0.33	0.40	0.44	0.49	0.35	0.42	0.47	0.52
	Level 2	$3,489	14,325	14,325	-	15.81	-$506	$2,932	$3,485	$3,908	$4,317	0.98	0.40	0.44	0.49	0.35	1.00	1.12	1.24
	Level 3	$3,887	13,904	13,904	-	16.04	-$281	$4,285	$5,093	$5,712	$6,310	1.19	0.40	0.44	0.49	0.35	1.31	1.47	1.62
CZ5 9bE	Base case		11,844	11,844	-	18.84													
	Level 1	$4,279	11,372	11,372	-	18.71	-$129	$1,517	$1,803	$2,022	$2,233	0.37	0.43	0.49	0.54	0.35	0.42	0.47	0.52
	Level 2	$4,450	10,962	10,962	-	18.82	-$18	$2,834	$3,368	$3,777	$4,172	0.64	0.43	0.49	0.54	0.35	0.76	0.85	0.94
	Level 3	$4,398	10,558	10,558	-	18.78	-$63	$4,134	$4,914	$5,511	$6,087	0.95	0.43	0.49	0.54	0.35	1.12	1.25	1.38
CZ6 9bE	Base case		12,521	12,521	-	17.38													
	Level 1	$4,323	12,016	12,016	-	17.24	-$136	$1,623	$1,929	$2,164	$2,390	0.39	0.46	0.52	0.57	0.38	0.45	0.50	0.55
	Level 2	$4,323	11,650	11,650	-	17.15	-$224	$2,800	$3,327	$3,732	$4,122	0.68	0.46	0.52	0.57	0.38	0.77	0.86	0.95
	Level 3	$4,323	11,299	11,299	-	17.53	$145	$3,928	$4,668	$5,235	$5,783	0.88	0.46	0.52	0.57	0.38	1.08	1.21	1.34
CZ7 9bE	Base case		15,657	15,657	-	17.61													
	Level 1	$4,323	15,214	15,214	-	17.56	-$52	$1,425	$1,694	$1,900	$2,099	0.33	0.40	0.44	0.49	0.33	0.39	0.44	0.49
	Level 2	$4,323	14,836	14,836	-	17.51	-$94	$2,638	$3,135	$3,516	$3,884	0.62	0.40	0.44	0.49	0.33	0.73	0.81	0.90
	Level 3	$4,323	14,528	14,528	-	17.47	-$135	$3,631	$4,315	$4,839	$5,346	0.87	0.40	0.44	0.49	0.33	1.00	1.12	1.24

I.17 Lift

Two different lift technologies with different levels of energy performance were identified and their annual energy was calculated. A common lift technology without regenerative braking represented the base case whilst an example of best practice technology with regenerative braking was used for the test case. No pricing for lifts was obtained. There is no pricing analysis conducted for lifts. Only the energy performance benefits are applied in the models

Appendix J - Solar Photovoltaics Analysis

J.1 Residential PV Analysis Inputs and Methodology

J.1.1 Objectives of PV Analysis

The objective of the residential PV analysis is to determine an appropriate amount of PV to be included in the 'Net Energy Trajectories', based on the maximum cost-effective amount of PV for each building type in each climate zone, with average assumptions about building occupancy and energy consumption patterns.

The Net Energy Trajectories are intended to provide an illustrative forward pathway for net energy and emissions performance of each building type in each climate zone based on the use of on-site renewables. The Net Energy Trajectories will therefore provide a benchmark for energy and emissions performance, and a target year for achieving net zero energy and emissions.

It is clear that some buildings will have different characteristics to the assumptions used for this analysis, and the opportunity for each building will differ. Some buildings will not have access to solar energy due to shading. Some buildings will have much lower energy consumption than the typical building assumed in this analysis (meaning that the maximum cost-effective PV system size may be lower) and others will have much higher energy consumption (meaning that the cost-effective PV system size may be higher). This approach will focus on on-site renewables, but other options to achieve net zero energy or carbon include: procurement of nearby renewable energy supply; purchase of off-site renewable energy; or decarbonisation of grid electricity supply.

J.1.2 Methodology for Residential PV Analysis

For each archetype the calculated maximum percentage export permissible while maintaining a BCR>1.25 was determined based on pricing for energy savings (internally used PV generation) and export of local PV generation to the grid. The resultant maximum percentage export figures are provided in Table 4-153.

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For each archetype model, the total annual energy consumption, including plug appliance loads was then identified. Refer to Section B.7 for plug appliance calculations. Subsequently, the maximum PV capacity and annual generation of each system was calculated based on unshaded coverage of the assigned number of panels (panels assumed to be nominally sized 1.65 m x 1 m). Panel efficiencies were assumed to increase by 2.5% every 5 years (refer to Table 4-150) for the Net Energy Trajectories.

Table 4-150 Panel efficiency (and rating) versus trajectory year

Trajectory year	Panel Efficiency (%)	Panel Rating (W)
0	15.0%	250 W
5	17.5%	290 W
10	20.0%	330 W
15	22.5%	370 W

The ratio of generated energy use to household energy use was then calculated and compared against Figure 103 to estimate the percentage of export using the morning/night profiles that included air-conditioning (which is the most conservative option of the three options available – refer to Section A.1.1 for notes on the derivation of Figure 103).

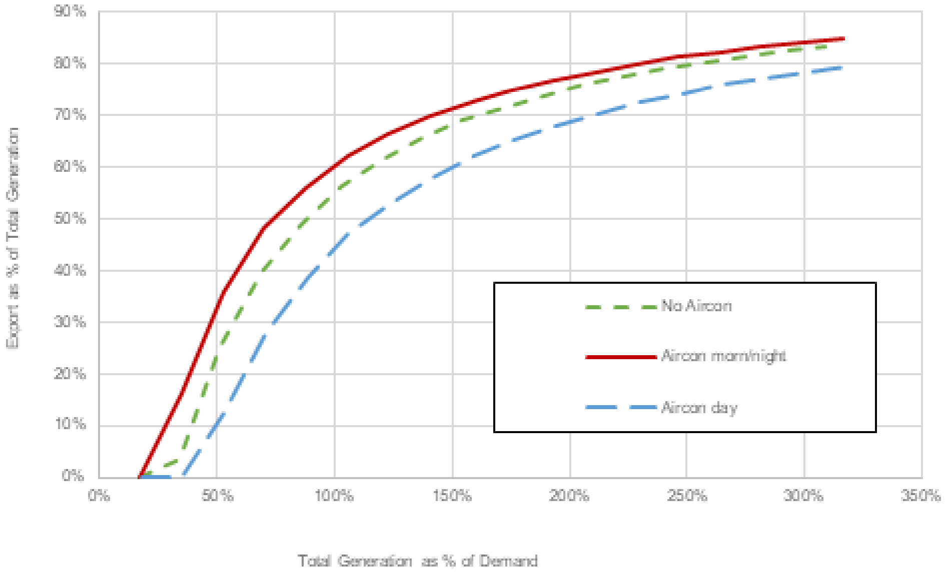

Figure 103: Percentage export as a function of the ratio of total generation to site energy use demand

If the percentage of export was greater than the maximum percentage calculated, then Figure 103 was used to calculate the PV generation permitted within the export cap and back calculated to find the maximum PV install size. If the percentage of export was less than the maximum percentage previously calculated and provided in Table 4-153, then the roof maximum capacity calculated in became the maximum PV install size.

J.1.3 Implementation

The benefit of using PV systems for the attached and detached residential archetypes was analysed using online PVWatts calculator[55] 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, and in a north facing configuration on the apartment archetype roof. The analysis was carried out for four Climate Zones 2, 5, 6 and 7, and four different orientations. The hip type roof was considered for the attached and detached archetypes, and a flat roof for the apartment archetype. The specifications of the PV systems used are summarised in Table 4-151. Table 4-152 summarises the available roof areas and roof pitch of the detached, attached and apartment archetypes and the DC system size installed when the orientation of the house was at orientation of 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 m² for the detached archetype, 14.5 m² for the attached archetype), as were the East and West facing sections (37 m² for the detached archetype and 29 m² 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 4-151: Specifications of the residential 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

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

The quantity of roof space available for PV is smaller in apartment buildings, both because the roof area to floor area ratio is much smaller and also because there will be plant space on the apartment roof that may create shading and access issues that restrict PV capacity.

For a typical single storey apartment of a given floor area, the corresponding gross roof area is equal to the apartment floor area divided by the number of floors in the building. However, the number of floors in apartment buildings varies widely. Data gathered for NABERS for apartments for approximately 200 apartment buildings or complexes indicated that the average apartment building has 12 floors of apartments (10^{th} to 90^{th} percentile range 2-27 floors, median 6 floors). Applying a de-rating factor of 0.5 to account for roof space lost to plant, and a further 0.5 factor to account for the practicalities of array layout, the PV area available to the apartment can be estimated as $1/48^{th}$ of the apartment floor area (approximately $1/24^{th}$ of the area had the apartment been built as a detached single storey house).

The small scale of generation relative to use in an apartment means that the export ratio for that archetype can be considered to be nil.

For PV analysis Climate Zones 2, 5, 6 and 7 were represented by weather data from Brisbane, Sydney, Melbourne and Canberra 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.

J.1.4 Residential PV Analysis Outputs

The PV system ratings and resulting annual energy yields for inclusion into the Net Energy Trajectories are illustrated in Figure 104 through to Figure 107 for the conservative and accelerated technology scenarios for each of the trajectory years.

Table 4-152: Roof areas of the detached, attached, and apartment archetypes (Orientation of 0°)

Archetype	Roof Section	Sloped Roof Area (m²)	Roof Slope / Panel Tilt (°)	DC System Size (kW)			
				0 years	5 years	10 years	15 years
Apartment (Space Factor = 0.5, Mounting Factor = 0.5, 12 Floors)	North	76.4	20	0.25	0.29	0.33	0.37
	East	-	-	-	-	-	-
	South	-	-	-	-	-	-
	West	-	-	-	-	-	-
Attached (Space Factor = 0.4)	North	14.5	23	0.75	0.87	0.99	1.11
	East	29.1	23	1.75	2.03	2.31	2.59
	South	14.5	23	0.75	0.87	0.99	1.11
	West	29.1	23	1.75	2.03	2.31	2.59
Detached (Space Factor = 0.5)	North	77.1	23	6.00	6.96	7.92	8.88
	East	40.2	23	2.75	3.19	3.63	4.07
	South	83.5	23	6.00	6.96	7.92	8.88
	West	34.2	23	2.75	3.19	3.63	4.07

Table 4-153: Maximum percentage of export of PV generation permissible while maintaining a BCR>1.25

Building Type	Climate Zone	Cost ($)		Energy Use (kWh/year)							PV % Export				Export BCR			
		Base	Scenario	Base	Full Export	Full Internal	0yrs	5yr	10yr	15yr	0yr	5yr	10yr	15yr	0yr	5yr	10yr	15yr
Attached	CZ 2	$0	$8,625	0	1,651	5,188	3,447	2,427	1,685	1,651	49.2%	78.1%	99.0%	100.0%	1.25	1.25	1.25	1.29
Attached	CZ 5	$0	$8,625	0	1,495	4,697	3,448	2,426	1,685	1,604	39.0%	70.9%	94.1%	96.6%	1.25	1.25	1.25	1.25
Attached	CZ 6	$0	$8,625	0	1,472	4,626	3,448	2,427	1,685	1,604	37.4%	69.7%	93.3%	95.8%	1.25	1.25	1.25	1.25
Attached	CZ 7	$0	$8,625	0	1,667	5,240	3,448	2,426	1,685	1,667	50.2%	78.8%	99.5%	100.0%	1.25	1.25	1.25	1.30
Detached	CZ 2	$0	$30,188	0	5,778	18,160	12,068	8,496	5,896	5,778	49.2%	78.1%	99.1%	100.0%	1.25	1.25	1.25	1.29
Detached	CZ 5	$0	$30,188	0	5,231	16,439	12,068	8,492	5,897	5,623	39.0%	70.9%	94.1%	96.5%	1.25	1.25	1.25	1.25
Detached	CZ 6	$0	$30,188	0	5,149	16,182	12,066	8,492	5,899	5,612	37.3%	69.7%	93.2%	95.8%	1.25	1.25	1.25	1.25
Detached	CZ 7	$0	$30,763	0	5,833	18,332	12,301	8,653	6,008	5,833	48.3%	77.4%	98.6%	100.0%	1.25	1.25	1.25	1.28

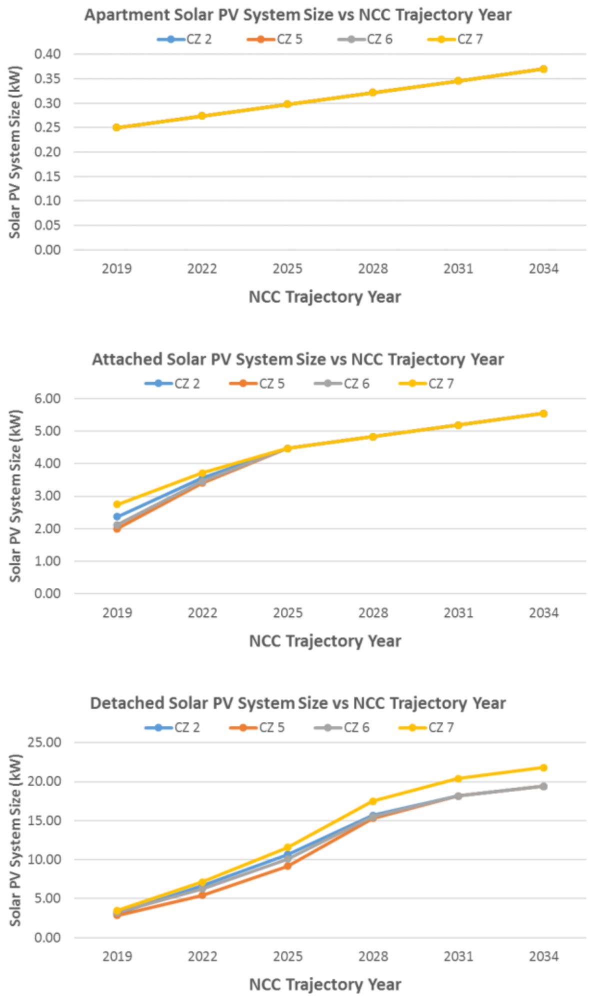

Figure 104: Conservative trajectories solar PV system rating (kW) for each archetype

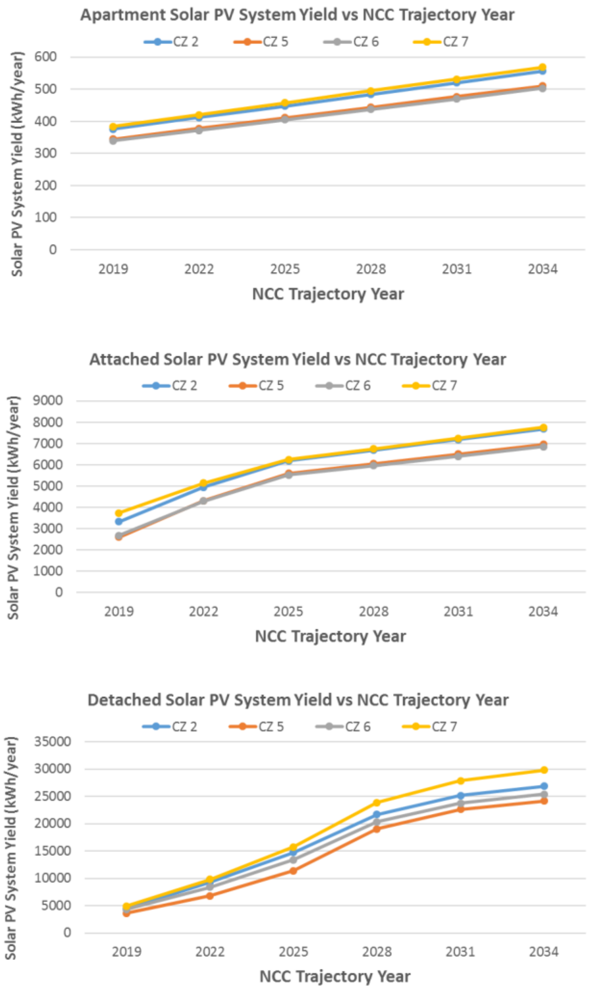

Figure 105: Conservative trajectories solar PV system yield (kWh/year) for each archetype

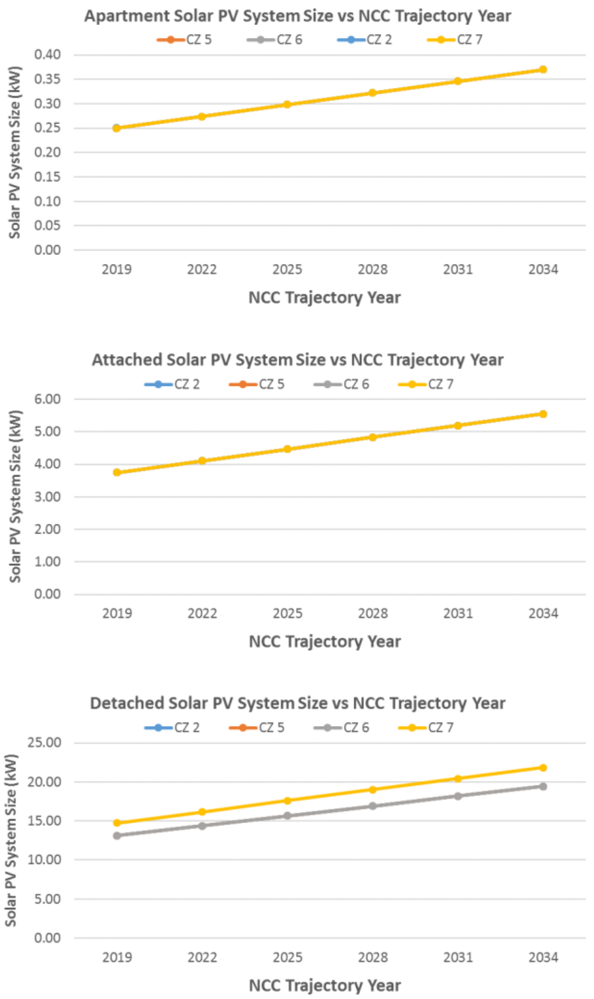

Figure 106: Accelerated Deployment trajectories solar PV system rating (kW) for each archetype

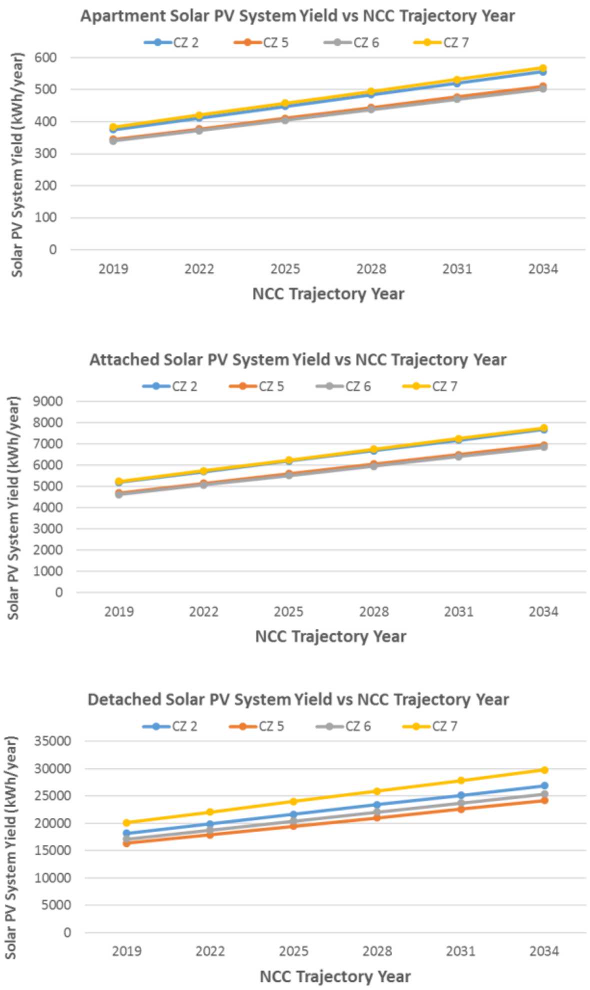

Figure 107: Accelerated deployment trajectories solar PV system yield (kWh/year) for each archetype

J.1.5 Derivation of the Solar Export Curve

The solar export curve in Figure 103 was derived by comparison of three typical household residential electricity profiles (Figure 108) against a generic solar profile (Figure 109). The percentage of export was calculated for each residential profile as the size of the PV array was increased. The results were then expressed in parameterized terms to enable application to a generic building, as required for the current use. The air-conditioning morning and night option produces highest rate of export, so this was been selected as the base scenario, as it produced the most conservative (smallest) sizing of PV array.

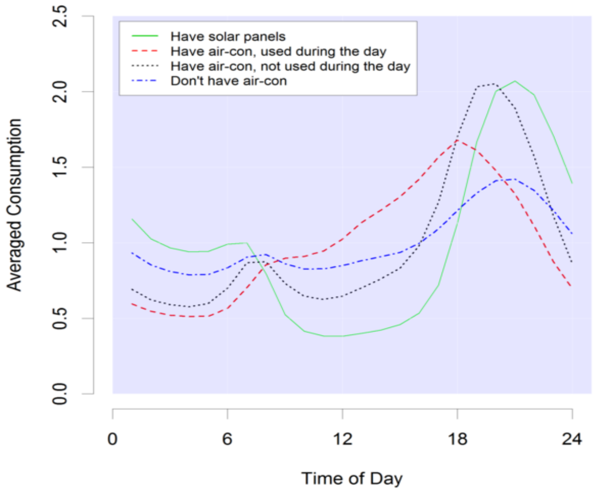

Figure 108 Typical residential energy profiles. The non-solar profiles were used as input data for this analysis. Source: https://www.daa.com.au/articles/case-studies/profiles-of-power/

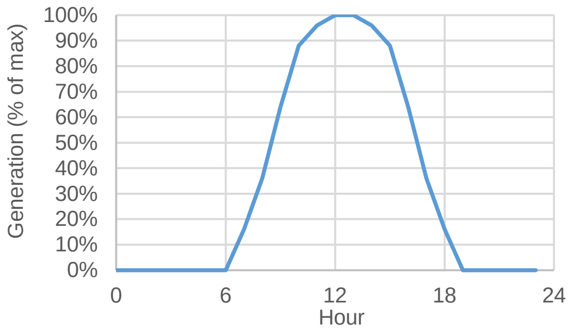

Figure 109 Generic solar generation profile (clear sky)

In accordance with the conservative trajectory target BCR range of 1-1.5, the residential rooftop PV arrays underwent a tuning process to determine the size of the PV array which would achieve a target BCR of 1.25.

The BCR is dependent on the construction cost of the PV array, the amount of generation and the export percentage which determines the energy cost savings. Since the amount of generation is proportional to the size of the PV array, which is also proportional to the construction cost, the BCR is essentially a function of the export percentage.

Therefore, the first step is to derive the export percentage required to achieve a target BCR of 1.25. This was determined for each archetype and climate zone in each scenario using the simulated building energy consumption and estimated maximum sized PV array generation as a starting point. If the BCR was too high, the export percentage was increased, since the export tariff was lower than the grid tariff, and if the BCR was too low, the export percentage was decreased.

With the required export percentages derived, they are compared to the maximum export percentage based on the maximum PV array generation. If the maximum export percentage is greater, then the PV array is reduced until the required export percentage is achieved. If the maximum export percentage is lower, then no further tuning can be done and the maximum PV array is taken to be the cost effective PV array size.

This process is illustrated in Figure 110.

Some important assumptions in the tuning process:

- A feed-in tariff of 31.81% of the grid power tariff was assumed, based on an export price of 7c/kWh and a today's grid tariff of 22c/kWh
- PV was modelled as having a cost learning rate
- Percentage of export was derived based on hourly generation and building energy consumption from simulation results.

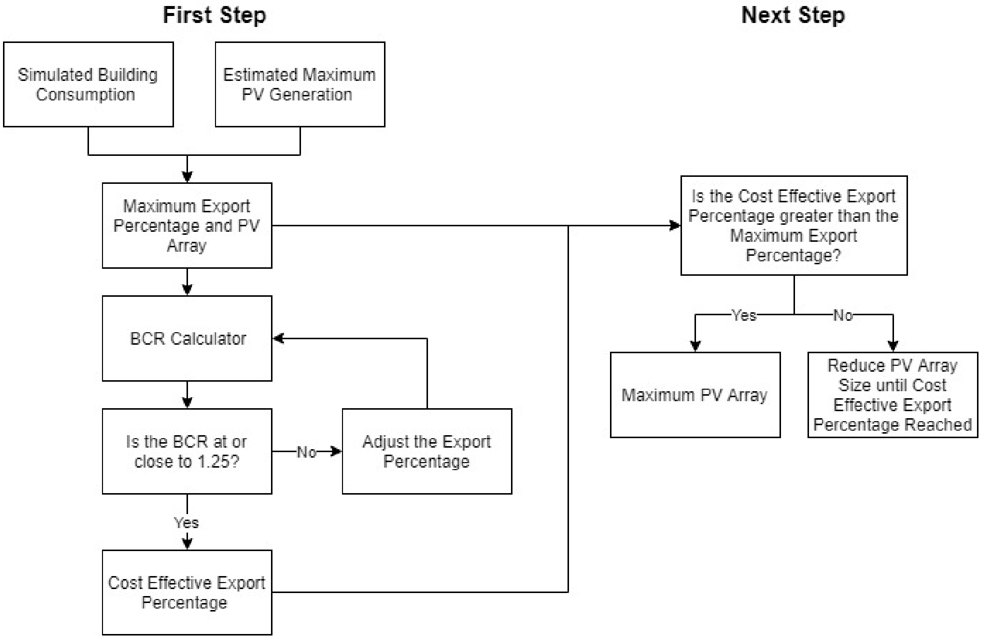

Figure 110: Process to derive the required export percentage for 1.25 BCR.

For the accelerated scenario, the maximum PV array size was used. The resulting sizes for both scenarios are presented in Tables 1 and 2 below.

Table 4-154: Conservative Trajectory PV array sizes

Archetype	Climate Zone	2019	2022	2025	2028	2031	2034
Apartment	CZ 2	0.25	0.274	0.298	0.322	0.346	0.37
	CZ 5	0.25	0.274	0.298	0.322	0.346	0.37
	CZ 6	0.25	0.274	0.298	0.322	0.346	0.37
	CZ 7	0.25	0.274	0.298	0.322	0.346	0.37
Attached	CZ 2	2.375	3.56	4.47	4.83	5.19	5.55
	CZ 5	2	3.41	4.47	4.83	5.19	5.55
	CZ 6	2.125	3.46	4.47	4.83	5.19	5.55

	CZ 7	2.75	3.71	4.47	4.83	5.19	5.55
Detached	CZ 2	3.125	6.644	10.657	15.658	18.165	19.425
	CZ 5	2.875	5.413	9.149	15.281	18.165	19.425
	CZ 6	3.25	6.259	10.077	15.513	18.165	19.425
	CZ 7	3.5	7.142	11.55	17.49	20.414	21.83

Table 4-155: Accelerated Trajectory PV array sizes

Archetype	Climate Zone	2019	2022	2025	2028	2031	2034
Apartment	CZ 2	0.25	0.274	0.298	0.322	0.346	0.37
	CZ 5	0.25	0.274	0.298	0.322	0.346	0.37
	CZ 6	0.25	0.274	0.298	0.322	0.346	0.37
	CZ 7	0.25	0.274	0.298	0.322	0.346	0.37
Attached	CZ 2	3.75	4.11	4.47	4.83	5.19	5.55
	CZ 5	3.75	4.11	4.47	4.83	5.19	5.55
	CZ 6	3.75	4.11	4.47	4.83	5.19	5.55
	CZ 7	3.75	4.11	4.47	4.83	5.19	5.55
Detached	CZ 2	13.125	14.385	15.645	16.905	18.165	19.425
	CZ 5	13.125	14.385	15.645	16.905	18.165	19.425
	CZ 6	13.125	14.385	15.645	16.905	18.165	19.425
	CZ 7	14.75	16.166	17.582	18.998	20.414	21.83

J.2 Commercial PV Analysis Inputs and Methodology

The methodology for the commercial scenario is largely the same as in the residential PV analysis, except for a few key differences:

- A feed-in tariff of 35.04% of the grid power tariff was assumed, based on an export price of 5.5c/kWh and a today's grid tariff of 15.7c/kWh
- Simulated PV generation profiles were used instead of estimated
- Both a cost and efficiency learning rate was implemented for PV. The efficiency learning rate was an improvement of 0.5% per year.

The resulting cost effective and maximum PV array sizes are presented in Tables 3 and 4 below. It is noted that almost all of the cost effective arrays are the same as the maximum array. This is because of the increasing cost of electricity coupled with the learning curves for both cost and efficiency that together contribute to greatly increasing the BCR for PV.

Table 4-156: Cost Effective PV array sizes

Archetype	Climate Zone	2019	2022	2025	2028	2031	2034
3B	2	25.92	28.51	42.16	77.93	94.35	101.09
	5	25.92	28.51	42.16	77.93	94.35	101.09
	6	25.92	28.51	42.16	77.93	94.35	101.09
	7	25.92	28.51	42.16	77.93	94.35	101.09
5A	2	23.81	26.19	83.71	251.52	322.83	345.89
	5	23.81	26.19	83.71	251.52	322.83	345.89
	6	23.81	26.19	83.71	251.52	322.83	345.89
	7	23.81	26.19	83.71	251.52	322.83	345.89
6C	2	23.81	26.19	42.85	88.09	108.33	116.06
	5	23.81	26.19	42.85	88.09	108.33	116.06
	6	23.81	26.19	42.85	88.09	108.33	116.06
	7	23.81	26.19	42.85	88.09	108.33	116.06
9aD	2	28.22	31.05	36.94	48.98	55.64	59.62
	5	24.84	29.69	36.94	48.98	55.64	59.62
	6	20.89	28.11	36.94	48.98	55.64	59.62

	7	28.22	31.05	36.94	48.98	55.64	59.62
9bE	2	10.94	12.04	14.77	20.78	23.92	25.63
	5	10.94	12.04	14.77	20.78	23.92	25.63
	6	10.51	11.86	14.77	20.78	23.92	25.63
	7	10.94	12.04	14.77	20.78	23.92	25.63

Table 4-157: Ambitious Trajectory PV array sizes

Archetype	Climate Zone	2019	2022	2025	2028	2031	2034
3B	2	25.92	28.51	42.16	77.93	94.35	101.09
	5	25.92	28.51	42.16	77.93	94.35	101.09
	6	25.92	28.51	42.16	77.93	94.35	101.09
	7	25.92	28.51	42.16	77.93	94.35	101.09
5A	2	23.81	26.19	83.71	251.52	322.83	345.89
	5	23.81	26.19	83.71	251.52	322.83	345.89
	6	23.81	26.19	83.71	251.52	322.83	345.89
	7	23.81	26.19	83.71	251.52	322.83	345.89
6C	2	23.81	26.19	42.85	88.09	108.33	116.06
	5	23.81	26.19	42.85	88.09	108.33	116.06
	6	23.81	26.19	42.85	88.09	108.33	116.06
	7	23.81	26.19	42.85	88.09	108.33	116.06
9aD	2	28.22	31.05	36.94	48.98	55.64	59.62
	5	28.22	31.05	36.94	48.98	55.64	59.62
	6	28.22	31.05	36.94	48.98	55.64	59.62
	7	28.22	31.05	36.94	48.98	55.64	59.62
9bE	2	10.94	12.04	14.77	20.78	23.92	25.63
	5	10.94	12.04	14.77	20.78	23.92	25.63
	6	10.94	12.04	14.77	20.78	23.92	25.63
	7	10.94	12.04	14.77	20.78	23.92	25.63

Appendix K - Building Stock Model

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.[56]

K.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 below. The distribution of the stock by state and territory in 2017 is shown in Figure 113.

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

Figure 111: Residential Building Stock Totals by Type, 2001 – 2050, Australia [Source: Strategy. Policy. Research.]

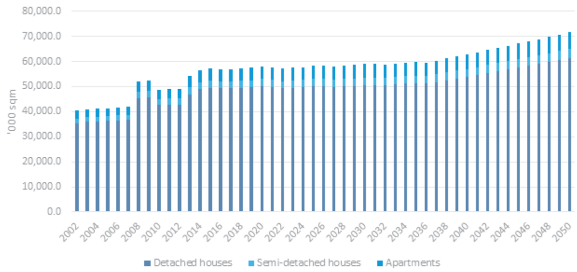

Figure 112: Annual Floor Area Built to Code, Residential Buildings by Type, 2002 – 2050, Australia [Source: Strategy. Policy. Research.]

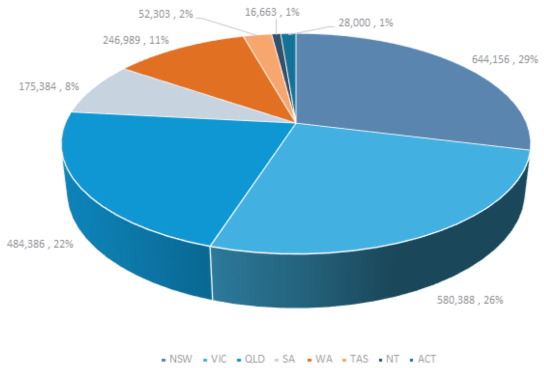

Figure 113: Distribution of Total Residential Stock by State and Territory, 2017 ('000 sqm, %). [Source: Strategy. Policy. Research.]

K.2 Non-Residential Stock Model

Figure 114 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.[57] 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 34) 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.

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

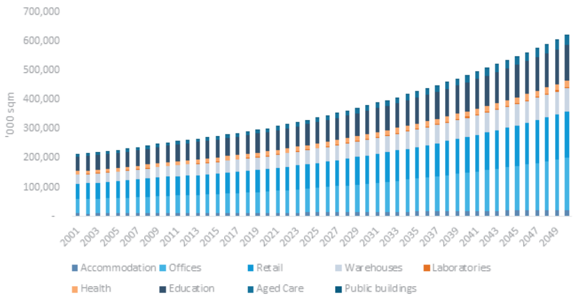

Figure 114: Non-Residential (Identified) Stock Projection ('000 sqm). [Source: Strategy. Policy. Research.]

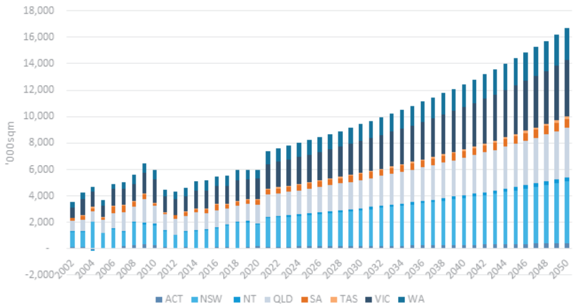

Figure 115: Annual Build to Code, Identified Non-Residential Buildings ('000 sqm). [Source: Strategy. Policy. Research.]

The distribution of the identified non-residential stock by state/territory in 2017 is shown in Figure 116 below, while the distribution of the stock by building type is shown in Figure 117.

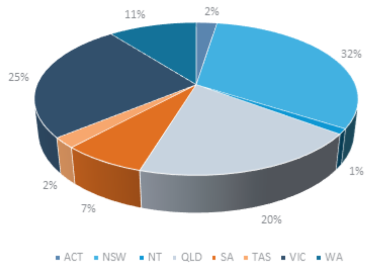

Figure 116: Non-Residential (Identified) Building Stock by State/Territory, 2017. [Source: Strategy. Policy. Research]

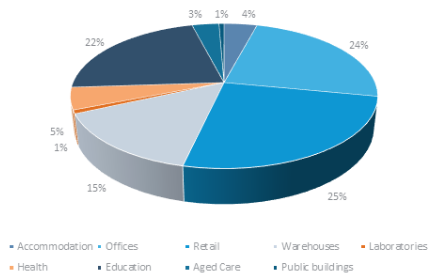

Figure 117: Distribution of Identified Non-Residential Stock by Building Type, 2017. [Source: Strategy. Policy. Research]

K.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 74 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 4-158: 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 <u>average</u> 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%18F[58]
Class 3 Hotels, etc	✓	1:1 Mapping	That the energy intensity of archetype is representative of <u>average</u> 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%
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%

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

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.

K.4 Estimation of Energy Performance in Non-Modelled Climate Zones

K.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 75 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 74 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).

K.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.[59] 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 4-159 below 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 Table 4-160.

Table 4-159: 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

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

	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)[60]	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
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 4-160: 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

[60] Simple average of the two data points.

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.[61] 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).

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