Introduction to background reports on H1 Energy Efficiency

The Ministry of Business, Innovation and Employment (MBIE) is committed to being transparent about the activities it undertakes as stewards of the Building Code. For the proposals in this year's annual update, the consultation document contains relevant details on the reasons for change, relevant options considered, analysis of the options, proposed transition periods and draft versions of proposed acceptable solutions and verification methods. While we believe this information is sufficient for the consultation document, we heard feedback that further details would be useful.

We have been asked for further details on the analysis used to formulate the proposals for:

› Proposal 1. Energy efficiency for housing and small buildings

› Proposal 2. Energy efficiency for large buildings

In recognition of this, we have provided the following two reports from BRANZ and Beca that provide background information and assumptions used in the analysis of the proposed changes.

These reports served as a starting point for formulating options for public consultation. They were commissioned in 2020 through a New Zealand Government procurement process with the scope of work split into two halves for small buildings and larger buildings.

Within their specific scope, BRANZ were asked to provide the following information:

- Thermal modelling of a sample of residential dwelling typologies (single-storey detached, two-storey detached, medium density and apartment building) to determine options for new climate zones and thermal envelope performance settings (R-values), including impacts on heating and cooling energy use and indoor temperatures.
- A Cost Benefit Analysis (CBA) of options for thermal envelope performance settings.
- A Carbon Impact Analysis (both embodied carbon and operational energy) of options for thermal envelope performance settings.

Within their specific scope, Beca were asked to provide the following information:

- Investigation of five typical large building types based on recent consents: education, healthcare, office, retail and residential.
- Creation of sample building of each type representing an average across all the buildings of that type.
- Assessment and reallocation of climate zones across New Zealand according to NIWA's 18 climate files.
- Develop cost index of agreed construction details to achieve specified insulation values.
- Financial cost benefit analysis across the various building typologies, climate zones and R values.
- Assessment and reporting of the Cost Benefit Analysis and Net Present Value including recommendations based solely on financial cost benefit.
- Assessment and feedback of revised R-values in terms of emissions and energy reduction.

The focus of this work started with a discussion on energy savings versus the necessary investment in construction to achieve those savings and whether a balance in costs could be achieved over the life of the building. Upon a review of the initial review of draft reports, MBIE identified that more aggressive insulation requirements may be necessary to fulfil longer-term objectives outlined for the Building for Climate Change programme of work. This recognises that there are other drivers for higher levels of insulation in buildings beyond pure energy savings. The importance of other co-benefits (that were unable to be quantified in BRANZ's and Beca's cost benefit analyses) was also highlighted when MBIE presented this topic to the Code Advisory Panel in September and November 2020.

In early 2021, MBIE asked BRANZ to provide further analysis of proposed options for consultation. This information was used to formulate the infographic on energy savings and initial investment in construction (Figure 1.4 and Table 1.8 in the consultation document).

Introduction to background reports on H1 Energy Efficiency

MBIE would like to take this opportunity to thank BRANZ and Beca and the experts who contributed to these reports. MBIE appreciates that these reports provided a solid foundation for us to consider the implications for the design of new buildings in New Zealand. However, for more information on the regulatory context and other factors to consider for these proposals, we encourage you to review the discussion in the consultation document.

Anna Cook
Acting Manager, Building Performance and Engineering

Analysis to Inform A Review of Large Non-Residential and Apartment Building Thermal Performance Settings and Climate Zones

Prepared for Ministry of Business, Innovation & Employment

Prepared by Beca Limited

30/March/2021

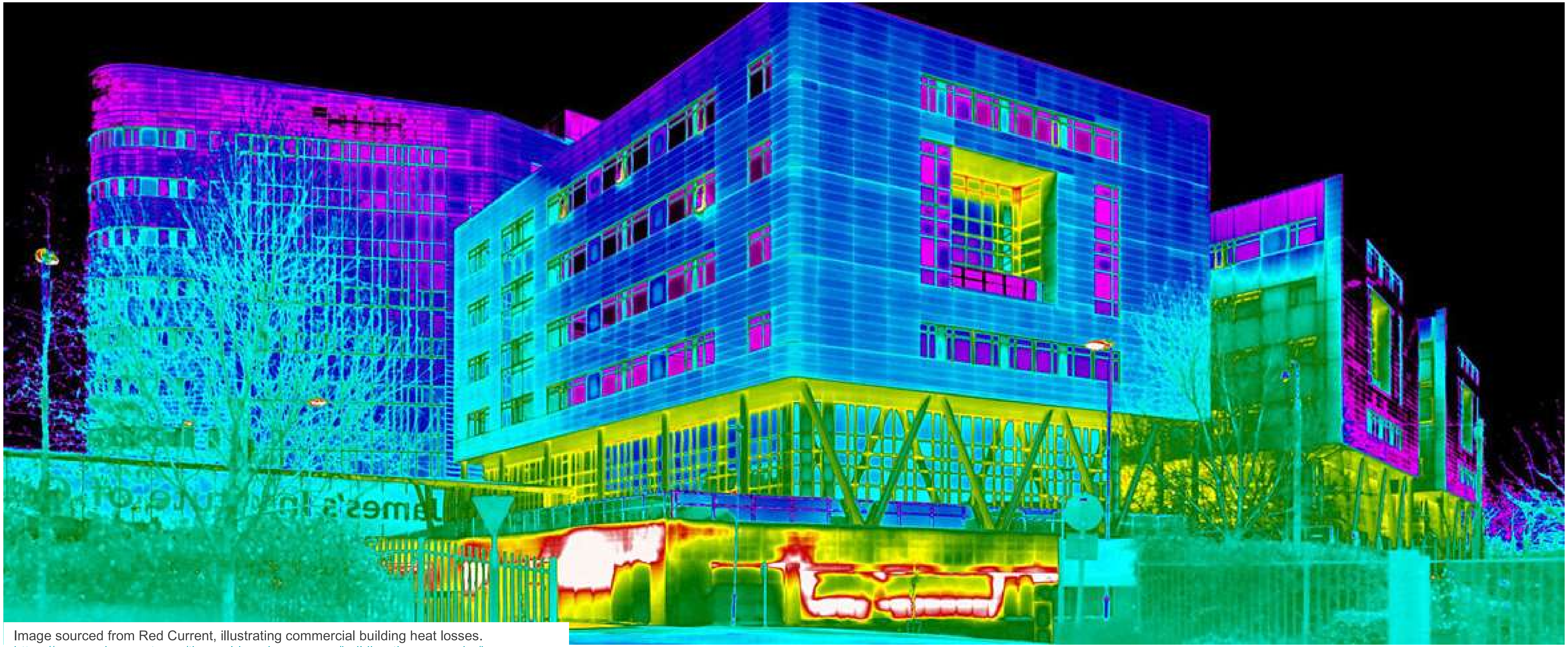


Image sourced from Red Current, illustrating commercial building heat losses.
https://www.red-current.com/thermal-imaging-surveys/building-thermography/breeam

Revision History

Revision Nº	Prepared By	Description	Date
A	Anthony Gates	Draft for MBIE Comment	16 December 2020
B	Scott Smith	Final Report – Incorporating feedback and commentary on additional analysis provided	30 March 2021

Document Acceptance

Action	Name	Signed	Date
Prepared by	Anthony Gates	pp Scott Smith	16 Dec 2020
Reviewed by	Scott Smith		30 Mar 2021
Approved by	Scott Smith		30 Mar 2021
on behalf of	Beca Limited		

Contents

Appendices

Executive Summary

The New Zealand Building Code (NZBC) is administered by the Ministry of Business, Innovation, & Employment (MBIE), and receives updates periodically. The Building System Performance (BSP) team within MBIE have engaged Beca to provide detailed analysis of thermal envelope performance values to inform a review of the minimum thermal envelope element requirements, specifically for large buildings greater than 300m².

This report outlines the methodology, results, and analysis undertaken to inform any potential changes to the minimum requirements as outlined within NZS4243.1:2007.

Through parametric building energy modelling, 166,320 model permutations were created; this consisted of five (5) building typologies, six (6) locations, eight (8) wall R-values, seven (7) roof R-values, nine (9) floor R-values, and eleven (11) window and glazing types. The building energy models were used to generate the annual heating and cooling consumption data and operational costs. The annual operational costs were paired with thermal envelope capital costs to undertake a financial cost benefit analysis. The financial metrics consider a 50-year operational life, using Net Present Value (NPV) and Benefit Cost Ratio (BCR).

Generally, the uplift in construction cost is significantly larger than any resulting energy cost reductions, resulting in a very limited number of financially beneficial increases to the current minimum R-values. The following table lists the building typologies and locations that financially benefit from R-value improvements, and provides the most cost optimal insulation performance options available.

Building Typology	Location	Wall R-value	Roof R-value	Floor R-value	Window	EnPI kWh/m².yr	EnPI Improvement Compared to Baseline	Operational Emission Reductions from Baseline kg.CO_2-e/m²	Operational Emissions Improvement Compared to Baseline	BCR	$NPV/m²
Healthcare	AUK	1.2	1.9	1.91	Single Glazing	49	14%	1.69	16%	3.93	$7
Healthcare	NAP	1.5	1.9	1.91	Single Glazing	73	1%	0.24	2%	1.14	$0
Healthcare	TUR	1.5	1.9	1.91	Single Glazing	98	2%	0.35	2%	1.62	$1
Healthcare	WGN	1.5	1.9	1.91	Single Glazing	69	2%	0.31	2%	1.3	$0
Healthcare	CHC	1.5	1.9	1.91	Single Glazing	120	1%	0.39	2%	1.85	$1
Healthcare	QT	1.5	1.9	1.91	Single Glazing	129	2%	0.46	2%	2.1	$1
Large Multi-Residential	AUK	1.2	1.9	1.91	Single Glazing	9.7	28%	0.40	28%	5.5	$24
Large Multi-Residential	NAP	1.5	1.9	1.91	Single Glazing	13.6	20%	0.36	20%	14.9	$25
Large Multi-Residential	TUR	1.5	4.0	1.91	Double Glazing	18.1	34%	0.17	34%	1.2	$7
Large Multi-Residential	WGN	1.5	1.9	1.91	Single Glazing	10.9	4%	0.05	4%	2.0	$2
Large Multi-Residential	CHC	1.5	4.0	1.91	Double Glazing	22.3	31%	0.20	31%	1.3	$14
Large Multi-Residential	QT	1.5	4.0	1.91	Double Glazing	24	35%	0.25	35%	1.6	$27
Retail	AUK	1.2	1.9	1.91	Single Glazing	26	3%	0.09	3%	2.8	$3
Retail	CHC	1.5	1.9	1.91	Single Glazing	34	1%	0.03	1%	1.1	$0
Retail	QT	1.5	1.9	1.91	Single Glazing	35	1%	0.02	1%	1.2	$0

Highlighted values are greater than current minimum requirements.

Office and School typologies were identified as having no financially favourable increases to R-values.

Sensitivity analysis has been undertaken with respect to the capital costs, energy costs, and annual energy escalation rates. This showed that the results and conclusions of this study are insensitive to significant changes in these variables. The outcomes of the sensitivity analysis are:

- Construction costs would need to be >30% more cost effective (cheaper) to provide more financially favourable outcomes for increased minimum R-values.
- Operational costs (both current energy costs and annual escalation rates) would need to be in the order of twice the current estimates to provide more financially favourable outcomes for increased minimum R-values.

Generally, the results of this project highlight and confirm what has previously been identified with large buildings (>300m²); that the thermal envelope performance has limited impact on the overall building energy consumption. This is a result of low thermal envelope area compared to the volume of the building, coupled with the timing and extent of occupation. The largest contributors to the heating and cooling energy in large buildings are typically the outdoor air and internally generated heat loads (equipment, lighting, and people). Only in buildings with significant night-time operation (e.g. hospitals, large multi-residential) does the envelope performance become a significant determining factor in financial performance.

With limited financially favourable outcomes of increased R-values in large buildings (>300m²), we would recommend that information included with public consultations clearly defines the scope of what has been tested and emphasise the assumptions, sensitives analyses, and limitations that have been used to arrive at the conclusions stated within this report.

1 Introduction

The New Zealand Building Code (NZBC) is administered by the Ministry of Business, Innovation, & Employment (MBIE), and receives updates periodically. The Building System Performance (BSP) team within MBIE have engaged Beca to provide detailed analysis of thermal envelope performance values to inform a review of the minimum thermal envelope element requirements, specifically for large buildings greater than 300m².

This report outlines the methodology, results, and analysis undertaken to assist with informing whether there should be updates to the minimum requirements as outlined within NZS4243.1:2007.

The outcomes and recommendations presented in this report do not constitute good design requirements and should only be used to inform proposed changes to the minimum Building Code compliance values within NZS4243.1.

1.1 Context

The following provides context to this study with respect to Building Code compliance methods and the Standard NZS4243 which is used to demonstrate compliance.

1.1.1 NZ Building Code Compliance Methods

Building Code Clause H1 Energy Efficiency outlines compliance requirements for buildings, including the thermal envelope requirements. In general, the New Zealand Building Code is a performance-based code, providing minimum performance requirements that must be met or exceeded to demonstrate compliance.

There are two compliance methods, Acceptable Solution (AS1) and the Verification Method (VM1). In summary, AS1 relates to the Schedule and Calculation method, whereas VM1 requires the use of energy modelling; these compliance methods are described as follows:

1.1.2 H1/AS1 Building Code Compliance – Schedule Method and Calculation Method

NZS4243.1:2007 sets out minimum thermal envelope R-Values that can be used under the Schedule Method and the reference building values used for the calculation method.

The Schedule method provides an option to demonstrate Building Code compliance through using a look up table where if the envelope element (walls, floors, roofs, and windows) exceed the required R-values, the building complies with the Building Code. This compliance method is applicable to buildings that are greater than 300m² conditioned floor area and have a total window to wall ratio of 50% or less (regardless of orientation).

The Calculation method compares a reference case building against the proposed building to determine which building has the lowest heat loss; if the proposed building is calculated to have less heat loss, then the building complies with Building Code. The calculation method allows for elements to have performance trade-offs, such as including higher performance walls to outweigh a roof with a lower than schedule method R-value.

1.1.3 H1/VM1 Building Code Compliance – Modelling Method

Thermal energy modelling can be used to calculate the heating and cooling energy performance of buildings demonstrate Building Code compliance. If the proposed building consumes less than a refence building, the building's thermal envelope complies. This method must be used where buildings have a window to wall ratio of greater than 50%.

1.1.4 Brief History of NZS 4243.1 Development

The minimum thermal envelope performance requirements outlined in New Zealand Standard NZS4243 was last revised in 1996 (24 years ago). A revision in 2007 separated the thermal envelope and electric lighting performance requirements into two separate parts; Part 1 thermal envelope, Part 2 lighting. The 2007 revision did not change the thermal envelope minimum performance requirements.

To inform the 1996 revision, thermal energy modelling software was used to calculate the heating and cooling energy performance of two office buildings (with conditioned floor areas of 15,000m² and 3,000m²). The two buildings were calculated with a combination of internal loads, window to wall ratios, lighting power densities, and thermal envelope R-values. New Zealand's four (4) main centres were selected for all analyses; Auckland, Wellington, Christchurch, and Invercargill.

The analysis determined the financially beneficial minimum R-Values which have remained New Zealand Building Code minimum requirements. Refer to IPENZ Transactions, Vol. 24, 1997 for a summary of the development and analysis undertaken[1].

A follow up study was undertaken to test the impacts the thermal envelope R-values have on selected non-residential buildings[2]. The study assessed building typologies such as Supermarket, Retail Warehouse, School, Apartment Tower, Hotel, Small and Large Office. Additionally, sensitivity analysis of window-to-wall ratios, lighting power densities, internal load densities, and energy tariff rates was undertaken.

The outcome of the study identified that minimum thermal envelope performances requirements for climates south of Auckland are effective and the window to wall ratio limit of 50% was justifiable for all four climate zones tested. The study also confirmed that office buildings alone are not a suitable representation of large non-residential buildings as there are factors such as volume to façade ratio, operational hours, and internal loads which have an impact on the effectiveness of the building's thermal envelope performance.

1.1.5 Thermal Insulation of Non-Residential Buildings

Large non-residential buildings typically have a large floor plates and large internal volumes compared to the external façade area, resulting in the external environment having limited impact on the overall heating and cooling energy use. It is typically expected that these buildings have limited benefit (cooling and heating energy reductions) from an enhanced thermal envelope (greater than Building Code minimums).

In some scenarios there are detrimental effects on energy efficiency when using enhanced thermal envelopes (high R-values). Where a building has high internal heat gains, and located in a warm climate, there is a reduction of heat loss through the façade. This can result in an increase of cooling energy, which is greater than the reductions in heating energy.

[1] Bannister, Guan, & Page: 1997: Development of acceptable solutions for energy efficiency of office buildings.
https://www.researchgate.net/publication/252183675_Development_of_acceptable_solutions_for_energy_efficiency_of_office_buildings

[2] Bannister, Guan, & Isaacs: 1998: Testing Commercial Building Energy Standards.
https://www.researchgate.net/publication/296928227_Testing_commercial_building_energy_standards

2 Methodology

The methodology sets out how Building Energy Modelling (BEM) and elemental costing has been used to provide a Cost Benefit Analysis (CBA). The CBA identifies the financial benefits of providing greater thermal insulation compared to the base case scenario of current Building Code requirements.

2.1 Cost Benefit Analysis Process

Cost Benefit Analysis (CBA) ties together the elemental capital costs, calculated building energy performance, and operating costs over a selected timeframe (accounting for energy cost escalation over time).

The overall process is illustrated in Figure 1.

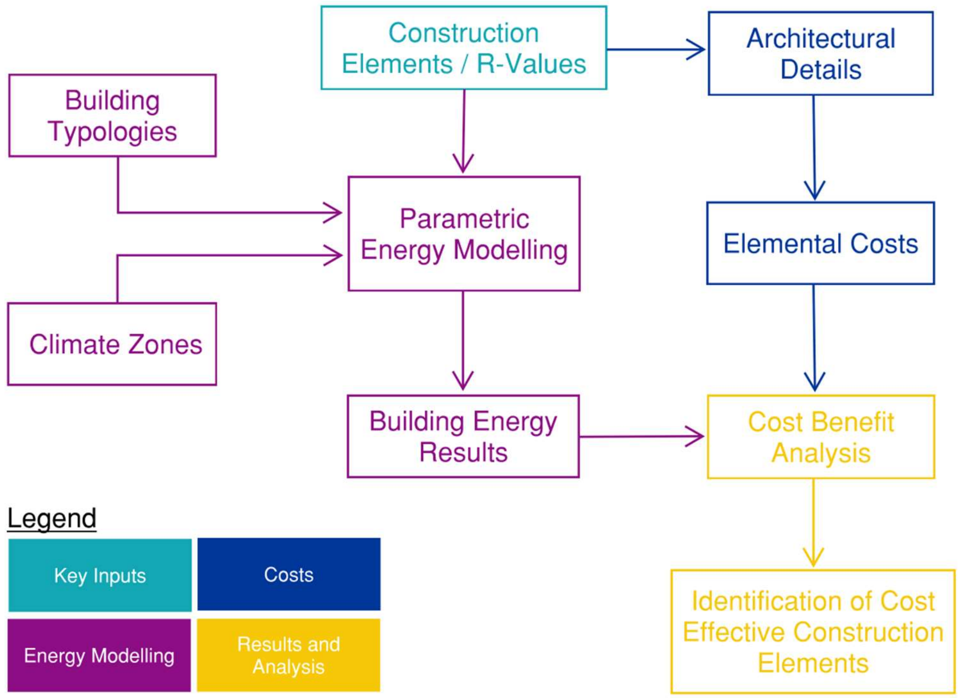


Figure 1. Overview of the Cost Benefit Process.

2.2 Building Energy Model (BEM) Tools

Computer based modelling software was used to generate 3D buildings and calculate the associated energy consumption. The software selected was Rhino/Grasshopper for the building geometry and parametric setup for calculating energy performance; EnergyPlus was used for the energy calculation engine.

2.2.1 Rhino / Grasshopper

Rhino is a 3D software package used for Computer Aided Design (CAD). In this situation, the software was used to visualise building built forms, their window to wall ratios, orientation, and assignment of materials, operating schedules and loads.

This project has used Rhino V6.

The main interface used to setup the parametric energy modelling was Grasshopper.

Grasshopper is a visual programming language which interfaces with Rhino. The programming enables 3D models to be manipulated using various algorithms as opposed to the model itself needed to be re-drawn or have manual inputs to parameters. The greatest benefit of using algorithms to modify the models is the ability to automate the process within defined modelling limits; this is how the parametric models for this study was created. Figure 2 illustrates the Grasshopper network of algorithms used in this study and the key components.

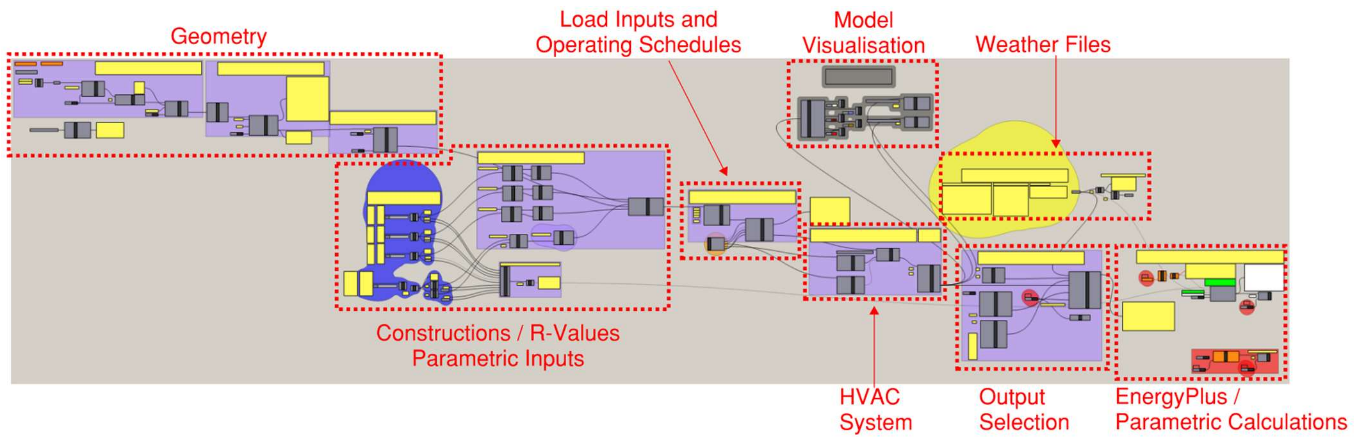


Figure 2. Grasshopper Parametric Modelling Network with Key Network Groups highlighted.

2.2.2 EnergyPlus

EnergyPlus is a whole building energy simulation program developed by the U.S Department of Energy (DOE). The validity of the EnergyPlus calculation engine is determined against *BESTEST* (Building Energy Simulation TEST) and *ANSI/ASHRAE Standard 140-2011: Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs.*

The calculation engine uses the modeling information generated within Rhino/Grasshopper and calculates the building's energy consumption using a Typical Meteorological Year (TMY) weather file to determine the heating and cooling requirements to maintain space temperature setpoint.

This project has used EnergyPlus Version 9-2.

2.3 Parametric Modelling

The parametric modelling undertaken in this project tests every possible combination of construction build ups for the building typologies within each climate location. 166,320 building energy models have been generated through the number of tested options as noted in Table 1.

Table 1. Parametric Elements Tested.

Item	Description	Number of Tested Options
Floor	Slab on grade floor build ups	9
Wall	Thermal values ranging from R0.3 to R5.0	8
Roof	Thermal values ranging from R1.9 to R7.0	7
Window	Thermal values ranging from clear single glazing to tinted low-e triple glazing.	11
Building Typology	Five building typologies, Refer to report Section 3	5
Location	Six locations throughout NZ, Refer to report Section 0	6

This “brute force” approach to parametric modelling provides a clear visual indication of the influence each element has on the energy performance. Sensitivity assessment of each element is therefore inherently provided with these results, reducing oversight of any potentially obscure construction arrangement which may be financially beneficial.

2.4 Tested R-values

The following tables summarise the tested R-values that have been assessed. As noted in Section 2.3, every combination has been modelled, resulting in 166,320 building energy models.

Table 2. Modelled Wall and Roof R-values.

Wall R-value	Roof R-value	Commentary
0.3	1.9	Overall R-Value Performance. (including thermal bridging effects) Models are based on concrete material properties. Elemental costs provide separate light and heavy weight options. Refer *Appendix C: Architectural Details* for construction build ups.
1.2	3.0	
1.5	3.5	
2.0	4.0	
2.5	5.0	
3.0	6.0	
4.0	7.0	
5.0		

Table 3. Modelled Floor R-values.

1.91	Slab on grade
1.95	Slab on grade w 25mm edge insulation
2.00	Slab on grade w 100mm edge insulation
2.85	Slab on grade w 25mm underslab insulation
5.62	Slab on grade w 100mm underslab insulation
2.88	Slab on grade w 25mm edge and 25mm underslab insulation
5.66	Slab on grade w 25mm edge and 100mm underslab insulation
2.92	Slab on grade w 100mm edge and 25mm underslab insulation
5.70	Slab on grade w 100mm edge and 100mm underslab insulation

Note on Determining Floor R-Values and Impacts on Study Findings

There are significant differences between the NZBC calculation methodologies (as per NZS4214) and real-world insulation performance highlighted in the BRANZ Home Insulation Guide.

The use of the BRANZ Home Insulation Guide is preferred for accuracy, however, the current minimum compliance pathway (and resulting costs) have been developed based on interpretation of NZS4214.

Whilst these two methods of determining R-Value for floors are in conflict, the results of the cost analysis are not sensitive to increases in floor R-values and these do not materially impact on the findings of this project.

Table 4. Modelled Windows Properties.

Window Performance U-value / SHGC	Equivalent R-value	Description	
*U5.80 / 0.84	0.17	Aluminium Joinery, Clear Glass	Single Glazing
*U5.80 / 0.60	0.17	Aluminium Joinery, Tint Glass	
U4.76 / 0.71	0.21	Thermally Broken Aluminium Joinery, Low-e Glass	
U3.85 / 0.74	0.26	Aluminium Joinery, Clear Glass	Double Glazing
U3.85 / 0.50	0.26	Aluminium Joinery, Tint Glass	
U3.23 / 0.69	0.31	Aluminium Joinery, Low-e Glass	
U3.23 / 0.50	0.31	Aluminium Joinery, Tint Low-e Glass	
U2.56 / 0.69	0.39	Thermally Broken Aluminium Joinery, Low-e Glass	
U2.56 / 0.45	0.39	Thermally Broken Aluminium Joinery, Tint Low-e Glass	
U1.61 / 0.60	0.62	Thermally Broken Aluminium Joinery, Tint Glass	Triple Glazing
U1.61 / 0.40	0.62	Thermally Broken Aluminium Joinery, Tint Low-e Glass	

*We note EnergyPlus has a limitation where U5.8 (R0.17) is the highest U-Value able to be modelled.

2.5 Elemental Costs

Elemental costs have been developed based on architectural sketches. The sketches illustrate a typical elemental build-up for floors, walls, roofs, and windows.

We note there are many ways to design each element with the use of different materials or construction methods. The construction build-ups are commonly different for each building type. The build-ups used in this project are specific to achieve the thermal performances only; as such, the construction build-ups may not be designed with respect to other typical considerations such as interstitial condensation or acoustic performance requirements.

Refer to *Appendix C: Architectural Details* for a summary of the architectural sketches.

Refer to Section 5.2.3 for a breakdown of the elemental cost premiums.

2.6 Limitations

Key limitations of this study are:

- All R-values calculated use the one-dimension heat transfer methods as described within NZS 4214.
- No secondary cost reductions are considered through the likes of reduced central cooling and heating plant.
- Weather files used are TMY weather files and therefore do not account for any extreme weather patterns or future estimates that may be associated with climate change.
- Building energy is calculated using energy modelling software, based on minimum performing building designs in accordance with NZBC, relevant Standards, and standard industry practices.
- This model has included a number of simplifications that are appropriate for relative performance assessment.
- The study is limited to relative energy, capital, and resulting CBA outcomes; absolute figures are not reliable as indicators of real-world performance nor should they be relied on for policy setting.

3 Building Typologies

Large non-residential and multi-residential buildings are typically unique in their design, particularly with respect to built-form (shape). Selecting a constructed building to represent a “typical” building typology would not be considered a fair representation of the typology. Therefore, minimum Building Code compliant built-forms were developed to represent each typology. The Building Code compliant built-form models are an appropriate assumption for the macro analysis of the minimum thermal envelope requirements.

3.1 Typologies

Five (5) building typologies have been selected based on the most common large non-residential and multi-residential buildings. These are:

- Office
- Retail
- Healthcare
- School
- Large multi-residential (i.e. apartment tower)

3.2 Building Consents Per Typology

A review of issued building consent numbers has been undertaken to understand the influence of building typology mix on financial benefits for all of New Zealand. This provides insight into how many buildings of each typology are likely to be constructed going forward and what trade-offs might exist for typology wide insulation settings. The “historic number of building consents issued” has been used to determine likely future typology mix.

Building Consent numbers for the whole of NZ have been provided by MBIE, sourced from Statistics NZ. The trends shown within Figure 3 would be expected to align with the general population and regional/city growth.

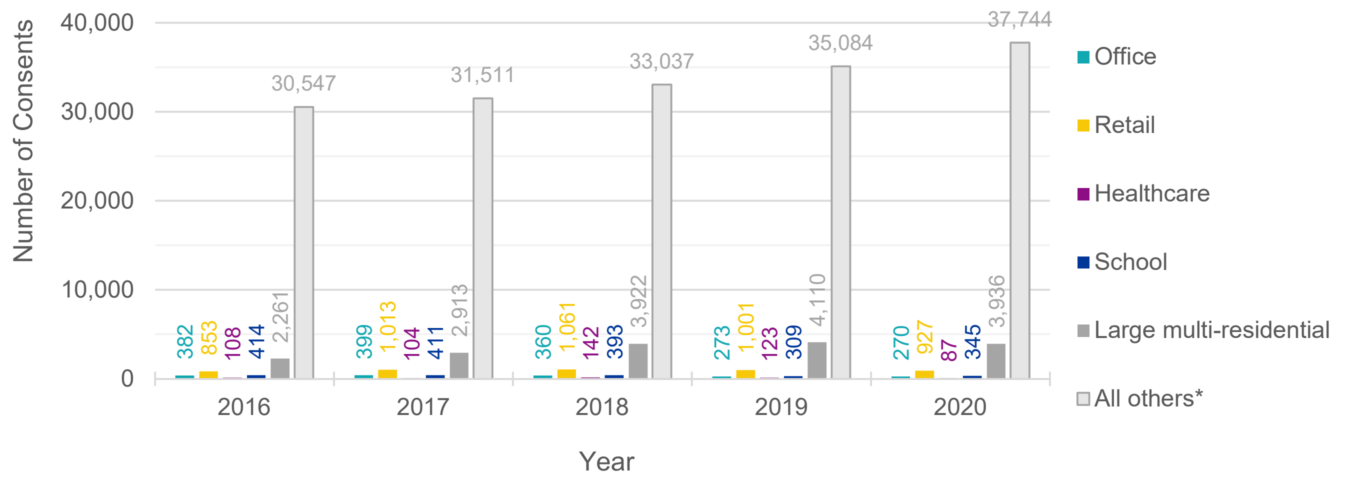


Figure 3. Number of Building Consents per Building Typology

The large building typologies explored within the project contribute to approximately 13% of all new builds. Table 5 provides a breakdown of the contribution each building typology has as a percentage of the total number of annual building consents issued over the previous 5 years.

Table 5. Building Consent Numbers

Annual Values June ending	2016	2017	2018	2019	2020	Historic Annual Average
Large multi-residential	6.5%	8.0%	10.1%	10.0%	9.1%	**8.7%**
Healthcare	0.3%	0.3%	0.4%	0.3%	0.2%	**0.3%**
School	1.2%	1.1%	1.0%	0.8%	0.8%	**1.0%**
Retail	2.5%	2.8%	2.7%	2.4%	2.1%	**2.5%**
Office	1.1%	1.1%	0.9%	0.7%	0.6%	**0.9%**
All others*	88.4%	86.7%	84.9%	85.8%	87.2%	**86.6%**

Source: Building Consents, Statistics NZ via MBIE.

Note: * *All others* include Houses, Townhouses, hotels, social buildings, shops, restaurants, and other small-scale consented works.

The total number of issued building consent show an approximate 5% increase year-on-year increase over the last five years. The majority of increases is contributed by small buildings, not assessed within this project (housing, social buildings, and small shop fitouts).

Large buildings, including multi-residential, remain relatively stable with a range of 11-15% as a percentage of the total. We note that retail, defined as “big box” retail, is combined with other large distribution centres and storage facilities due to the similar building descriptions within the source data. The big box retail specifically is anticipated to be a small proportion of this value making it less influential than the consent numbers suggest.

Building consents during 2020 have experienced a downturn in numbers which is likely resulting from the global pandemic and the associated economic uncertainties.

3.3 Building Performance Sketch Models

Building energy modelling can be a very detailed process when attempting to match reality; a process commonly referred to as “model calibration” or “digital twin”. Developing a digital twin is amplified with commercial buildings due to the complexity of the buildings and the systems within them. Factors influencing the energy performance include occupant behaviour, condition of HVAC plant, and how the building is commissioned and controlled.

Performance sketch models are generic models which include key geometric features and operational functions of a building. Specific features of the models include built-form, window-to-wall ratios, construction R-values, occupancy rates, and orientation; these features are used to represent a minimum Building Code compliant building.

Due to minimal design details being required, they can be setup at early conceptual/massing design stages. The features typically have high influence on the energy performance of buildings and results in a performance outcome that are not too dissimilar to what would be anticipated in reality.

The performance sketch models used in this project are similar to the template models generated as part of the BRANZ Building Energy End-use Study (BEES) project[3]. The BEES template models were able to provide a fair representation of New Zealand’s the commercial building stock for further assessment purposes.

[3] BRANZ BEES Energy Modelling: https://www.branz.co.nz/environment-zero-carbon-research/bees/modelling/

3.3.1 Performance Sketch Model – Modelling Parameters

The performance sketch models have been developed to represent Building Code minimum requirements, complying with NZS4243.1: 2007.

Height factors (height to footprint ratio) and form factors (square to rectangular shape) of each typology was defined through a desktop review via virtual site visits using services such as *Google Maps* with *Street View*.

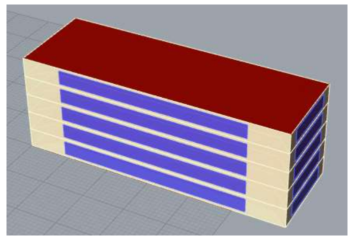
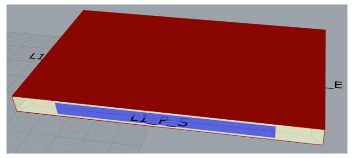
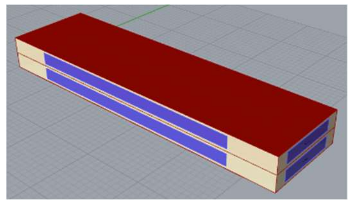
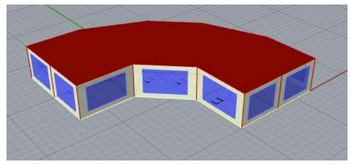
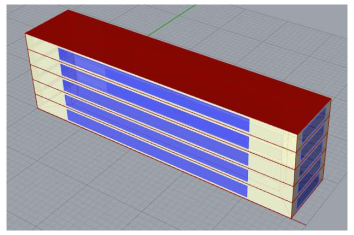
All models have centrally located windows with a window-to-wall ratio of 50% in all orientations.

The models are orientated with the longest façades facing north and south; this avoided large glazing areas with east and west facing glazing which would have overestimated the cooling energy impacts.

School is the only non-rectangular typology. The chevron shape was decided as schools are less site constrained with respect to solar orientation and subject to more passive design solutions such as natural ventilation which becomes sensitive to solar gains.

Key parameters and descriptions of the five (5) building typologies are noted in Table 6.

Table 6. Building Typology Model Summary.

Building Typology	Model Image	Key Parameters	Description of Buildings Represented
Office		Conditioned Floor Area: 6,334m² Footprint: 62.1 x 20.4m Height: 22.8m Overall 4.57m Floor to Floor	>5 levels Mid-high rise buildings Small footprint to height ratio
Retail		Conditioned Floor Area: 6,915m² Footprint: 110 x 62.9m Height: 7m Overall / Floor to Floor	Big box retail Standalone sites Large footprint, large volume
Healthcare		Conditioned Floor Area: 1,659m² Footprint: 55.2 x 15m Height: 5.8m Overall 2.9m Floor to Floor	Low rise hospital Clinics and emergency centres excl. patient bed wards 24/7 operation
School		Conditioned Floor Area: 426m² Height: 4.6m Overall / Floor to Floor	Standalone classroom blocks Modelled to account for multiple orientation impacts
Large Multi-residential		Conditioned Floor Area: 2,292m² Footprint: 47.7 x 9.6m Height: 14.2m Overall 2.84m Floor to Floor	>5 levels Large apartment towers Retirement villages Student accommodation

Refer to *Appendix B: Key Modelling Assumptions* for further specific inputs and modelling assumptions that have been used.

Limitations of the Models

These performance sketch models are a simplification of a NZS4243.1:2007 compliant building and considered an appropriate assumption for a macro analysis of prescriptive building code settings. The simplification does not account for passive design strategies that could be considered with new builds; for example, external solar shading, orientation specific window-to-wall ratios, building-site orientation.

By using the performance sketch models, the built forms may result in an overestimation of energy consumption (and insulation benefits) compared to designs that passively reduce heat losses and gains. These benefits can be realised through the use of modelled compliance pathways in the Building Code.

We note that the application of NZS4243.1:2007 to a residential building is inconsistent with Building Code compliance requirements and may result in recommendations (and description of benefits) that do not align with current regulatory requirements. The this methodology was used as a parallel study for apartment buildings under the relevant standard (NZS4218) was being undertaken, and a decision regarding inclusion of apartment buildings under NZS4243 was being evaluated.

4 Climate Assessment

A climate assessment has been undertaken to group similar heating and cooling energy consumption requirements throughout New Zealand. The purpose of this activity is to provide a limited set of performance requirements across New Zealand, and limit the extent of subsequent modelling undertaken to determine optimal insulation levels.

We note there have been several climate studies specific to energy modelling of buildings within New Zealand; each study categorises the climate and weather in different ways. This ranged from raw weather file data assessment to selection based on construction activity, a summary of these methods are as follows:

- Cory, 2016[4] identified seven (7) climate zones to represent New Zealand. This was based on grouping similar performance indicators together; temperature, humidity, solar radiation, daylight, wind, and comfort hours.
- The 1997 development of NZS4243 simply used the four (4) main centres of NZ. This corresponded to where the majority of building activity happens. The locations selected were Auckland, Wellington, Christchurch, and Invercargill.
- BRANZ have identified six (6) climate zones as part of the residential and small buildings H1 thermal envelope improvement study. These climates are represented by the cities Auckland, Napier, Wellington, Taupo/Turangi, Christchurch, and Queenstown.

4.1 New Zealand's Weather and Climates Zones

NIWA (National Institute of Water and Atmospheric Research) defines New Zealand's climate as "*complex and varies from warm subtropical in the far north to cool temperate climates in the far south, with severe alpine conditions in the mountainous areas*". The variance in weather and climate is illustrated by NIWA in the below images with respect to historic mean annual temperatures, Sunshine hours, and rainfall.

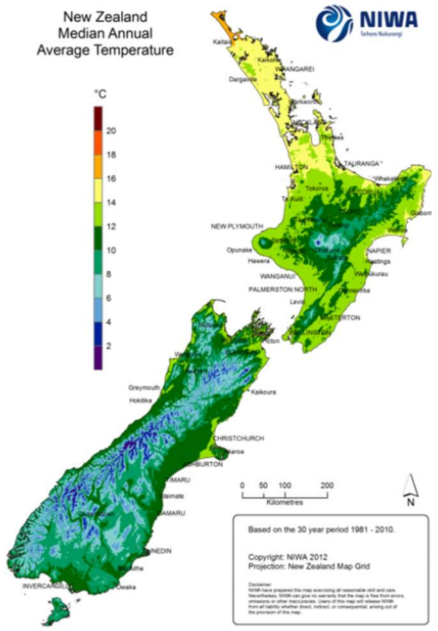


Figure 4. Mean Annual Temperature.

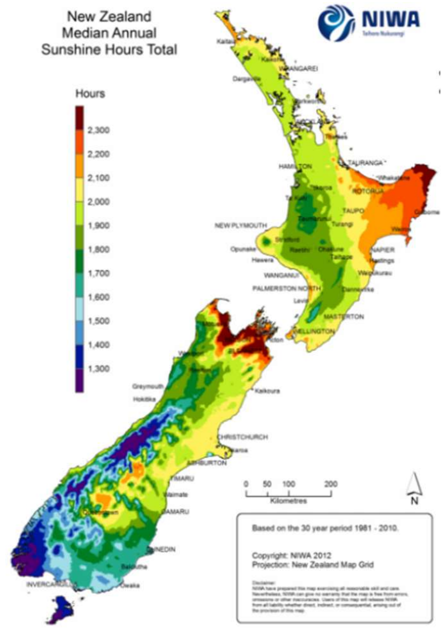


Figure 5. Mean Annual Sunshine Hours.

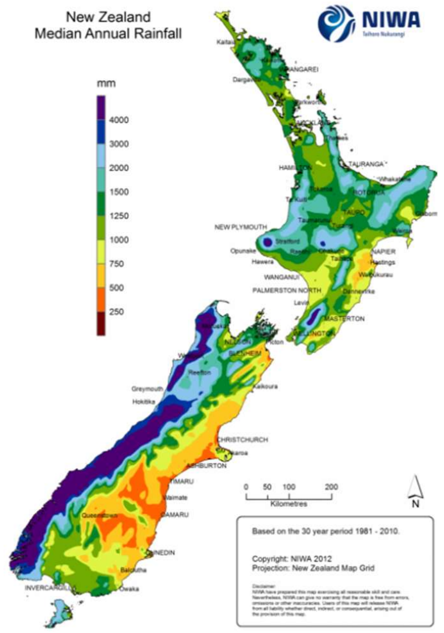


Figure 6. Mean Annual Rainfall.

4.1.1 Current Climate Zones

For thermal envelope Building Code compliance, three climate zones are defined by NZS 4218 and NZS 4243. The same zones are defined for both small (<300m²) and large (>300m²) buildings. The zones are listed below and summarised in Figure 7:

- Zone 1: Auckland and Northland.
- Zone 2: North Island, Excluding Zone 1 and central region.
- Zone 3: Central North Island, and South Island.

These three climate zones represent weather patterns which are typically warm, mild, and cold climates.

Originally, these zones were defined based on construction activity around main city centres and a building's response to heating demands. Heating is used as a performance indicator as it is influenced by the increase of R-values, cooling energy typically has minimal impact through changing R-values.

Heating is only a Building Code requirement for specific building types; early childhood and old people's homes (NZBC G5: Indoor Environment).

Figure 7. NZS4243.1:2007 Climate Zones.

4.1.2 Weather files

Building Energy Models (BEM) use weather files to calculate the heating and cooling energy requirements.

New Zealand has 18 weather file locations available; these weather files are TMY (Typical Meteorological Year) files. TMY weather files represent a "typical" weather year, not accounting for unseasonable weather events (too high or too low) or influences such as predicted climate change scenarios.

TMY weather files are based on approximately 30 years of measured data, dating back from 2009 and do not account for future climate change related impacts.

[4] Cory, S. 2016: Victoria University of Wellington Thesis:
An Exploration of the Feasibility of Converting the New Zealand Commercial Buildings Stock to be Net Zero Energy.

4.2 Models for Climate Assessment

All five (5) building typology models have been used to review the influences (similarities and differences) of the 18 weather file locations across New Zealand. The weather influences a building's heating and cooling primarily as a result of:

- HVAC, outdoor air rates, and operating hours.
- Thermal Envelope, R-value, airtightness, and area.

HVAC systems, outdoor air rates, and occupancy are consistent in the assessment models to eliminate the influence this has on the thermal envelope performance.

The thermal envelope influence is assessed using the five building typologies and two sets of construction R-values.

As the purpose of this study is to inform improvements in thermal envelope performance, the sensitivity of climate zoning to insulation levels was investigated. This is described in the following sections.

4.2.1 Constructions

Two construction build-ups are used; Baseline and Enhanced Insulation values. Both constructions are used in all 18 weather file locations.

Baseline Constructions

Baseline constructions align with the minimum Schedule Method compliance requirements of NZS 4243.1:2007. These are grouped into two climate zones as outlined in Table 7.

Enhanced Insulation

Enhanced insulation constructions are the same values for all climate zones. They identify how the heating and cooling requirements change in response to thermal envelope performance. Refer to listed enhanced R-values within Table 7.

Table 7. Climate Assessment R-values.

Parameter	Baseline NZS 4243: Schedule Method		Enhanced Insulation
Current Climate Zone	**1**	**2&3**	**1 & 2 & 3**
Roof	R1.9	R1.9	R4.0
Walls	R0.3	R1.2	R3.0
Floors	*R1.3	R1.3	R2.5
Glazing	**Clear Single Glazing. R_{window}: 0.15 SHGC: 0.84	**Clear Single Glazing. R_{window}: 0.15 SHGC: 0.84	Double Glazing, thermally broken joinery. R_{window}: 0.39 SHGC: 0.69

* No Requirement, Climate zone 2&3 requirements used.
** No Requirement, least preferable option selected.

4.2.2 Thermal Energy Results

Figure 8 below shows the average heating, cooling and combined thermal energy demands across typologies for the 18 weather file locations in New Zealand.

Location	Energy Demands (Baseline Insulation) Heating kWh/m²	Energy Demands (Baseline Insulation) Cooling kWh/m²	Energy Demands (Baseline Insulation) Total kWh/m²	Energy Demands (Enhanced Insulation) Heating kWh/m²	Energy Demands (Enhanced Insulation) Cooling kWh/m²	Energy Demands (Enhanced Insulation) Total kWh/m²
Northland-Kaitaia	19	45	63	11	41	52
Auckland-Auckland	20	46	66	12	35	47
Bay.of.Plenty-Tauranga	22	45	67	15	39	54
Taranaki-New.Plymouth	26	26	52	18	22	40
East.Coast-Napier	30	41	71	21	35	56
Waikato-Hamilton	32	40	72	23	35	58
Manawatu-Paraparaumu	33	14	47	23	12	35
Wellington-Wellington	35	12	48	26	11	37
Nelson.Marlborough-Nelson	36	35	71	24	30	54
Rotorua-Rotorua	40	20	60	26	17	43
Wairarapa-Masterton	45	41	86	33	34	66
Taupo.King.Country-Turangi	45	29	74	32	25	57
West.Coast-Hokitika	48	9	57	34	8	41
Canterbury-Christchurch	55	28	82	39	24	63
Otago-Dunedin	55	6	61	40	5	45
Southland-Invercargill	63	5	67	48	4	52
Queenstown.Lakes-Queenstown	68	20	87	46	16	63
Central.Otago-Lauder	71	27	98	53	22	76

Figure 8. Thermal Demand Across Weather File Locations

4.3 Determining Climate Zones

Individual heating and cooling energy consumption profiles can be quite different in each geographic location. Grouping weather file results based on heating alone will not provide a good description of the climate differences relevant to this study.

To account for this, a two-step approach has been undertaken to group similar climate zones.

The two-step approach groups locations firstly by heating energy performance then secondly by combined heating and cooling energy performance, as illustrated in Figure 9. Heating is used initially as it provides a clear geographic gradient of heating demands across New Zealand (consistent with current climate mapping). Combing heating and cooling energy as the second differentiator allows localised climate differences (cooling impacts) to be assessed while retaining heating as a primary influencer. This approach was discussed and agreed with MBIE.

Figure 9. Two-Step Approach to Defining Climate Zones

4.3.1 Heating Energy

There is a general geographic gradient of heating energy consumption from top to bottom of New Zealand, Lowest to highest consumption (a notable exception being the North Island's Central Plateau).

By way of example, the Office building typology in Northland is calculated at 7 kWh/m² of annual heating energy, while the same model in Invercargill results in 34 kWh/m² of annual heating energy; both locations use the same BEM, therefore maintaining the same space temperature conditions.

4.3.2 Cooling Energy

Large buildings are typically cooling dominated; requiring more cooling than heating to maintain occupant comfort. This is primarily due to the deep floor plates which results in reduced external influences (i.e. façade area to floor area is less than a typical small building); large buildings typically experience higher internal loads emitting heat from equipment and people.

Annual cooling energy is observed to have a less consistent geographical gradient. This is because of other factors which influence the cooling energy, primarily solar exposure. These models do not include passive solar design strategies (orientation, solar shading, etc) and therefore are expected to have higher than typical cooling loads. Nelson is an example where the location typically experiences cool winter temperatures, however modelling results have indicated cooling energy similar to central North Island locations.

4.3.3 Grouping Parameters

Grouping of climate zones are based on the thresholds where there are clear changes of thermal performance requirements. For both heating and cooling thermal requirements, these thresholds are as displayed in Table 8.

Table 8. Thermal Performance Thresholds.

Climate Description	Heating Energy	Heating + Cooling Energy
Low	<50 kWh/m²	<=60 kWh/m²
Mild	-	60 - 70 kWh/m²
High	>=50 kWh/m²	>=70 kWh/m²

4.4 Identified Zones

Similar climate zones are identified using 1) heating and 2) heating + cooling energy performance indicators. For simplicity, the average value across all building typologies is used for analytical purposes. Refer to section 4.4.1 for a breakdown of the energy for each building typology.

Five climate zones have been identified as a result of the BEM heating and cooling energy results. The five identified climate zones are described in Table 9 and illustrated within Figure 10. This summary uses the baseline insulation performance value model as thermal demand differences between locations were clearer. However, the groupings proposed are suitable for the enhanced insulation results (which would dictate fewer zones if utilised). Refer to Section 4.4.2.

Each grouped climate zones has a representative weather file based on the highest populated city within the climate zone grouping. Population is a relatively good indicator of potential construction activity. The nominated city per climate zone is highlighted in the following table.

Table 9. Identified Similar Climate Zones and Proposed Groupings

Climate ID	Description	City / Region included in Grouping
1A	Low Heating, High Cooling	Northland ***Auckland** Bay of Plenty
1B	Low Heating, Mild Cooling	Napier ***Hamilton** Taupo Wairarapa Nelson / Marlborough
1C	Low Heating, Low Cooling	Rotorua New Plymouth Manawatu ***Wellington** West Coast
2A	High Heating, Mild Cooling	***Christchurch** Queenstown Lauder
2B	High Heating, Low Cooling	***Dunedin** Southland

* Representative city based on highest population.

4.4.1 Building Typology Performances

Heating energy performance for each building typology and 18 weather file locations are shown in Table 10. This illustrates there is visually indicative grouping of locations based on performance thresholds.

Table 11 illustrates the energy consumption of heating and cooling combined for each building typology and location. Both tables represent the annual average heating and cooling energy per square meter of conditioned floor area.

Healthcare and Large Residential buildings are observed to have higher heating energy requirements than the other building types which is a result of longer operating hours of the modelled HVAC system. Through using the average performance indicator value to group the weather file locations, specific building typology impacts are less influential for the climate zone it represents.

As an average across the five typologies, there are generally clear energy performance threshold for grouping climate zones.

Table 10. Heating Zone Groupings.

Location	Office	Retail	Healthcare	School	Large Residential	Average	
Northland-Kaitaia	7	10	45	6	27	19	
Auckland-Auckland	8	10	48	8	30	21	
Bay.of.Plenty-Tauranga	8	12	52	10	30	22	
East.Coast-Napier	11	16	66	14	42	30	
Waikato-Hamilton	12	16	73	15	45	32	
Taupo.King.Country-Turangi	19	22	96	21	69	45	
Nelson.Marlborough-Nelson	15	20	77	18	49	36	
Wairarapa-Masterton	19	22	95	22	67	45	
Rotorua-Rotorua	15	19	95	17	56	40	
West.Coast-Hokitika	22	25	97	24	70	48	
Taranaki-New.Plymouth	10	14	59	11	36	26	
Manawatu-Paraparaumu	14	18	69	16	48	33	
Wellington-Wellington	17	19	69	19	53	35	<50, Low Heating↑
Canterbury-Christchurch	26	29	108	31	79	55	>50, High Heating↓
Queenstown.Lakes-Queenstown	33	35	139	37	94	68	
Central.Otago-Lauder	36	37	139	40	105	71	
Otago-Dunedin	27	29	104	30	83	55	
Southland-Invercargill	34	35	108	38	98	63	

Table 11. Heating + Cooling Zone Groupings.

Zone	Location	Office	Retail	Healthcare	School	Large Residential	Average	Divisions
Heating Zone 1 Low Heating	Northland-Kaitaia	53	67	120	36	50	65	60 - 70
	Auckland-Auckland	51	60	115	33	51	62	
	Bay.of.Plenty-Tauranga	54	66	126	37	53	67	
	East.Coast-Napier	52	64	133	43	63	71	>=70
	Waikato-Hamilton	53	67	137	39	66	72	
	Taupo.King.Country-Turangi	47	59	142	38	86	74	
	Nelson.Marlborough-Nelson	49	65	134	37	69	71	
	Wairarapa-Masterton	57	71	158	53	90	86	
	Rotorua-Rotorua	35	45	131	24	65	60	<=60
	West.Coast-Hokitika	31	39	114	27	74	57	
	Taranaki-New.Plymouth	35	49	103	22	50	52	
	Manawatu-Paraparaumu	28	36	96	20	52	47	
	Wellington-Wellington	29	35	93	25	57	48	
Heating Zone 2, High Heating	Canterbury-Christchurch	50	61	151	52	97	82	>=70
	Queenstown.Lakes-Queenstown	51	59	170	50	106	87	
	Central.Otago-Lauder	60	69	180	59	122	98	
	Otago-Dunedin	32	37	114	34	85	61	<70
	Southland-Invercargill	39	41	117	40	100	67	

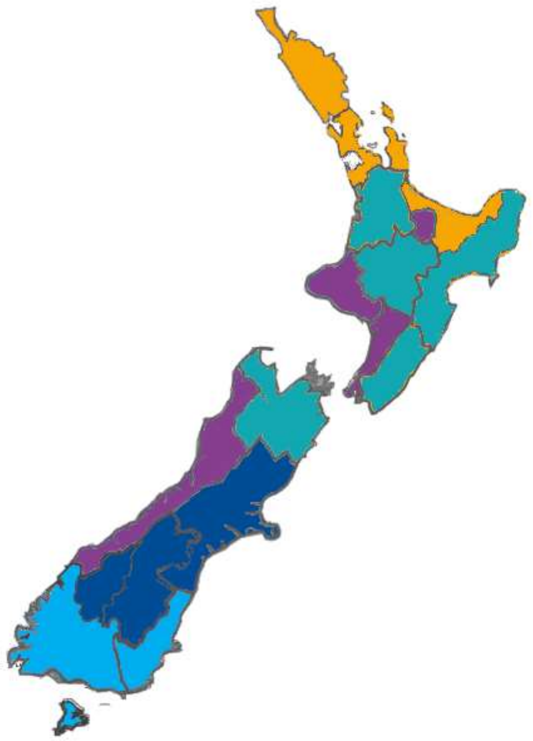


Figure 10. Baseline Insulation Climate Zones (Proposed).

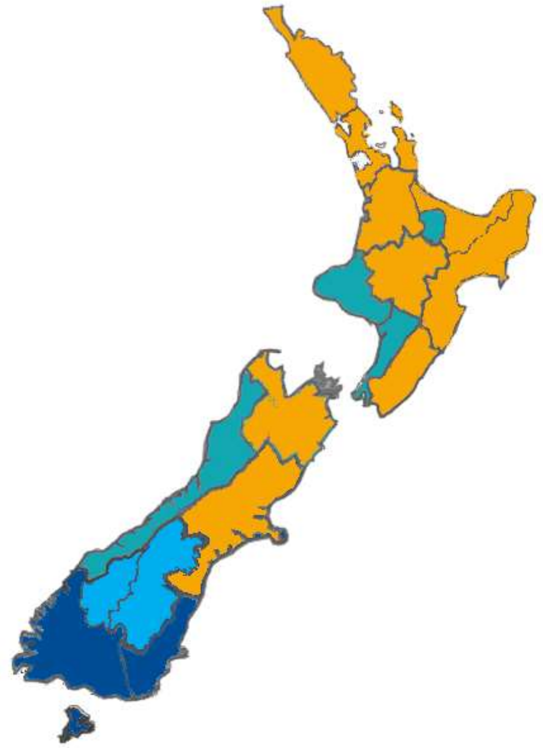


Figure 11. Enhanced Insulation Climate Zones.

4.4.2 Influence of Insulation

Generally, the thermal energy performance using the “enhanced insulation” experiences less variation between climate zones. This is because the heating and cooling energy consumption is less influenced by the external environment. The outcome of enhancing the insulation is that fewer climate zones are required to provide a description of the thermal demand outcomes. Refer to Figure 11 for the visual representation of climate zones.

The modelling results indicate the enhanced insulation impacts the heating energy greater than the cooling energy consumption. As a result, using the same grouping parameter thresholds as noted in Table 8, the grouped locations change across the whole of New Zealand.

Overall, it was recommended that the baseline insulation values are used to determine climate zoning. This results in a greater number of zones, which are aligned to current minimum performance values. This approach reduces the risk that climate zoning will influence the insulation improvement recommendations.

4.4.3 Residential and Small Buildings Comparison

For comparative purposes, the climate zones proposed within this study have been compared against the zoning identified as part of the residential and small buildings study undertaken by BRANZ. We note the assessment methodology and criteria is different between the two studies. BRANZ climate zones are illustrated in Figure 12.

Referring to Figure 10 through Figure 12; there are similarities with the South Island. The North Island has more variation between the two studies, with large buildings demonstrating a more consistent grouping of adjacent weather file zones. In comparison, the residential and small building zoning proposed has climate zones which are spread across the North Island (i.e. west coast and east coast of the North Island being the same proposed climate zone).

4.5 MBIE Feedback and Request of Climate Zones

Following presentation of the results and data provided, MBIE has undertaken their own analysis and requested an alternative grouping of climate zones. Their independent analysis identified that there are reasonable clusters of results, particularly with heating, which can group the energy outcomes to align with the parallel study undertaken by BRANZ for small and residential buildings. This provides a consistent set of climate zones for both residential and non-residential buildings.

Six (6) climate zones have been requested to be used which covers the regions as illustrated in Figure 12. The representative weather files selected to use within the energy modelling for analytical purposes are:

- Auckland
- Napier
- Turangi
- Wellington
- Christchurch
- Queenstown

These six weather file locations are used for the parametric modelling and cost benefit analysis.

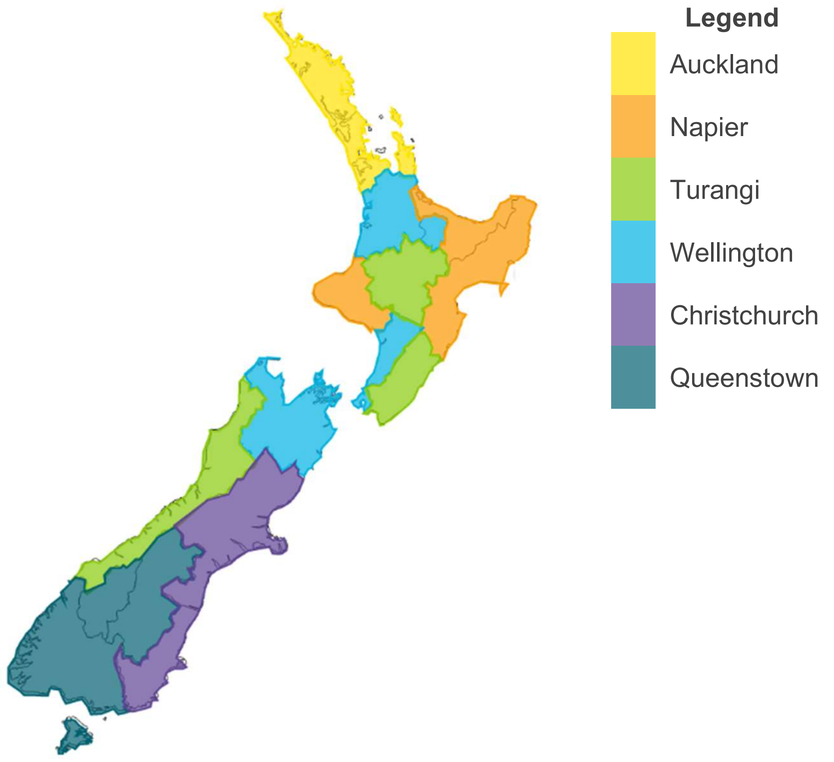


Figure 12. Proposed Residential and Small Building Climate Zones (BRANZ).

Validation of Climate Zones

The final energy consumption analysis shows that non-residential buildings are less sensitive to climatic variations.

Aligning climate zones with the BRANZ study does not materially impact on the findings of this project.

5 Cost Benefit Analysis

The primary cost indicator used for the financial cost benefit analysis is the Net Present Value (NPV) and Benefit Cost Ratio (BCR).

NPV is the difference between the present value of cash inflows and the present value of cash outflows over a period of time. It is commonly used as an indicator for determining financial returns of an investment; in this case, the financial benefits of increasing R-values in comparison to the reduction of energy consumption.

Equation 1. Net Present Value

$$NPV = \sum_{t=1}^{n} \frac{R_t}{(1+i)^t}$$

Where:

$R_t = Net\ cash\ inflow - outflow\ during\ a\ single\ period, t$

$i\ = Discount\ rate\ or\ return\ that\ could\ be\ earned\ in\ alternative\ investments$

$t = number\ of\ time\ periods$

BCR is an indicator showing the relationship between the relative costs and benefits. If a project has a BCR greater than 1.0, the project is expected to be deliver a positive financial return.

As this study is comparing against minimum insulation level cost performance, all insulation improvements were treated as individual investment opportunities with related NPV outcomes.

5.1 Architectural Inputs

Architectural drawings have been developed to illustrate how the different whole element R-values can be achieved through the construction build-ups. The construction build-ups generally use NZS 4214 as the calculation method and account for thermal bridge elements within the build-ups. We note there are limitations with this calculation method as it only accounts for a one-dimensional linear heat transfer; therefore only accounts for heat losses at the junctions (such as where a wall and roof connect) based on face area of junction details associated with each element. NZS 4214 is used as it is a referenced within H1 AS/1 calculation method to demonstrate Building Code compliance.

We note there is almost a limitless possible combination of construction materials to achieve elemental R-values; this project has selected common build-ups that are used with large buildings. There are also construction methodologies which could also be more economical such as prefabricated solutions, however these are currently not mature or common within the NZ construction industry – this assumption has been subjected to sensitivity analysis.

Refer to *Appendix C: Architectural Details* for the architectural drawings developed.

5.2 Cost Benefit Inputs

The following documents the input parameters that have been used to calculate the cost benefit analysis.

5.2.1 Financial Rates

The following financial rates have been used within the Cost Benefit Analysis:

- **Discount Rate: 5%**[5]
  Current rate noted by NZ Treasury for public projects specific to office and accommodation buildings, September 2020.
- **Energy Escalation: 3%**[6]
  An annual escalation rate for energy costs, excluding the cost of inflation. Based on 20-year historic figures.

  We note this does not account for any non-linear future escalations that may happen as a result of carbon associated fuel taxes, uncertainty around Tiwai Point aluminium smelter, or investment and utilisation on the inter-island HVDC for example.

5.2.2 Assessment Period

A 50-year assessment period has been selected for this analysis.

This period was selected as it aligns with the minimum structural durability requirements of the Building Code and therefore expected minimum lifespan of new buildings.

No central plant replacement or maintenance costs have been provided within the analysis period. We note central heating and cooling system have a typically lifespan of up to 30 years before needing replacement.

5.2.3 Construction Cost Premiums

Costs have been developed based on the architectural drawings, refer Section 5.1. These were developed using common materials for large building types and may not represent the lowest cost options available; therefore cost premiums have been used to reduce the influence particular products (i.e. cladding) have on the overall capital cost.

Cost premiums in this context are defined as the increase of cost above the baseline cost; where the baseline cost is the cost to achieve current Building Code minimum performance R-values. By using cost premiums, this removes the costs associated with the likes of wall linings and cladding systems which are consistent between options and therefore the financial analysis only relates to the differences in insulation and associated wall thicknesses.

Initial construction capital costs only are used within this assessment, no allowance is provided for on-going maintenance, cleaning, or replacement costs over the 50-year cost assessment period. The capital costs do not account for any co-cost reductions such as reduced capacity of HVAC plant equipment. This has been excluded as there is not a direct relationship between insulation performance and HVAC equipment costs, which is subject to a wide variety of costing variables such as system types, outdoor air rates, building geometry, sizing margins etc.

The cost premiums are illustrated in Table 12 through to Table 15. Each table value is the cost per elemental area ($/m²) compared to current minimum thermal performance requirements. For example, to increase a heavy weight roof R-value from 1.9 to 3.0, this will cost an additional $14 per square meter of roof area.

Table 12. Floor Cost Premiums

Floor R-value	Cost Premium
1.9	$0
2.0	+ $1
2.2	+ $2
2.8	+ $9
5.5	+ $28
2.9	+ $11
5.6	+ $29
3.1	+ $12
5.7	+ $30

Table 13. Roof Cost Premiums

Roof R-value	Cost Premium	
	Light Weight	Heavy Weight
1.9	$0	$0
3.0	+ $24	+ $14
3.5	+ $26	+ $14
4.0	+ $27	+ $14
5.0	+ $126	+ $29
6.0	+ $176	+ $44
7.0	+ $227	+ $54

Table 14. Window Cost Premiums

Window Values	Cost Premium
U5.80 / SHGC0.84	$0
U5.80 / SHGC0.60	+ $63
U4.76 / SHGC0.71	+ $259
U3.85 / SHGC0.74	+ $100
U3.85 / SHGC0.50	+ $163
U3.23 / SHGC0.69	+ $229
U3.23 / SHGC0.50	+ $299
U2.56 / SHGC0.69	+ $342
U2.56 / SHGC0.45	+ $470
U1.61 / SHGC0.60	+ $641
U1.61 / SHGC0.40	+ $913

[5] The Treasury, NZ Discount Rates: https://www.treasury.govt.nz/information-and-services/state-sector-leadership/guidance/financial-reporting-policies-and-guidance/discount-rates.
[6] MBIE, Energy Statistics, Prices spreadsheet: https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/energy-prices/

Table 15. Wall Cost Premiums

Wall R-Value	Cost Premium per Elemental Area Compared to Current Minimum Requirements			
	Climate Zone 1		Climate Zone 2&3	
	Light Weight	Heavy Weight	Light Weight	Heavy Weight
0.3	$0	$0	-	-
1.2	+ $10	+ $10	$0	$0
1.5	+ $15	+ $20	+ $5	+ $10
2.0	+ $45	+ $25	+ $35	+ $15
2.5	+ $53	+ $30	+ $43	+ $20
3.0	+ $96	+ $65	+ $86	+ $55
4.0	+ $119	+ $138	+ $110	+ $129
5.0	+ $127	+ $128	+ $117	+ $118

5.2.4 Capital Costs - Regional Cost Factors

Identical capital cost rates have been assigned to all geographic locations in the assessment. The rates used are based on typical values for Auckland and Christchurch. Auckland and Christchurch have similar rates and are noted to be the highest rates experienced within New Zealand.

It is acknowledged that there are cost differences across the country per region, Table 16 indicates the regional cost factors in relation to the Auckland / Christchurch rates.

Table 16. Regional Cost Differences

Region	Analysis Climate Zone	Construction Cost Rates Differences	Comment
Northland / Auckland	Auckland	0.0%	CBA values
Central North Island	Turangi & Napier	-2.0%	
Lower North Island	Wellington	-8.0%	
Upper South Island	Nelson	-1.0%	Location not used within modelling assessment
Mid South Island	Christchurch	0.0%	CBA values
Lower South Island	Queenstown	-2.0%	
Negative values represent less expensive construction material rates.			

5.2.5 Operational Costs and System Efficiencies

The values provided within Table 17 document the inputs that have been used to calculate the financial outcomes.

Generally, the system efficiencies and operational costs have been selected based on typical systems that are understood to be within each building typology. Operational costs are building and customer specific values, therefore to provide a reasonable value, this is based on prior experience with the building typologies and fuel type (electric or gas).

As these input parameters can vary for each typology, sensitivity analysis on the inputs was also tested; refer to Section 0.

Table 17. Operational Cost Benefit Inputs

Building Typology	Cooling System			Heating System		
	Efficiency	Operational Cost $/kWh	Description	Efficiency	Operational Cost $/kWh	Description
Office	210%	0.15	Air-Cooled Chiller	83%	0.06	Gas fuelled boiler
Retail	230%	0.19	Roof package units, DX system	230%	0.19	Roof package units, DX system
Healthcare	350%	0.12	Water-cooled chiller with Cooling Towers	83%	0.04	Gas fuelled boiler
School	210%	0.19	Air-Cooled Chiller	83%	0.08	Gas fuelled boiler
Large Residential	250%	0.25	Heat pump, DX split system	150%	0.25	Combination allowance of heat pump DX split system and Direct electric resistance heaters

Note: All system efficiencies provide allowances for air (fan) & water (pump) distribution related energy as well as system distribution losses.
All cooling systems are electric energy source systems.

Whilst there is a trend towards more efficient and low carbon heating sources (e.g. heat pumps) this study assumes current efficiency levels are maintained. This will increase the financial performance of proposed insulation improvements as energy costs will be higher for inefficient heating sources and care should be taken when interpreting results.

5.3 Cost Sensitivity Analysis

To understand the relationship between input variables and the conclusions drawn from the outputs, sensitivity analysis using key input variables has been undertaken. This adjusts key input variables and identifies how much the results change (either positively or negatively). This process provides a greater level of confidence with the conclusions that are drawn from the financial analysis.

The following key input variables have been used in the sensitivity analysis:

- Capital Costs ($/m²): 30% reduction in capital costs.
- Energy Rates ($/kWh): 50% increase in operational costs at year 0.
- Energy Escalation Rate (%): 6% year-on-year increase of energy costs.

These scenarios should results in a more favourable financial outcome for increased insulation levels and are used to understand the extent of change in context that would need to occur to materially impact on findings.

5.4 Operational Carbon Emissions

As part of the cost benefit analysis, carbon emissions have also been noted as a consideration. We note carbon costs associated with the Emissions Trading Scheme (ETS) are built into the energy rates (Table 17).

There are currently no regulated carbon emissions targets for buildings and the scope of this analysis does not include for recommendations relating to carbon emissions. However, carbon emission reductions have been presented as they illustrate the importance of reducing heating energy and demands through enhanced insulation values.

The following emission rates (*Ministry for Environment 2019 Summary of Emissions Factors*) are used for assessment purposes:

- Electricity: 0.105 kg/kWh.CO_2-e
- Gas: 0.218 kg/kWh.CO_2-e

6 Results

The following provides a summary of the key outcomes and trends that have been observed within the analysis. The results are presented for each building typology. Each thermal envelope enhancement that results in a financially beneficial outcome is highlighted. Financially beneficial outcomes are assessed through Benefit to Cost Ratio (BCR) and Net present Value (NPV).

Refer to *Appendix D: Financial Analysis* for a full breakdown of results.

6.1 Analytical Dashboard

A dashboard has been developed to process the large volumes of data and undertake the sensitivity analysis. Refer to Appendix D: Financial Analysis for an image of the dashboard and how it can be used to filter and calculate the results.

The following sections are snapshots of the outcomes that have been observed through the analysis.

6.2 Healthcare

Healthcare buildings have been modelled to operate 24/7, as such they result in the greatest energy consumption compared to the other building types. This aligns with what would be anticipated for healthcare buildings.

Heating energy has a range of 15-110 kWh/m².yr; while cooling is 3-14 kWh/m².yr. Figure 13 illustrates the differences in energy as a result of the difference thermal envelope R-values.

When wall R-values are R-2.5 or greater and floors R-2.9 or greater, the lower range values for cooling increases; the average values remain relatively stable at ~10 kWh/m².yr across all R-values.

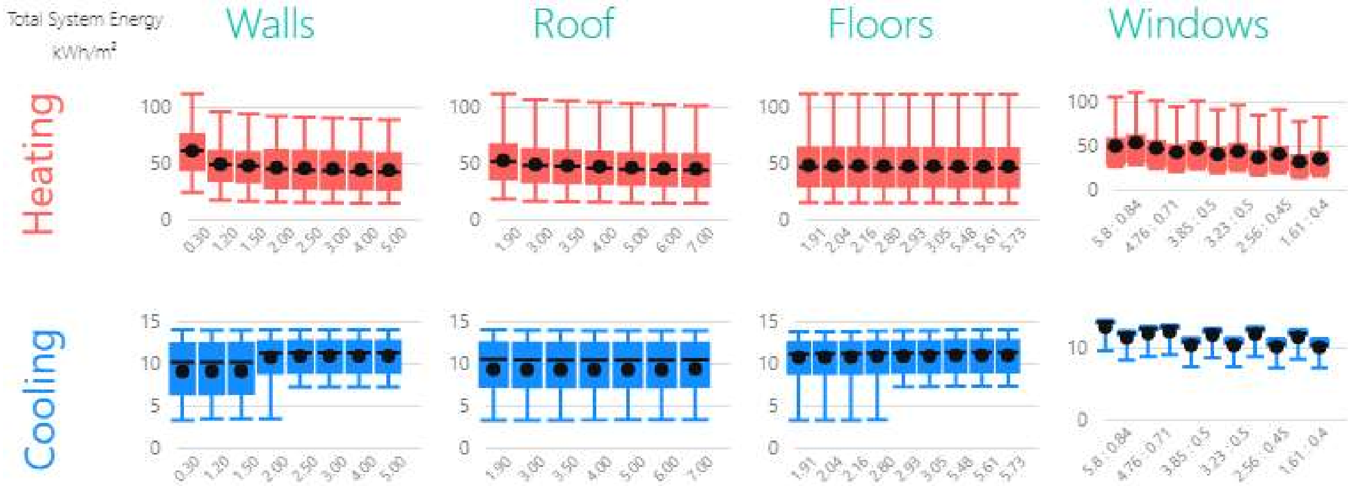


Figure 13. Healthcare, Heating and Cooling Energy Performance Index per Construction Element (all climate locations).

Healthcare facilities are observed to have a financial benefit through minor insulation increases in comparison to the current baseline insultation values.

Only wall enhancements are observed to provide financial benefits to this building typology.

The following table identifies the "financially preferrable" insulation performance enhancements. This being the enhancements which deliver the most positive financial return.

Table 18. Healthcare, Financially Preferable Enhancements.

Location	Wall	Roof	Floor	Window U-value / SHGC	EnPI kWh/m²	Operational Emissions Reduction kg.CO_2-e/m²	EnPI & Emissions Improvement Compared to Baseline	BCR	$NPV/m²
AUK	1.2	1.9	1.91	5.8 / 0.84	49	1.69	14% / 16%*	3.93	$7
NAP	1.5	1.9	1.91	5.8 / 0.84	73	0.24	1% / 2%	1.14	$0
TUR	1.5	1.9	1.91	5.8 / 0.84	98	0.35	2% / 2%	1.62	$1
WGN	1.5	1.9	1.91	5.8 / 0.84	69	0.31	2% / 2%	1.3	$0
CHC	1.5	1.9	1.91	5.8 / 0.84	120	0.39	1% / 2%	1.85	$1
QT	1.5	1.9	1.91	5.8 / 0.84	129	0.46	2% / 2%	2.1	$1

Highlighted values are greater than current minimum requirements.
*Emission reductions are greater than EnPI reductions due to the gas heating source reductions.
$NPV/m² values of $0 have been rounded to nearest whole dollar per m²

6.3 Large Multi-residential

The heating and cooling energy performance index is illustrated within Figure 14. Depending on climate, heating energy range is 0-25 kWh/m².yr; while the cooling range is 1-9 kWh/m².yr.

Generally, it is shown that walls and windows have the greatest influence on the energy performance. As wall R-values exceed R-2.0, there are diminishing heating energy reductions.

Cooling energy is less influence by construction R-values; when walls and floors exceed R-2.0 and R-2.9 Respectively, it is observed to have less spread (range between high to low results), however the mean of the results remain relatively stable.

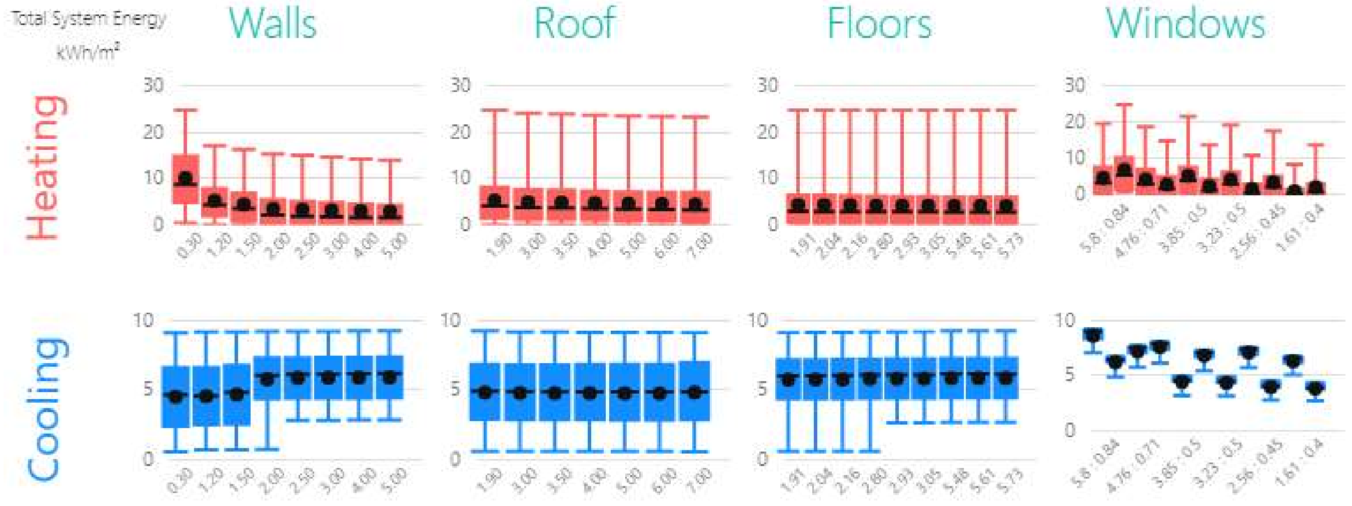


Figure 14. Large Residential, Heating and Cooling Energy Performance Index per Construction Element (all climate locations).

Large multi-residential buildings have been observed to have financial benefits through enhanced wall insulation, for the majority of climate locations.

In climates Turangi, Christchurch, and Queenstown there are also financial benefits to enhancing the roof and windows in addition to the wall enhancements. Although windows have the highest cost premiums associated, double glazing within standard aluminium joinery is observed to provide a financial return through energy reductions.

There are further thermal envelope enhancements that have been observed to still provide a financial benefit, albeit at a lower NPV rate. For example, increasing Auckland walls to R-2.0 and roof to R-3.5 results in an NPV/m² of $10 (less than the best return of $24 but still positive and delivering higher energy efficiency).

Table 19. Large Multi-residential, Financially Preferable Enhancements.

Location	Wall	Roof	Floor	Window U-value / SHGC	EnPI kWh/m²	Operational Emissions Reduction kg.CO_2-e/m²	EnPI & Emissions Improvement Compared to Baseline	BCR	$NPV/m²
AUK	1.5	1.9	1.91	5.8 / 0.84	9.7	0.40	28%	5.5	$24
NAP	1.5	1.9	1.91	5.8 / 0.84	13.6	0.36	20%	14.9	$25
TUR	1.5	4.0	1.91	3.85 / 0.74	18.1	0.17	34%	1.2	$7
WGN	1.5	1.9	1.91	5.8 / 0.84	10.9	0.05	4%	2.0	$2
CHC	1.5	4.0	1.91	3.85 / 0.74	22.3	0.20	31%	1.3	$14
QT	1.5	4.0	1.91	3.85 / 0.74	24	0.25	35%	1.6	$27

Highlighted values are greater than current minimum requirements.

As per the scope of this study the improvements are based on comparison to the requirements of NZS4243 and do not reflect improvements above existing residential building standards which are subject to a parallel study.

It should be noted that the analysis methodology identifies the most financially favourable combinations for wall, floor, roof and glazing thermal performance. In large residential buildings the impacts of these trade-offs may be disproportionally applied to individual residences. For example, improving wall and glazing insulation levels at the expense of roof insulation levels will deliver whole building performance improvements, but expose top floor apartments (with roof) to greater levels of heat loss. This affect is apparent in all building types, but only in residential buildings is the ownership of benefits unfairly distributed. The application of building insulation performance standards in situations where the scope of Building Consent compliance and Ownership Titles are different should be considered by MBIE.

6.4 Office

Office building heating and cooling energy consumption is observed to have relatively low sensitivity to external environment. Depending on climate location and insulation performance, heating energy range is 5-35 kWh/m².yr; while the cooling range is 2-18 kWh/m².yr.

Thermal envelope enhancements for walls has illustrated a reduction in heating energy consumption as an average throughout all climate locations. The mean values are shown to have diminishing heating reductions when R-values exceed R-2.0. It is noted that there are adverse effects of overheating when the wall R-values are greater than R-2.0.

Energy performances as a result of different windows are primarily driven by the solar heat gain coefficient of the glazing, not the overall thermal R-value.

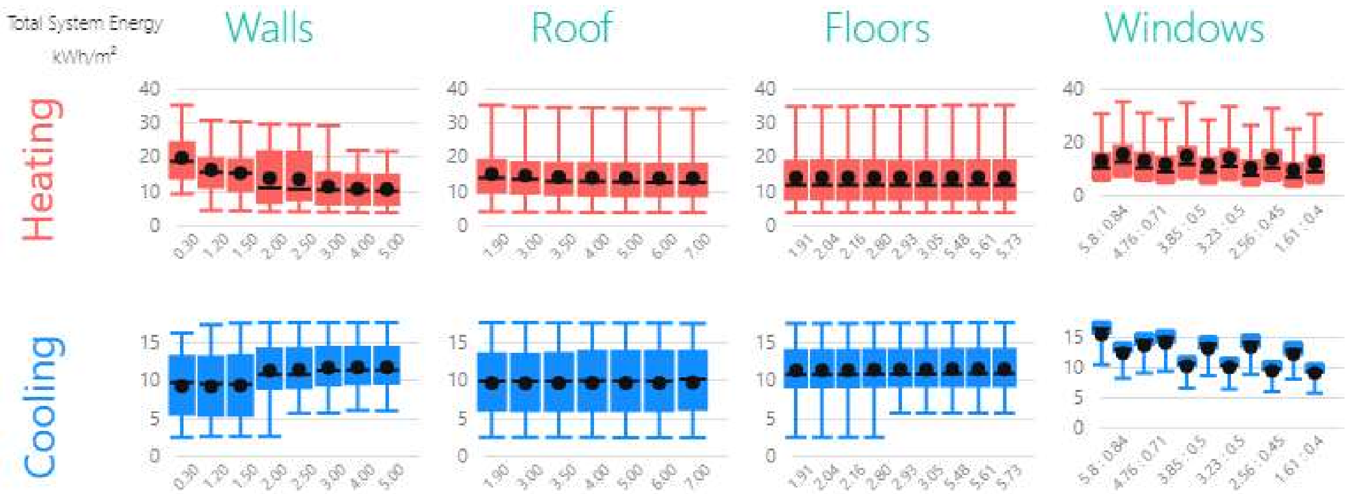


Figure 15. Office, Heating and Cooling Energy Performance Index per Construction Element (all climate locations).

There have been no financially preferable insulation enhancements identified with office buildings.

6.5 School

Schools heating energy has a range of 8-25 kWh/m².yr; while the cooling energy is 2-15 kWh/m².yr.

There is a step change in the mean energy consumption observed when wall R-values exceed R-1.5; heating energy reduces, however cooling energy increases. Window enhancements can reduce cooling energy as a result of a lower SHGC and Low-e coating; mean heating energy remains relatively stable with all window permutations.

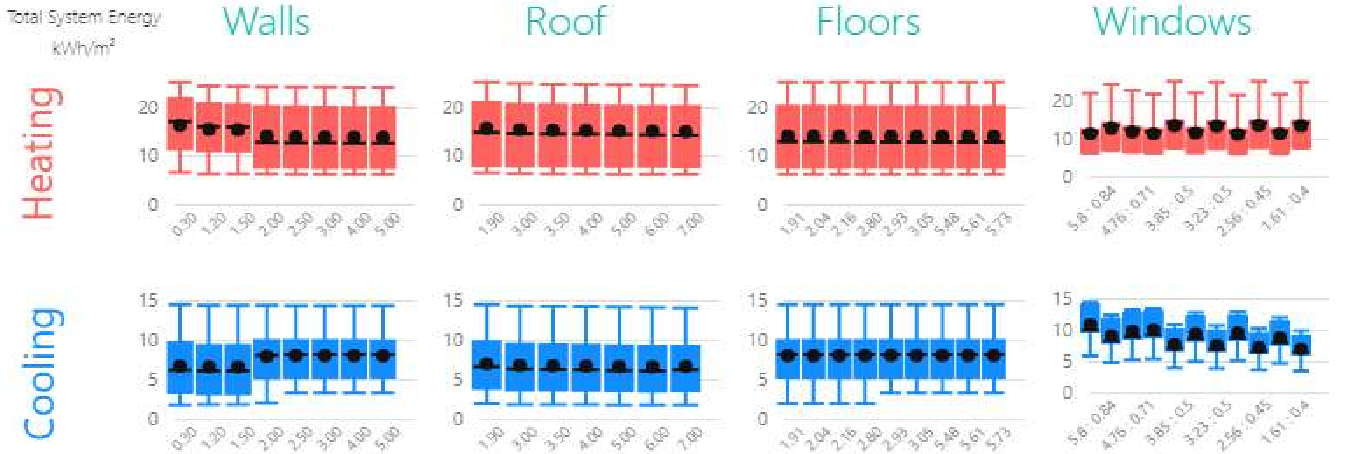


Figure 16. School, Heating and Cooling Energy Performance Index per Construction Element (all climate locations).

There are no enhanced thermal insulation values that are financially preferable.

6.6 Retail

Retail buildings are observed to have a heating energy consumption of 6-21 kWh/m².yr; while cooling is 4-17 kWh/m².yr depending on the thermal envelope performance values.

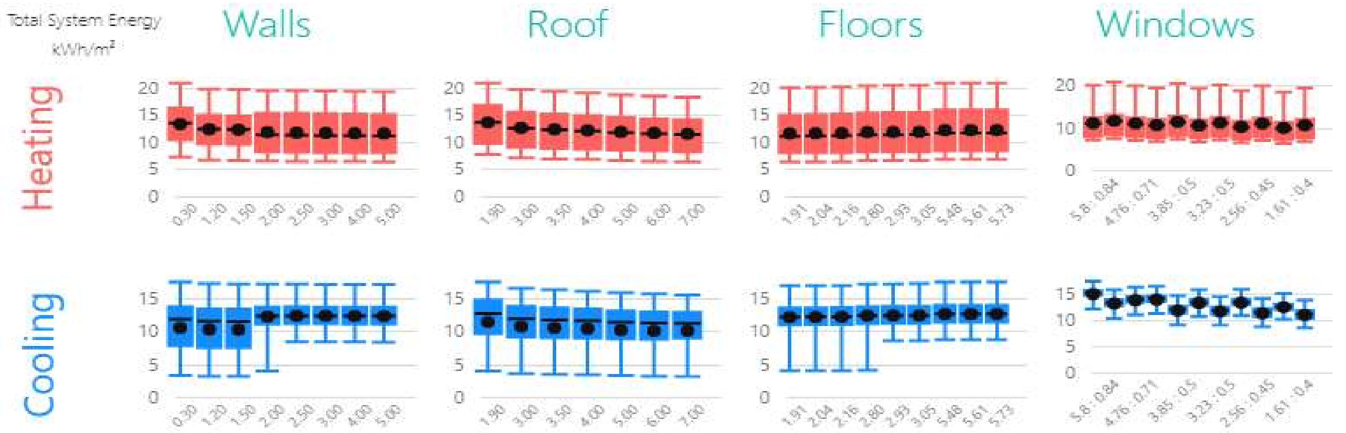


Figure 17. Retail, Heating and Cooling Energy Performance Index per Construction Element (all climate locations).

Retail facilities are observed to have a financial benefit through minor insulation increases in comparison to the current baseline insultation values.

Only wall enhancements are observed to provide financial benefits to this building typology.

The following table identifies the "financially preferrable" insulation performance enhancements. This being the enhancements which deliver the most positive financial return.

Location	Wall	Roof	Floor	Window U-value / SHGC	EnPI kWh/m²	Operational Emissions Reduction kg.CO2-e/m²	EnPI & Emissions Improvement Compared to Baseline	BCR	$NPV/m²
AUK	1.2	1.9	1.91	5.8 / 0.84	26	0.09	3%	2.8	$3
CHC	1.5	1.9	1.91	5.8 / 0.84	34	0.03	1%	1.1	$0
QT	1.5	1.9	1.91	5.8 / 0.84	35	0.02	1%	1.2	$0

Highlighted values are greater than current minimum requirements
$NPV/m² values of $0 have been rounded to nearest whole dollar per m²

Intuitively the large extent of roof area of the modelled retail building should be a significant source of heat loss and an opportunity for reduced energy consumption and costs. However, the capital costs associated with upgrading a large roof are also significant. With a perspective of cost optimisation there is no preference for roof insulation increases.

6.7 Financially Favourable Options

Table 20 provides a combined summary of all financially favourable options.

Table 20. Summary of the Financially Favourable Options.

Building Typology	Location	Wall	Roof	Floor	Window U-value / SHGC	EnPI kWh/m²	Operational Emissions Reduction kg.CO2-e/m²	EnPI & Emissions Improvement Compared to Baseline	BCR	$NPV/m²
Healthcare	AUK	1.2	1.9	1.91	5.8 / 0.84	49	1.69	14% / 16%*	3.93	$7
	NAP	1.5	1.9	1.91	5.8 / 0.84	73	0.24	1% / 2%	1.14	$0
	TUR	1.5	1.9	1.91	5.8 / 0.84	98	0.35	2% / 2%	1.62	$1
	WGN	1.5	1.9	1.91	5.8 / 0.84	69	0.31	2% / 2%	1.3	$0
	CHC	1.5	1.9	1.91	5.8 / 0.84	120	0.39	1% / 2%	1.85	$1
	QT	1.5	1.9	1.91	5.8 / 0.84	129	0.46	2% / 2%	2.1	$1
Large Multi-residential	AUK	1.5	1.9	1.91	5.8 / 0.84	9.7	0.40	28%	5.5	$24
	NAP	1.5	1.9	1.91	5.8 / 0.84	13.6	0.36	20%	14.9	$25
	TUR	1.5	4.0	1.91	3.85 / 0.74	18.1	0.17	34%	1.2	$7
	WGN	1.5	1.9	1.91	5.8 / 0.84	10.9	0.05	4%	2.0	$2
	CHC	1.5	4.0	1.91	3.85 / 0.74	22.3	0.20	31%	1.3	$14
	QT	1.5	4.0	1.91	3.85 / 0.74	24	0.25	35%	1.6	$27
Retail	AUK	1.2	1.9	1.91	5.8 / 0.84	26	0.09	3%	2.8	$3
	CHC	1.5	1.9	1.91	5.8 / 0.84	34	0.03	1%	1.1	$0
	QT	1.5	1.9	1.91	5.8 / 0.84	35	0.02	1%	1.2	$0

Highlighted values are greater than current minimum requirements.
*Emission reductions are greater than EnPI reductions due to the gas heating source reductions.

6.8 Sensitivity Analysis

Sensitivity analysis has been undertaken to identify which input parameters may alter the financial outcomes, and therefore overall conclusions.

6.8.1 Capital Costs

High capital costs are one of the main reasons many of the insulation enhancements are not financially favourable.

Capital construction costs can vary significantly per contractor, per construction method, and per region; therefore reducing capital costs is expected to provide a more favourable financial outcome to the CBA.

As a benchmark value, a 30% reduction in capital cost has been explored within the sensitivity analysis. This value has been selected as it covers the regional differences of up to 8% (refer Section 5.2.4), as well as additional construction cost reductions of up to 22% which the construction industry may be able to achieve through the main contractor's ability to construct for less, or prefabrication vs. in situ construction methods.

The below examples in Table 21 and Table 22 indicates the additional financially favourable permutations that are achieved through reduced capital costs (shown as modelling iterations that drop below the cost optimal line). In summary, only the Auckland climate delivers additional financially favourable permutations, primarily with the wall R-values increasing up to R-2.5 and floors increasing to R-2.16.

Table 21. Retail Building, Capital Cost Sensitivity Analysis – Additional Favourable Construction Elements.

Locations	Wall	Floor	Roof	Window U-value / SHGC
AUK	1.2	2.04	-	5.80 / 0.60
	1.5	2.16		
	2.0			
	2.5			

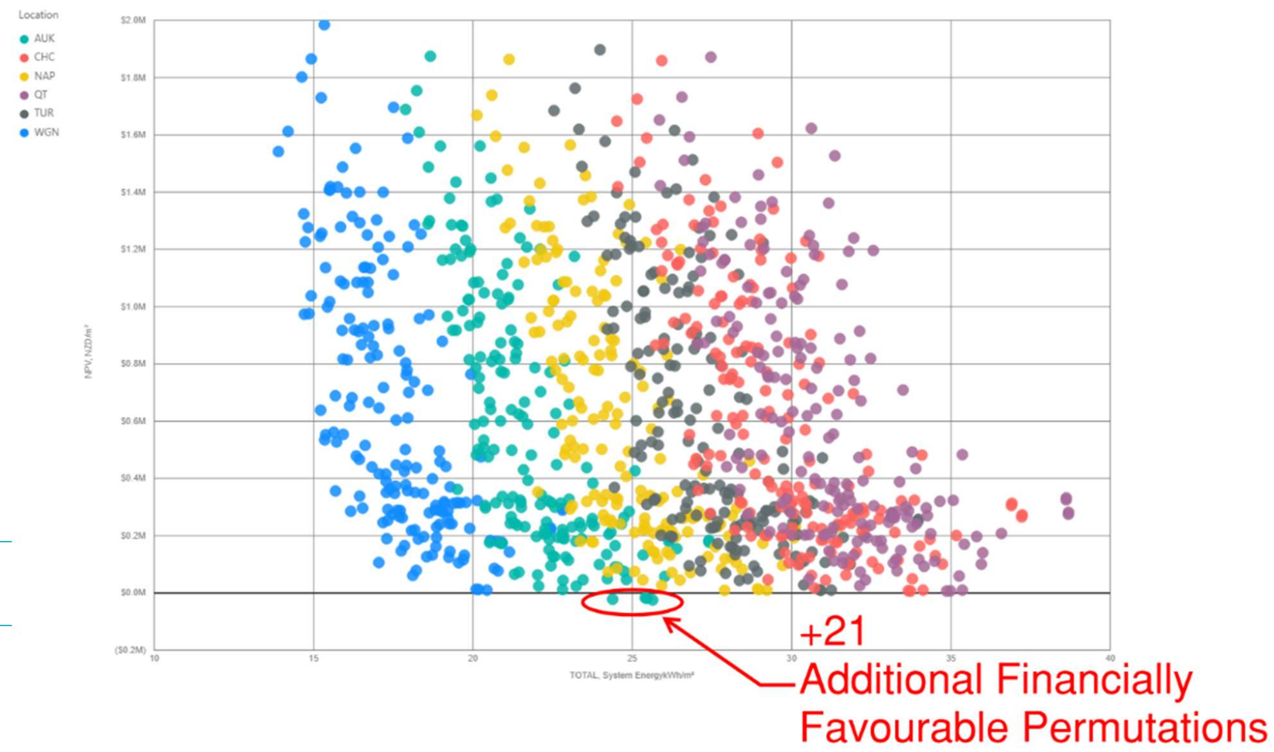
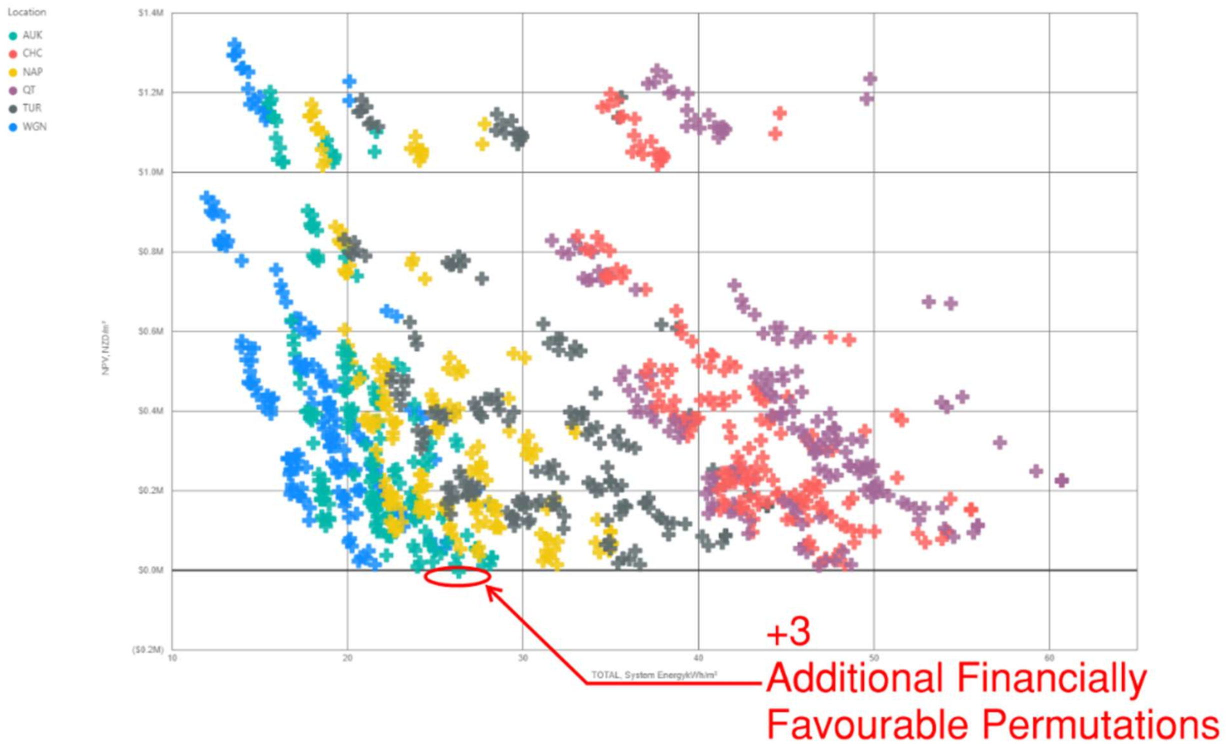


Table 22. Office Building, Capital Cost Sensitivity Analysis – Additional Favourable Construction Elements

Locations	Wall	Floor	Roof	Window U-value / SHGC
AUK	1.2	2.04	-	-
		2.16		



Generally, the overall outcome based on the sensitivity for these two building typologies has identified that the capital cost at 30% less than the cost estimates used within the analysis is favourable for enhanced wall and floor R-values within the Auckland climate.

Overall, this minor influence does not change the overall conclusions of this project.

6.8.2 Energy Cost Rates

Energy rates are specific to each building occupier; based on experience across multiple facility types it has been observed that the energy rates of small energy consumers (single office occupier) can be in the order of twice the price of large energy consumers with multiple buildings (i.e. a hospital or university).

Aligning with the range of energy cost rates observed, sensitivity analysis has tested a rate of twice the assessment values, noted as follows:

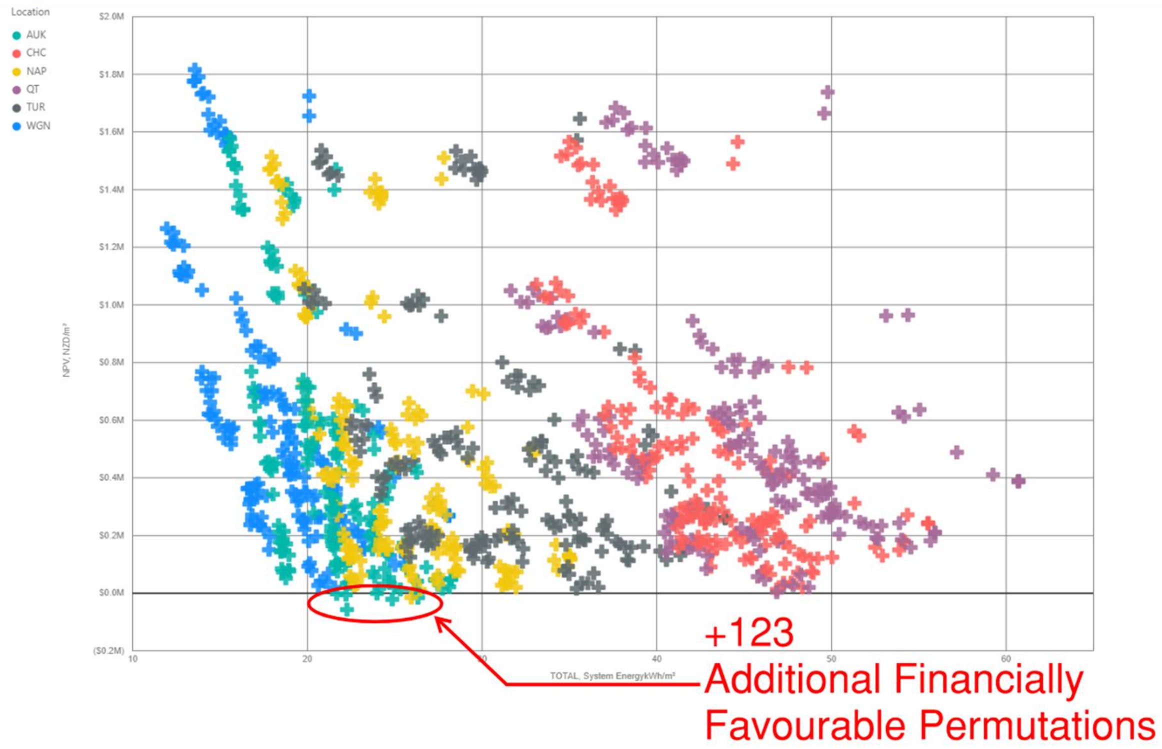
- Office: Cooling: $0.30/kWh (electric) and Heating: $0.12/kWh (gas)
- Retail: Cooling and Heating $0.38/kWh (both electric)

It has been observed that energy rates need to be in the order of twice the typical anticipated values for the conclusions and outcomes to change. As illustrated in Table 23 and Table 24, through increasing energy rates the financial benefit of energy savings becomes favourable for additional construction insulation R-values.

Office buildings are only influenced win the Auckland and Napier climate zones, with enhancements to all construction elements having financially favourable outcomes. This suggests the assumed gas heating energy sources are still too inexpensive to become favourable in the colder climates.

Table 23. Office Building, Energy Rates Sensitivity Analysis – Additional Financially Favourable Construction Elements

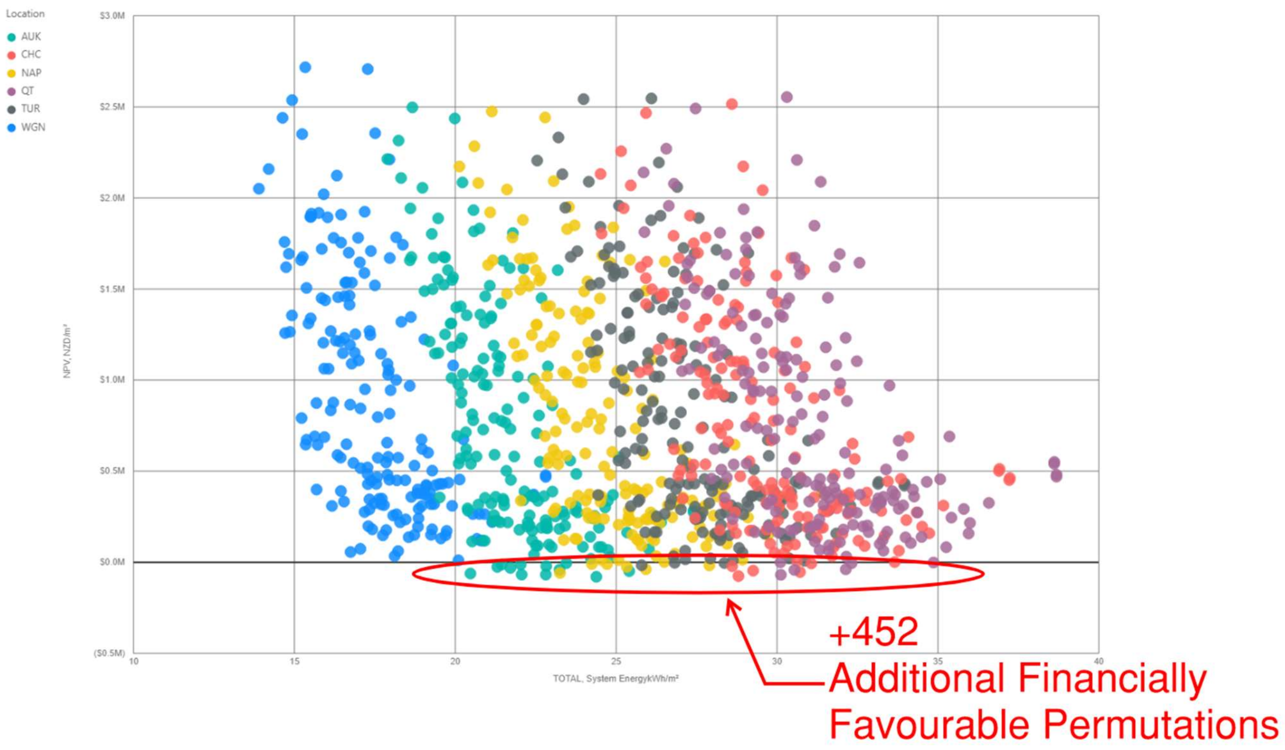
Locations	Wall	Floor	Roof	Window U-value / SHGC
AUK	1.2	2.04	3.0	5.80 / 0.60
NAP	1.5	2.16	3.5	3.85 / 0.50
	2.0	2.80	4.0	
	2.5	2.93	5.0	
		3.05	6.0	
		5.48	7.0	
		5.61		
		5.73		



Retail buildings with electric cooling and heating sources show favourable outcomes for enhanced construction R-values for all locations except for Wellington. Generally the walls, roof, and windows are observed to provide the most favourable outcomes.

Table 24. Retail Building, Energy Rates Sensitivity Analysis – Additional Financially Favourable Construction Elements

Locations	Wall	Floor	Roof	Window U-value / SHGC
AUK	1.5	2.04	3.0	5.80 / 0.60
NAP	2.0	2.16	3.5	3.85 / 0.74
TUR	2.5		4.0	3.85 / 0.50
CHC	3.0			
QT				



<u>Overall, it is observed that energy rates need to be in the order of twice the current typical energy rates for additional financially favourable options to be identified and recommended.</u>

6.8.3 Energy Escalation Rates

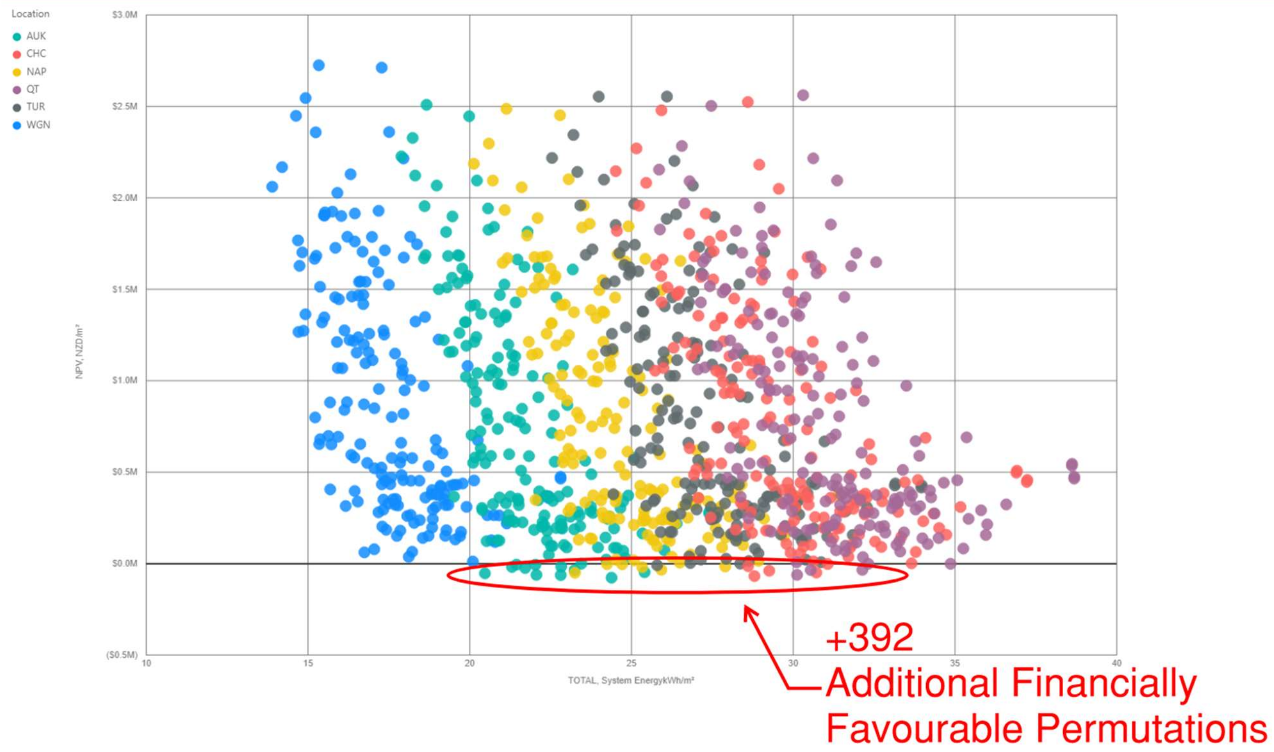
There are currently several unknowns with respect to how the future of energy prices will change. The price will be influenced through various scenarios and uncertainties including Tiwai Aluminium smelter shutdown, HVDC upgrades, and uptake of electrification (transition away from fossil fuel heating sources).

A rate of 6% (year on year increase) has been selected to represent a theoretical scenario of significant electrical infrastructure investment throughout New Zealand. This would equate to a doubling of energy rates every 12 years (i.e. 15c/kWh in 2020, 30c/kWh in 2032); an escalation rate which historically has not been observed.

The outcomes of a higher annual energy escalation rate indicates a greater number of construction elements which are financially favourable; an additional 392 modelled permutations for the retail building typology. The additional construction elements and locations are illustrated in Table 25.

<u>Table 25. Retail Building, Energy Escalation Sensitivity Analysis – Additional Financially Favourable Construction Elements</u>

Locations	Wall	Floor	Roof	Window U-value / SHGC
AUK	1.2	2.04	3.0	5.80 / 0.60
TUR	1.5	2.16	3.5	3.85 / 0.74
NAP	2.0		4.0	3.85 / 0.50
CHC	2.5			
QT	3.0			

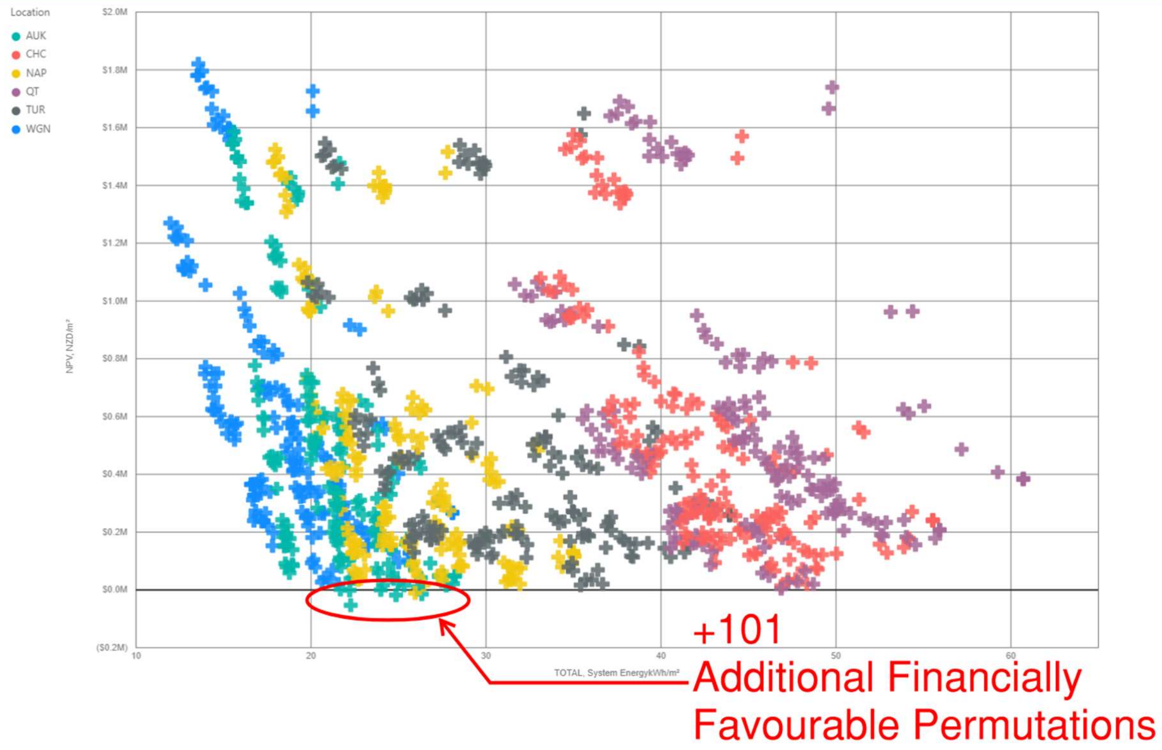


The initial analysis indicated that office buildings have no financially preferable insulation enhancements.

Table 26 illustrates that increasing annual energy escalation rates by twice the current predicted rates provides up to 101 more financially favourable insulation enhancements. This includes all thermal envelope elements except for windows, and only within the Auckland and Napier climates.

Table 26. Office Building, Energy Escalation Sensitivity Analysis – Additional Financially Favourable Construction Elements

Locations	Wall	Floor	Roof	Window U-value / SHGC
AUK	1.2	2.04	3.0	5.80 / 0.60
NAP	1.5	2.16	3.5	3.85 / 0.50
	2.0	2.80	4.0	
	2.5	2.93	5.0	
		3.05	6.0	
		5.61	7.0	



Overall, the results are indicating that energy escalation rates are influencing the financial benefits, however the arbitrary doubling of the annual energy escalation rate may not be realistic.

Further analysis should be undertaken by energy market experts (i.e. energy generators, energy retails, and the grid operator) to confirm in what scenarios would the energy escalation rates increase or decrease and to what extent they would change on an annual basis.

7 Outcomes and Conclusions

Generally, the cost of construction is significantly larger than associated energy costs, resulting in a limited number of financially beneficial increases to the current minimum R-values.

For healthcare buildings that operate 24 hours, there is financial benefit to increasing wall R-values as follows:

- Auckland: Walls R-1.2.
- Rest of the Country: Walls R-1.5.

Large multi-residential buildings (24-hour occupied) have been identified to have financial benefits as follows:

- Auckland, Napier and Wellington: Walls R-1.5.
- Turangi, Christchurch, and Queenstown: Walls R1.5, Roof R-4.0, Windows U-3.85.

Consideration should be given to how this aligns with the residential and small building requirements.

Retail buildings have only shown financial benefits as follows:

- Auckland: Walls R-1.2.
- Christchurch and Queenstown: Walls R-1.5.

Office and School buildings do not have favourable financial outcomes through increased R-values.

These buildings are highly ventilated and dominated by occupant loads. This significantly limits the impact that increased insulation levels have on the energy performance of the building. Alternative energy reduction strategies (i.e. heat recovery, HVAC efficiency etc) will likely yield better returns.

Sensitivity analysis has identified that:

- Construction costs would need to be >30% more cost effective (cheaper) to provide more financially favourable outcomes for increased minimum R-values.
- Energy costs would need to be in the order of twice the current estimates to provide more financially favourable outcomes for increased minimum R-values.
- Annual energy escalation rates would need to be ~6% or greater to provide more financially favourable outcomes for increased minimum R-values.

Overall, large buildings contribute to approximately 13% of all new buildings annually, based on issued building consent numbers. Large multi-residential buildings have the largest proportion of new builds for large scale buildings between 8% and 10%. Schools and office type buildings have a similar contribution to new builds at approximately 1% each.

7.1 Co-Benefits of Enhanced Insulation

This project has assessed the impacts of enhanced insulation through financial cost benefit analysis only. Although CBA is a reasonable metric to assess the financial outcomes, it does not account for non-financial or indirect financial benefits which are also positive outcomes.

The following are key co-benefits that have not been directly assessed within this project, however should be considered or explored further.

Key co-benefits of enhanced insulation are:

- **Reduced Operational Energy:** Predominantly with reduced heating required to maintain space temperature setpoints; however consideration needs to be given to how this may have adverse effects of increased cooling energy requirements.
- **Reduced Carbon Emissions:** As with the energy reductions, the associated carbon emissions can be significantly reduced through increased insulation.
- **Thermal Comfort:** Comfort of the building occupants will be improved through increased insulation, particular those that are next to the façade as it can reduce the radiant effects of heat transfer. Through increased insulation or alternative construction methods, the airtightness of the façade may also be improved, providing further thermal comfort benefits to occupants.
- **Health and wellbeing:** There have been may studies linking building occupant health and wellbeing to a building's performance; usually a low insulated building results in occupants having more sick and absentee days. Although often not an issue for large non-residential buildings as they typically operate with HVAC systems to maintain space temperatures within comfort levels.
- **Social:** Linked to the health and wellbeing of building occupants, the social benefits of enhanced insulation levels include occupants being able to work more productively, are generally happier / motivated, and are satisfied to occupy the building. There is also less strain on the public healthcare system as an indirect outcome.

7.2 Outcome Statements

The following 15 (no.) statements summarise the key results of the financially favourable outcomes:

1. For the Auckland climate zone, for healthcare buildings, increasing the R-values to R-1.2 (walls) will result in about an 0.1% increase in capital cost, but will result in $11,900 of net savings with 16% less operational emissions over the life of the building, with a benefit cost ratio of 3.93.
2. For the Napier climate zone, for healthcare buildings, increasing the R-values to R-1.5 (walls); will result in about an 0.1% increase in capital cost, but will result in $286 of net savings with 2% less operational emissions over the life of the building, with a benefit cost ratio of 1.14.
3. For the Turangi climate zone, for healthcare buildings, increasing the R-values to R-1.5 (walls), will result in about an 0.1% increase in capital cost, but will result in $1,266 of net savings with 2% less operational emissions over the life of the building, with a benefit cost ratio of 1.62.
4. For the Wellington climate zone, for healthcare buildings, increasing the R-values to R-1.5 (walls); will result in about an 0.1% increase in capital cost, but will result in $610 of net savings with 2% less operational emissions over the life of the building, with a benefit cost ratio of 1.3.
5. For the Christchurch climate zone, for healthcare buildings, increasing the R-values to R-1.5 (walls), will result in about an 0.1% increase in capital cost, but will result in $1,782 of net savings with 2% less operational emissions over the life of the building, with a benefit cost ratio of 1.85.
6. For the Queenstown climate zone, for healthcare buildings, increasing the R-values to R-1.5 (walls); R-4.0 (Roof), will result in about an 0.1% increase in capital cost, but will result in $2,236 of net savings with 2% less operational emissions over the life of the building, with a benefit cost ratio of 2.1.
7. For the Auckland climate zone, for Large multi-residential buildings, increasing the R-values to R-1.5 (walls) will result in about an 0.1% increase in capital cost, but will result in $54,457 of net savings with 28% less operational emissions over the life of the building, with a benefit cost ratio of 5.5.
8. For the Napier climate zone, for Large multi-residential buildings, increasing the R-values to R-1.5 (walls) will result in about an 0.1% increase in capital cost, but will result in $48,296 of net savings with 20% less operational emissions over the life of the building, with a benefit cost ratio of 5.0
9. For the Turangi climate zone, for Large multi-residential buildings, increasing the R-values to R-1.5 (walls); R-4.0 (Roof), U-3.85 / SHGC 0.74 (windows); will result in about an 1.4% increase in capital cost, but will result in $8,586 of net savings with 8% less operational emissions over the life of the building, with a benefit cost ratio of 1.7.
10. For the Wellington climate zone, for Large multi-residential buildings, increasing the R-values to R-1.5 (walls) will result in about an 0.1% increase in capital cost, but will result in $4,028 of net savings with 4% less operational emissions over the life of the building, with a benefit cost ratio of 2.0.
11. For the Christchurch climate zone, for Large multi-residential buildings, increasing the R-values to R-1.5 (walls); R-4.0 (Roof), U-3.85 / SHGC 0.74 (windows); will result in about an 1.4% increase in capital cost, but will result in $31,871 of net savings with 31% less operational emissions over the life of the building, with a benefit cost ratio of 1.3.
12. For the Queenstown climate zone, for Large multi-residential buildings, increasing the R-values to R-1.5 (walls); R-4.0 (Roof), U-3.85 / SHGC 0.74 (windows); will result in about an 1.4% increase in capital cost, but

will result in $62,158 of net savings with 35% less operational emissions over the life of the building, with a benefit cost ratio of 1.6.

13. For the Auckland climate zone, for retail buildings, increasing the R-values to R-1.2 (walls) will result in about an 0.1% increase in capital cost, but will result in $22,125 of net savings with 3% less operational emissions over the life of the building, with a benefit cost ratio of 2.8.
14. For the Christchurch climate zone, for retail buildings, increasing the R-values to R-1.5 (walls) will result in about an 0.1% increase in capital cost, but will result in $830 of net savings with 1% less operational emissions over the life of the building, with a benefit cost ratio of 1.1.
15. For the Christchurch climate zone, for retail buildings, increasing the R-values to R-1.5 (walls) will result in about an 0.1% increase in capital cost, but will result in $1,183 of net savings with 1% less operational emissions over the life of the building, with a benefit cost ratio of 1.2.

8 Supplementary Energy Efficiency Reporting

8.1 Energy Efficiency Benefits

The lack of significant financial justification for increasing insulation levels has resulted in MBIE pivoting their industry consultation away from financial benefit. A focus on the impacts (both positive and negative) from targeted energy efficiency improvements has been pursued.

The analysis methodology described in this report has enabled the supplementary reporting of energy and carbon benefits associated with each thermal performance improvement option analysed.

This shows that there are significant energy and carbon reductions available if sufficient capital investment is available. Whilst these differ across building typology and location, savings (in aggregate) in the order of 30% are theoretically feasible through insulation performance improvements.

It should be noted that the analysis undertaken is a simplified assessment of building energy performance consistent with the modelling protocols within the relevant NZ Standards. It is likely that the real-world energy performance of insulation improvements is less than this code compliance modelling results due to the realities of building construction and operation.

As a result of these findings, MBIE has provided a set of preferred insulation level options which reflect a gradual increase of performance across climate zones for further consultation.

This study has provided energy and carbon outcomes associated with these preferred outcomes to assist in consultation.

Any information included with public consultations should clearly define the scope of what has been tested and emphasise the assumptions, sensitives analyses, and limitations that have been used to arrive at the conclusions stated within this report.

8.2 Limitations and Recommendations for Future Work

The high whole of life costs associated with improving insulation levels highlights that other strategies for improving Building Code minimum energy performance settings are likely to yield more cost-effective energy efficiency improvements.

In particular, the following large building attributes should be considered:

- Solar aperture – which is a function of glazing areas, glazing shading performance and impacts of external shading devices. Whilst there are blunt tools in the current building code limiting the extent of glazing this could be significantly improved.
- Air tightness – highly dependent on location, but limits on infiltration and uncontrolled outdoor air intrusion would likely be effective
- HVAC Energy Efficiency
  - Plant equipment (currently only regulated by MEPS and not at building system level). Limits on delivery efficiency for fans, pumps, chillers, boilers etc would likely deliver benefits.
  - Ventilation heat recovery, volumes, fan energy consumption and controls – it is clear from the analysis undertaken to date that the extent of outdoor air provided to occupants in large buildings significantly reduces the benefits available through building thermal envelope improvements. Introducing controls on ventilation recovery would likely deliver better financial and energy efficiency returns.

Whilst these opportunities could be investigated independently, the ring fencing of energy efficiency opportunities into discrete studies is both time consuming and does not recognise the highly interdependent nature of building fabric, ventilation, and systems efficiency.

We would recommend MBIE undertake a more holistic study of energy efficiency improvements for large buildings by assessing the performance of typical buildings against established building code criteria from other jurisdictions.

A set of buildings could be analysed across climate zones utilising the performance standards from the National Construction Code (AU), Part L (UK) and ASHRAE 90.1 (USA).

A methodology could be constructed that highlighted the most cost-effective strategies to deliver energy and carbon reductions in line with Building for Climate Change updates.

It would have the supplementary benefit of harmonising building codes against other jurisdictions. This would potentially improve the cost effectiveness of compliance (due to a widening of suitably qualified practitioners).

Regardless of methodology applied, we would highly recommend that energy efficiency improvements available from changes in building systems and glazing solar performance are investigated prior to implementing significant uplifts to insulation performance (noting that some interim step changes may be appropriate to building momentum).

A

Appendix A: Abbreviations, Acronyms, and Shorthand References

Abbreviations, Acronyms, and Shorthand References

The following is a list of abbreviations, acronyms, and shorthand refences that have been used throughout this report, including a brief description (ordered alphabetically):

Item	Description
AS1	Acceptable Solution Method of compliance with the New Zealand Building Code
BEM	Building Energy Model
BESTEST	Building Energy Simulation TEST An internationally recognised methodology to test and validate the calculations and outputs from building energy modelling software.
BRANZ	Building Research Association of New Zealand
CBA	Cost Benefit Analysis Financial terminology describing
CBR	Cost Benefit Ratio Financial terminology describing relationship between the relative costs and benefits of a proposed project.
Climate Locations	
AUK	Auckland
TUR	Turangi
NAP	Napier
WGN	Wellington
CHC	Christchurch
QT	Queenstown
DX	Direct Expansion, Refrigerant cycle
EnPI	Energy Performance Indicator, Total (cooling + heating), unless noted otherwise kWh/m².yr
H1	New Zealand Building Code clause for Energy Efficiency
HVAC	Heating, Ventilation, and Air Conditioning
HVDC	High Voltage Direct Current
kWh	kilo Watt hour unit of energy consumption
m²	Metre squared, unit of floor area measurement
MBIE	Ministry of Business, Innovation, and employment
NPV	Net Present Value Financial terminology describing the difference between the present value of cash inflows and the present value of cash outflows over a period of time.
R-value	A measure of the thermal resistance of a material / construction build up. Unit is: K.m²/W
SHGC	Solar Heat Gain Coefficient
TMY	Typical Meteorological Year A standard of weather file used with BEM
U-value	A measure of the thermal conductivity of a material / construction build up. Unit is: W/m².K
NIWA	National Institute of Water and Atmospheric Research
NZ	New Zealand
NZBC	New Zealand Building Code
NZS 4218	New Zealand Standard for thermal envelope requirements, small buildings (<300m²)
NZS 4243.1:2007	New Zealand Standard for thermal envelope requirements, small buildings (>300m²)
VM1	Verification Method Method of compliance with the New Zealand Building Code

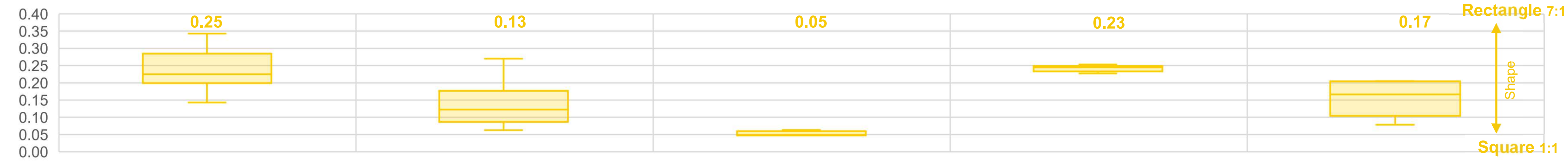
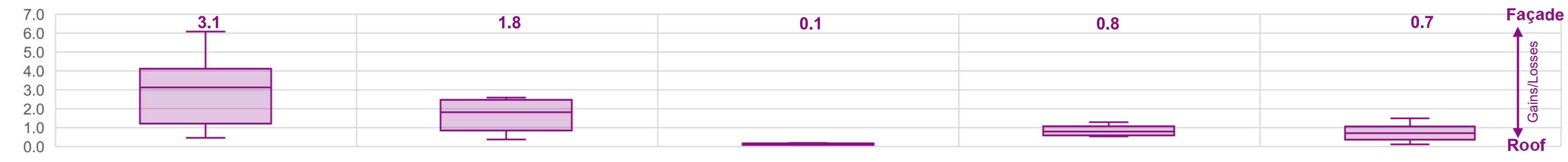
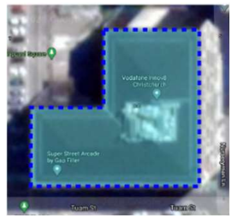
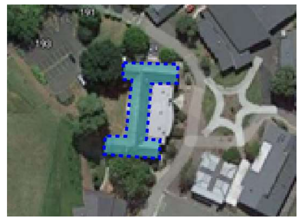
B

Appendix B: Key Modelling Assumptions

Key Modelling Assumptions

The following lists key assumptions used within the thermal energy modelling and analysis.

Typical Building Definitions

Typology	Large Residential	Office	Retail	School	Healthcare
Characteristics	Mid Rise, ~5 levels	Mid Rise, ~5 levels	Big Box Retail 1 level	Grouped Classrooms 1 level	Low rise and Clinics ~3 levels
Form Factor Perimeter Length / Footprint Area Proxy to the square or rectangular shape of the building					
Height Factor Total Building Height / Footprint Area (x100) Proportion of heat gains and losses across façade to roof. Higher Number = Greater façade Gains/losses					
Example Image					
Commentary	Apartments, Retirement village, Hotel, Motel. Low rise is suitably captured within the Residential classification of buildings. This focuses on the larger building types, >5 levels.	Buildings, >5 levels, roof has less of an overall impact (height factor). Highrise buildings would typically pursue the calculation or modelling method of NZS4243 due to other factors (e.g. WWR).		Primary and secondary schools only; Tertiary education is more likened to office built-forms and occupancy profiles.	Larger highrise hospitals typically house patient bed wards, so more likened to apartments. Healthcare buildings include 24 hour operation.

Clarifications

- Selection of form factors and height factor values are relatively correct to represent each building typology.
- Occupancy and operating profiles for schools have been refined to provide annual operating profiles, accounting for typical school year term times.
- Perimeter zones, up to four (4) metres will be applied to the geometry when the form factor results in building depth >4m.
- Temperature setpoints to maintain a temperature deadband of:
  - Schools: 18-24°C during occupied hours.
  - All other buildings: 21-23°C during occupied hours.
- Infiltration will be assigned to all buildings (within perimeter zones) at 0.15 ACH, with a façade air permeability which does not exceed: 1.6 l/m².s (NZS 4284:2008)
- School geometry is set up to account for multiple orientations as they typically are not restricted to a set orientation on site.
  i.e. Shaped as: 

Occupancy, Plug, and Lighting Densities

All input heat gain parameters are based on:

- NZS 4243.1:2007 (Occupancy and Plug)
- NZS 4243.2:2007, Amendment 1 2018 (Lighting)

These performance values are representative of “typical” building operations, therefore are considered non-specialist process spaces.

Typology	Occupancy heat gains W/m²	Plug Loads W/m²	Lighting W/m²
Large Residential Based on “Hotel / Motel”	2.9	2.7	6.0 (Rooms / Suites)
Office	2.7	8.1	9.0 (Open plan)
Retail	2.4	2.7	13.0 (Hardware / DIY / Supermarket)
School	9.7	5.4	10.0 (Classroom / Science / Technology)
Healthcare	3.6	10.7	10.0 (unspecified spatial function)

Profiles

Occupancy

The following illustrates the occupancy profiles for the different building typologies. These profiles are based on:

- NZS 4243.1:2007.
- Building typology *Large Residential* is based on NZS 4243.1:2007 - Housing.
- Building typology *Healthcare* is based on NZS 4243.1:2007 - Health with Residential Care.

	Day \ Time	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Large Residential	Weekday	100%	100%	100%	100%	100%	100%	100%	100%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	100%	100%	100%	100%	100%	100%
	Saturday	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	50%	50%	50%	50%	50%	50%	50%	70%	70%	70%	70%	100%	100%
	Sunday	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	50%	50%	50%	50%	50%	50%	50%	70%	70%	70%	70%	100%	100%
Office	Weekday	0%	0%	0%	0%	0%	0%	0%	0%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	5%	5%	5%	5%	0%	0%
	Saturday	0%	0%	0%	0%	0%	0%	0%	0%	10%	10%	10%	5%	5%	5%	5%	5%	5%	5%	0%	0%	0%	0%	0%	0%
	Sunday	0%	0%	0%	0%	0%	0%	0%	0%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	0%	0%	0%	0%	0%	0%
Retail	Weekday	0%	0%	0%	0%	0%	0%	0%	0%	60%	60%	60%	70%	70%	70%	70%	70%	70%	70%	40%	40%	40%	40%	0%	0%
	Saturday	0%	0%	0%	0%	0%	0%	0%	0%	60%	60%	60%	80%	80%	80%	80%	80%	80%	80%	20%	20%	20%	20%	0%	0%
	Sunday	0%	0%	0%	0%	0%	0%	0%	0%	10%	10%	10%	40%	40%	40%	40%	40%	40%	40%	0%	0%	0%	0%	0%	0%
Healthcare	Weekday	70%	70%	70%	70%	70%	70%	70%	70%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	85%	85%	85%	85%	70%	70%
	Saturday	70%	70%	70%	70%	70%	70%	70%	70%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	85%	85%	85%	85%	70%	70%
	Sunday	70%	70%	70%	70%	70%	70%	70%	70%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	85%	85%	85%	85%	70%	70%

- Values are a percentage of the peak occupancy.
- Peak values are defined in the previous pages.

Plug and Lighting

The following illustrates the equipment and lighting operating profiles for the different building typologies. These profiles are based on:

- NZS 4243.1:2007.
- Building typology *Large Residential* is based on NZS 4243.1:2007 - Housing.
- Building typology *Healthcare* is based on NZS 4243.1:2007 - Health with Residential Care.

	Day \ Time	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Large Residential	Weekday	3%	3%	3%	3%	3%	3%	3%	3%	23%	23%	23%	23%	23%	23%	23%	23%	23%	23%	27%	27%	27%	27%	20%	20%
	Saturday	3%	3%	3%	3%	3%	3%	3%	3%	23%	23%	23%	23%	23%	23%	23%	23%	23%	23%	27%	27%	27%	27%	20%	20%
	Sunday	3%	3%	3%	3%	3%	3%	3%	3%	23%	23%	23%	23%	23%	23%	23%	23%	23%	23%	27%	27%	27%	27%	20%	20%
Office	Weekday	5%	5%	5%	5%	5%	5%	5%	5%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	30%	30%	30%	30%	5%	5%
	Saturday	5%	5%	5%	5%	5%	5%	5%	5%	30%	30%	30%	15%	15%	15%	15%	15%	15%	15%	5%	5%	5%	5%	5%	5%
	Sunday	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Retail	Weekday	5%	5%	5%	5%	5%	5%	5%	5%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	50%	50%	50%	50%	5%	5%
	Saturday	5%	5%	5%	5%	5%	5%	5%	5%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	30%	30%	30%	30%	5%	5%
	Sunday	5%	5%	5%	5%	5%	5%	5%	5%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	5%	5%	5%	5%	5%	5%
Healthcare	Weekday	20%	20%	20%	20%	20%	20%	20%	20%	90%	90%	90%	85%	85%	85%	85%	85%	85%	85%	80%	80%	80%	80%	20%	20%
	Saturday	20%	20%	20%	20%	20%	20%	20%	20%	90%	90%	90%	85%	85%	85%	85%	85%	85%	85%	80%	80%	80%	80%	20%	20%
	Sunday	20%	20%	20%	20%	20%	20%	20%	20%	90%	90%	90%	85%	85%	85%	85%	85%	85%	85%	80%	80%	80%	80%	20%	20%

- Values are a percentage of the peak loads.
- Peak values are defined in the previous pages.

School Profiles

Schools have been adapted from NZS4243:2007 and refined to provide a more representative daily and annual operation. These changes include:

- Class hours ending at 3pm
- Allowances for annual school term times

Weekday

Occupancy

	Overnight	Morning				Midday				Afternoon				Evening	
	00:00 - 06:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00 - 23:00	Comment
Jan	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	Schools Closed
Feb	0%	20%	95%	95%	95%	95%	95%	95%	95%	95%	35%	5%	5%	0%	**Term 1** ~10wks, Feb - Mid-Apr
Mar	0%	20%	95%	95%	95%	95%	95%	95%	95%	95%	35%	5%	5%	0%	
Apr	0%	20%	95%	95%	95%	95%	95%	95%	95%	95%	35%	5%	5%	0%	
May	0%	20%	95%	95%	95%	95%	95%	95%	95%	95%	35%	5%	5%	0%	**Term 2** ~10wks, May - July
Jun	0%	20%	95%	95%	95%	95%	95%	95%	95%	95%	35%	5%	5%	0%	
Jul	0%	20%	95%	95%	95%	95%	95%	95%	95%	95%	35%	5%	5%	0%	
Aug	0%	20%	95%	95%	95%	95%	95%	95%	95%	95%	35%	5%	5%	0%	**Term 3** ~10wks, End Jul - Start Oct
Sep	0%	20%	95%	95%	95%	95%	95%	95%	95%	95%	35%	5%	5%	0%	
Oct	0%	20%	95%	95%	95%	95%	95%	95%	95%	95%	35%	5%	5%	0%	
Nov	0%	20%	95%	95%	95%	95%	95%	95%	95%	95%	35%	5%	5%	0%	**Term 4** ~10wks, End Oct - Mid Dec
Dec	0%	20%	95%	95%	95%	95%	95%	95%	95%	95%	35%	5%	5%	0%	

Plug and Lighting

	Overnight	Morning				Midday				Afternoon				Evening	
	00:00 - 06:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00 - 23:00	Comment
Jan	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	Schools Closed
Feb	5%	5%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	30%	5%	**Term 1** ~10wks, Feb - Mid-Apr
Mar	5%	5%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	30%	5%	
Apr	5%	5%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	30%	5%	
May	5%	5%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	30%	5%	**Term 2** ~10wks, May - July
Jun	5%	5%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	30%	5%	
Jul	5%	5%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	30%	5%	
Aug	5%	5%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	30%	5%	**Term 3** ~10wks, End Jul - Start Oct
Sep	5%	5%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	30%	5%	
Oct	5%	5%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	30%	5%	
Nov	5%	5%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	30%	5%	**Term 4** ~10wks, End Oct - Mid Dec
Dec	5%	5%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	30%	5%	

Weekends and Holidays

Occupancy

	Overnight	Morning				Midday				Afternoon				Evening	
	00:00 - 06:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00 - 23:00	Comment
Jan	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	Schools Closed
Feb	0%	0%	5%	5%	5%	5%	5%	5%	5%	5%	0%	0%	0%	0%	**Term 1** ~10wks, Feb - Mid-Apr
Mar	0%	0%	5%	5%	5%	5%	5%	5%	5%	5%	0%	0%	0%	0%	
Apr	0%	0%	5%	5%	5%	5%	5%	5%	5%	5%	0%	0%	0%	0%	
May	0%	0%	5%	5%	5%	5%	5%	5%	5%	5%	0%	0%	0%	0%	**Term 2** ~10wks, May - July
Jun	0%	0%	5%	5%	5%	5%	5%	5%	5%	5%	0%	0%	0%	0%	
Jul	0%	0%	5%	5%	5%	5%	5%	5%	5%	5%	0%	0%	0%	0%	
Aug	0%	0%	5%	5%	5%	5%	5%	5%	5%	5%	0%	0%	0%	0%	**Term 3** ~10wks, End Jul - Start Oct
Sep	0%	0%	5%	5%	5%	5%	5%	5%	5%	5%	0%	0%	0%	0%	
Oct	0%	0%	5%	5%	5%	5%	5%	5%	5%	5%	0%	0%	0%	0%	
Nov	0%	0%	5%	5%	5%	5%	5%	5%	5%	5%	0%	0%	0%	0%	**Term 4** ~10wks, End Oct - Mid Dec
Dec	0%	0%	5%	5%	5%	5%	5%	5%	5%	5%	0%	0%	0%	0%	

Plug and Lighting

	Overnight	Morning				Midday				Afternoon				Evening	
	00:00 - 06:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00 - 23:00	Comment
Jan	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	Schools Closed
Feb	5%	5%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	5%	**Term 1** ~10wks, Feb - Mid-Apr
Mar	5%	5%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	5%	
Apr	5%	5%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	5%	
May	5%	5%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	5%	**Term 2** ~10wks, May - July
Jun	5%	5%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	5%	
Jul	5%	5%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	5%	
Aug	5%	5%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	5%	**Term 3** ~10wks, End Jul - Start Oct
Sep	5%	5%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	5%	
Oct	5%	5%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	5%	
Nov	5%	5%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	5%	**Term 4** ~10wks, End Oct - Mid Dec
Dec	5%	5%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	5%	

C

Appendix C: Architectural Details

Architectural Details

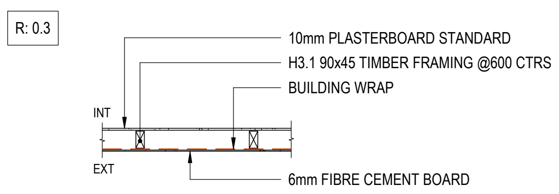
Architectural details provided are indicative only to achieve the resultant R-values for the purposes of this project's analysis. There are additional considerations that are not specifically addressed with this approach such as interstitial moisture; as such these details should not be used as typical construction details. Typical construction details designed in compliance with all aspects of the Building Code (including clauses E: Moisture) may result in less or greater thermal performance values.

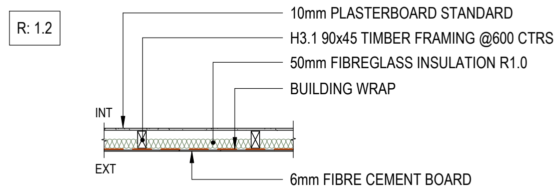
The details have been created for the purposes of developing an elemental cost index specific to the use within this study.

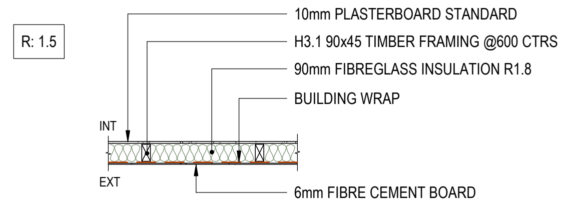
Drawing Plotted: 19/11/2020 4:15:54 pm

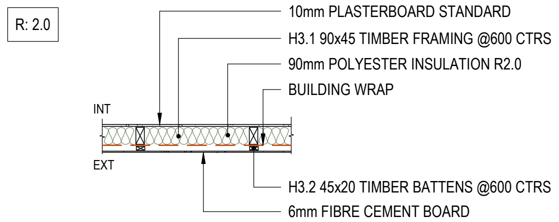
WALLS

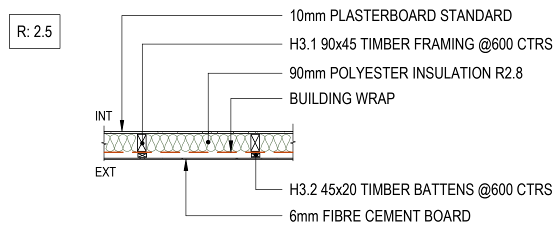
LIGHT WEIGHT

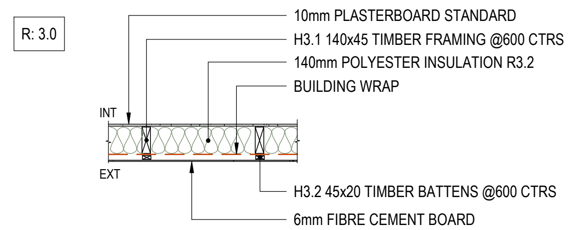


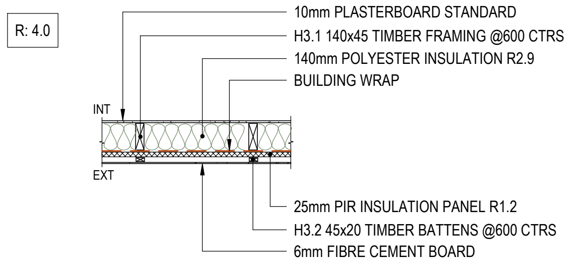


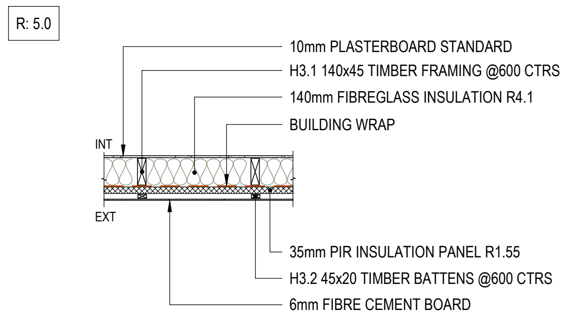












1 - WALLS - LIGHT WEIGHT
1 : 20

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No.	Revision	By	Chk	Appd	Date

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Original Scale (A1): 1 : 20
Reduced Scale (A3): Half A1
Design / Drawn / Dsg Verifier / Dwg Check

Client: MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT – HIKINA WHAKATUTUKI

Project: NZBC H1 - R-VALUE PERFORMANCE REVIEW, LARGE BUILDINGS
TYPICAL H1 SKETCHES

Title: CONSTRUCTION BUILD-UPS WALLS LIGHT WEIGHT

Discipline: ARCHITECTURE

Drawing No. 5137501-AR-7000
Rev.

Document No. P:\5137501\CAD\BIM\5137501-AR-2020-MBIE (Latest).rvt

DO NOT SCALE

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WALLS

HEAVY WEIGHT

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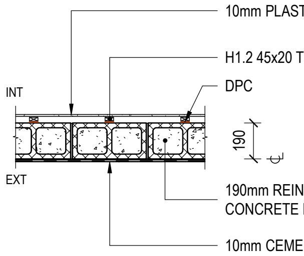

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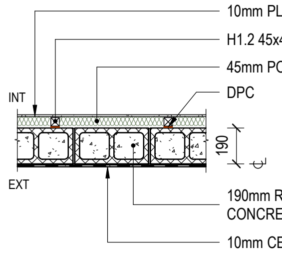

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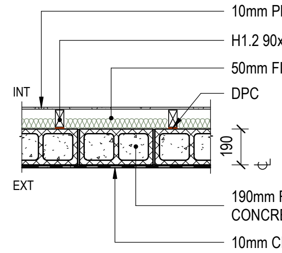

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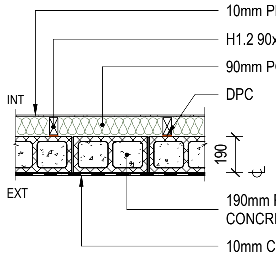

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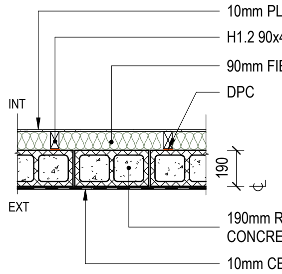

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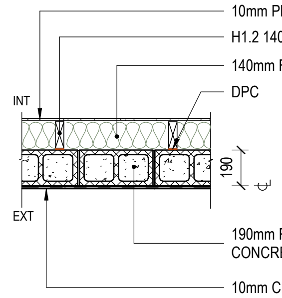

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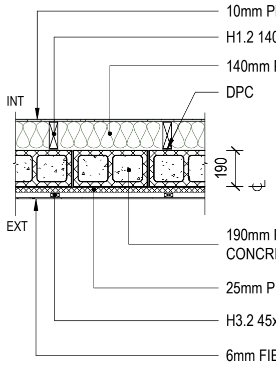

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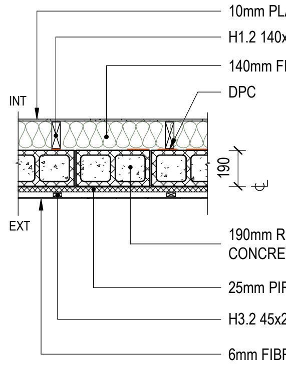

1 / - WALLS - HEAVY WEIGHT

1 : 20

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NOT FOR CONSTRUCTION

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Reduced Scale (A3) Half A1
Design
Drawn
Dsg Verifier
Dwg Check

Client: MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT, HIKINA WHAKATUTUKI

Project: NZBC H1 - R-VALUE PERFORMANCE REVIEW, LARGE BUILDINGS
TYPICAL H1 SKETCHES

Title: CONSTRUCTION BUILD-UPS WALLS HEAVY WEIGHT

Discipline: ARCHITECTURE

Drawing No. 5137501-AR-7001

Rev.

FLOORS

SLAB ON GRADE

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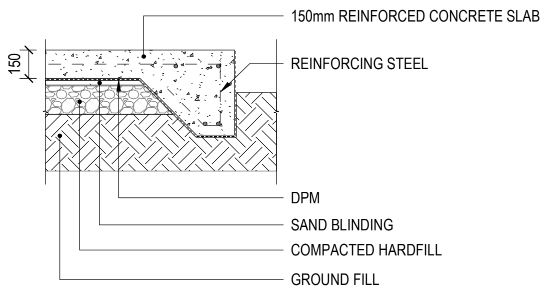

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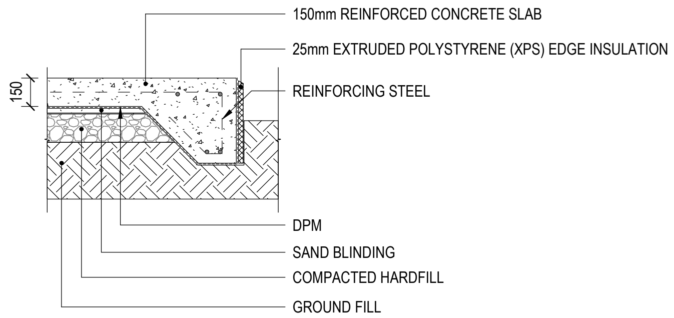

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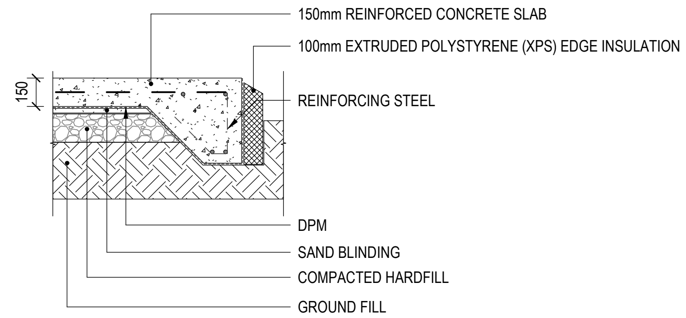

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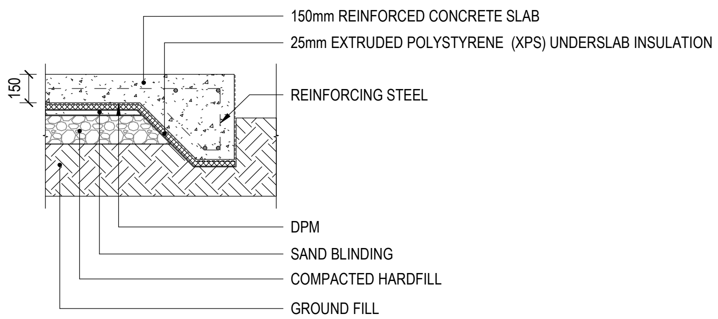

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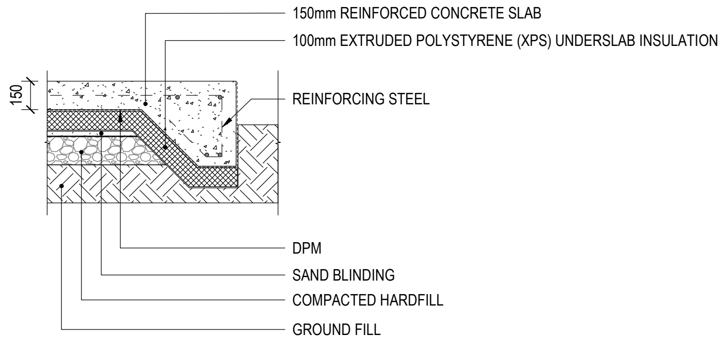

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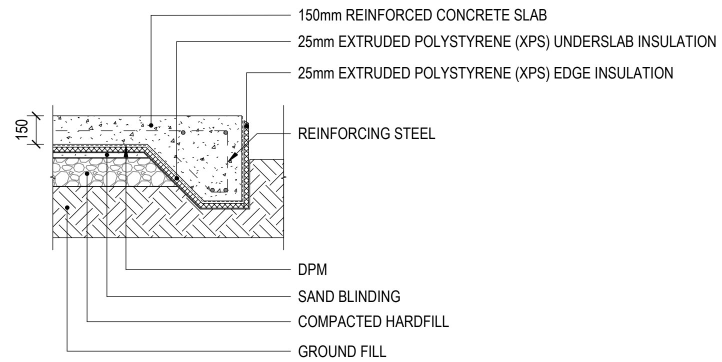

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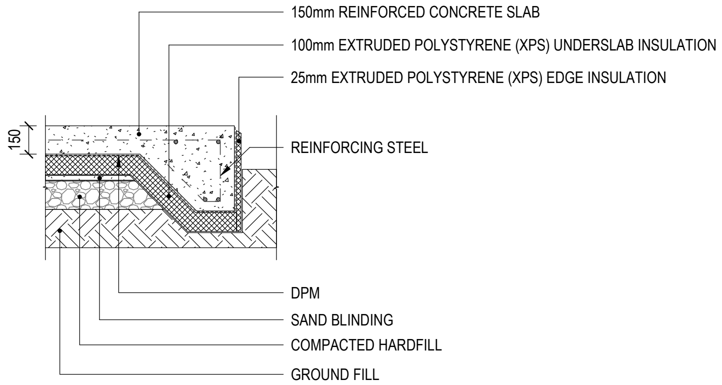

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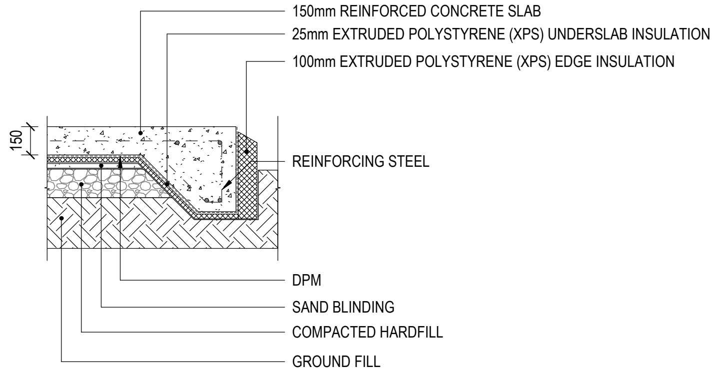

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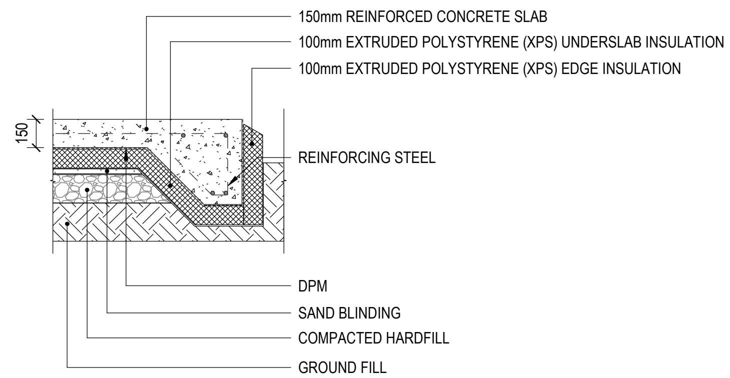

1 FLOORS
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FOR INFORMATION
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No. | Revision | By | Chk | Appd | Date

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Reduced Scale (A3) Half A1

Design
Drawn
Dsg Verifier
Dwg Check

Client: MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT HIKINA WHAKATUTUKI

Project: NZBC H1 - R-VALUE PERFORMANCE REVIEW, LARGE BUILDINGS
TYPICAL H1 SKETCHES

Title: CONSTRUCTION BUILD-UPS FLOORS

Discipline: ARCHITECTURE

Drawing No. 5137501-AR-7002

Rev.

Document No. P:\5135\5137501\CAD\BIM\5137501-AR-2020-MBIE (Latest).rvt

ROOFS - LIGHT WEIGHT

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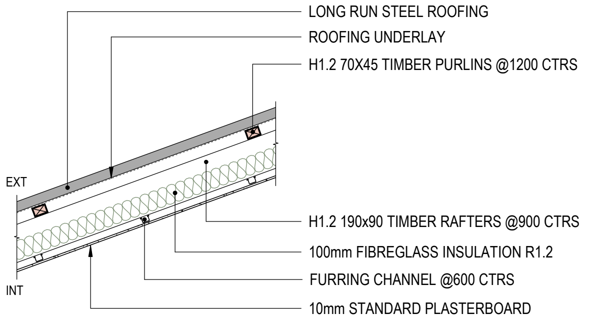

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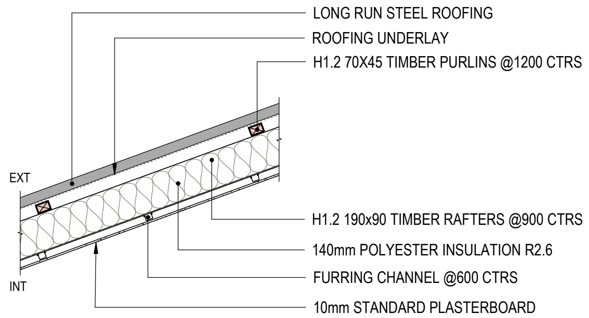

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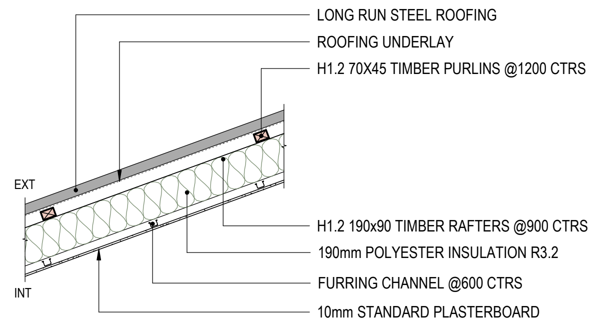

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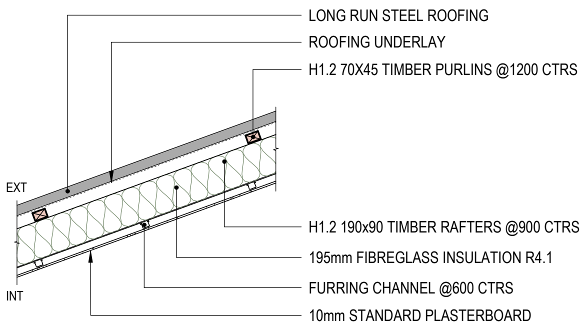

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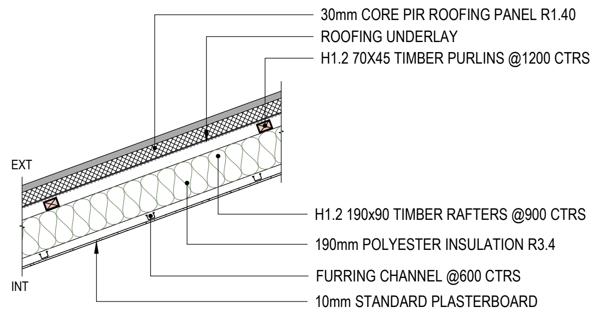

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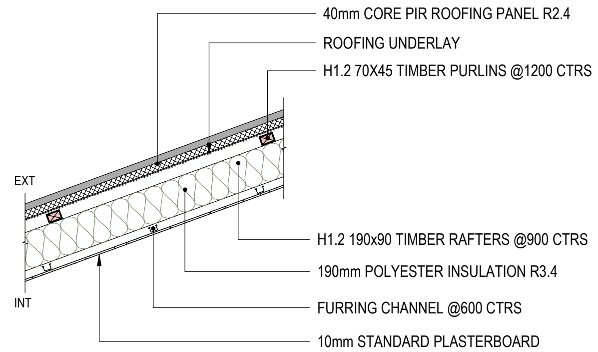

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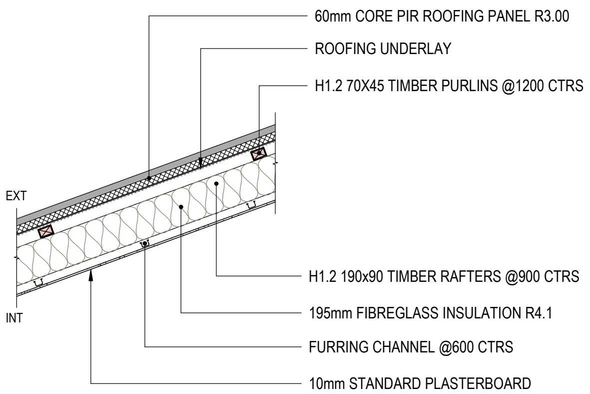

1 ROOFS - LIGHT WEIGHT
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FOR INFORMATION
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No.	Revision	By	Chk	Appd	Date

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Reduced Scale (A3) Half A1

Design
Drawn
Dsg Verifier
Dwg Check

Client: MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT HIKINA WHAKATUTUKI

Project: NZBC H1 - R-VALUE PERFORMANCE REVIEW, LARGE BUILDINGS
TYPICAL H1 SKETCHES

Title: CONSTRUCTION BUILD-UPS ROOFS LIGHT WEIGHT

Discipline: ARCHITECTURE

Drawing No. 5137501-AR-7003

Rev.

ROOFS - HEAVY WEIGHT

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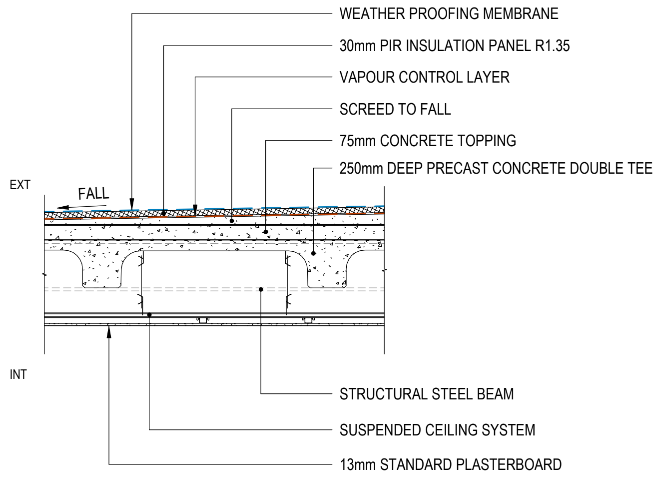

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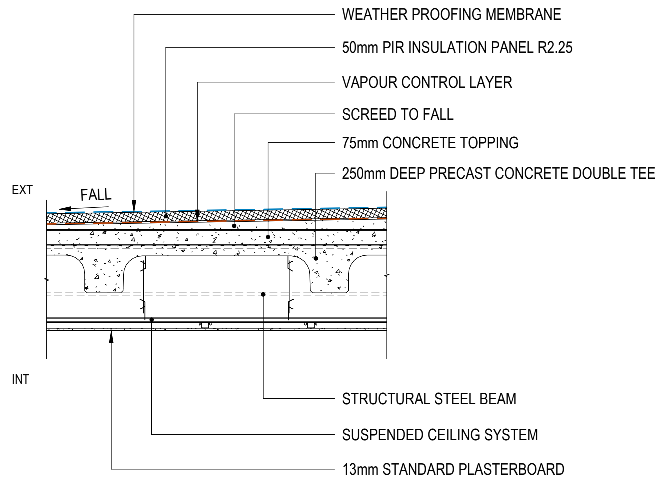

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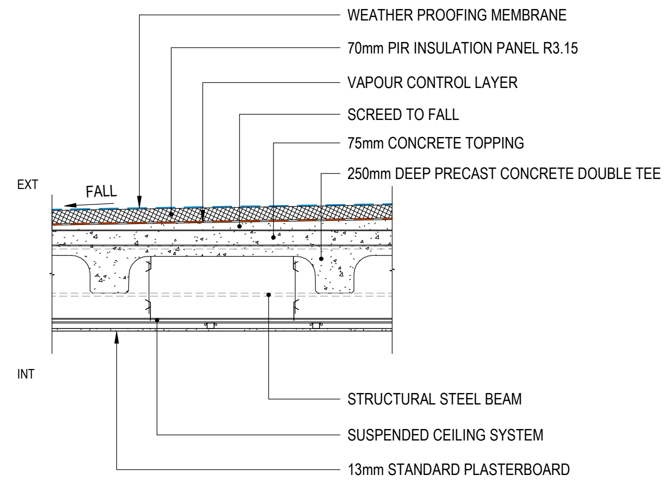

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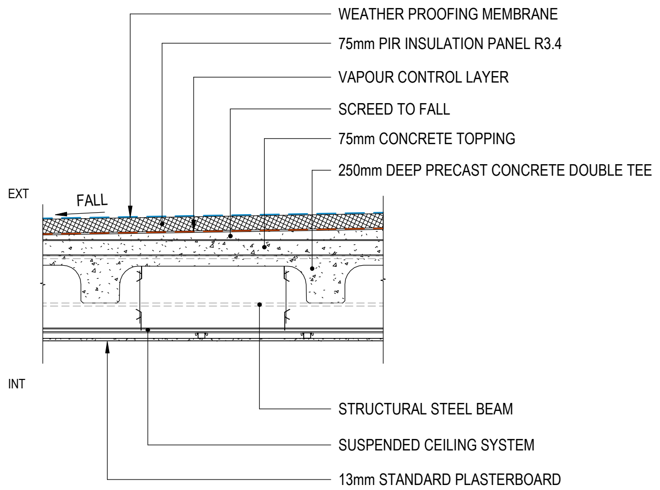

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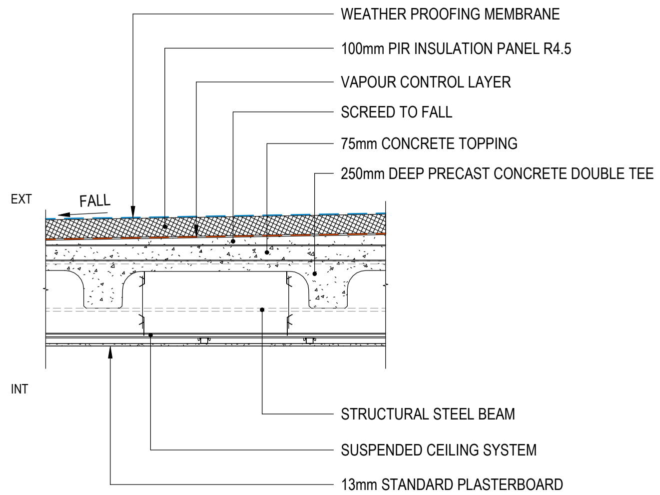

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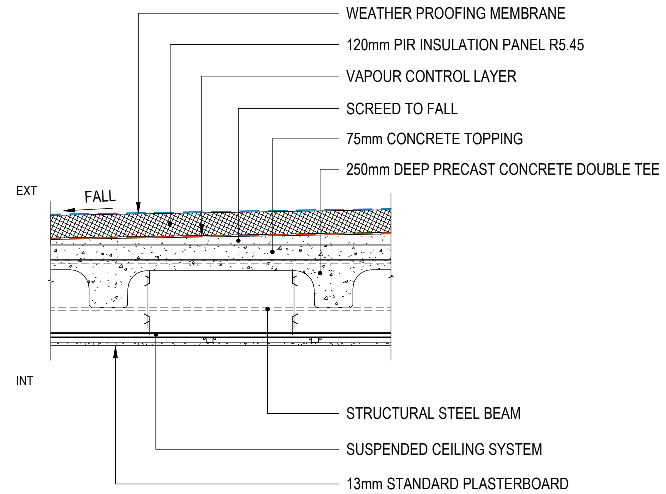

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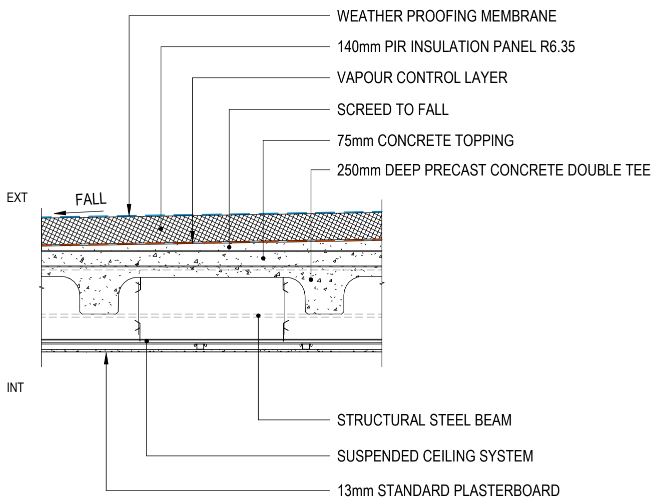

2 - ROOFS - HEAVY WEIGHT
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Reduced Scale (A3) Half A1
Design
Drawn
Dsg Verifier
Dwg Check

Client: MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HIKINA WHAKATUTUKI

Project: NZBC H1 - R-VALUE PERFORMANCE REVIEW, LARGE BUILDINGS
TYPICAL H1 SKETCHES

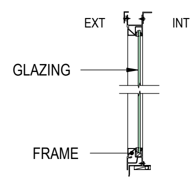
Title: CONSTRUCTION BUILD-UPS
ROOFS HEAVY WEIGHT

Discipline: ARCHITECTURE
Drawing No. 5137501-AR-7005
Rev.

Drawing Plotted: 19/11/2020 4:15:55 pm

GLAZING

SINGLE



NOMINAL THICKNESS (mm)	U VALUE	SHGC	FRAME TYPE	GLAZING TYPE
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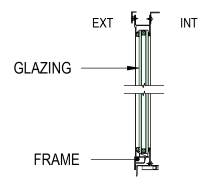
4	6.67	0.60	ALUMINIUM	TINT
5	4.76	0.71	ALUMINIUM	LOW - E

DOUBLE



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5 + 12 + 4	3.85	0.50	ALUMINIUM	TINT
4 + 12 + 4	3.23	0.69	ALUMINIUM	LOW - E
5 + 12 + 4	3.23	0.50	ALUMINIUM	TINT LOW - E
4 + 12 + 4	2.56	0.69	THERMALLY BROKEN ALUMINIUM	LOW - E
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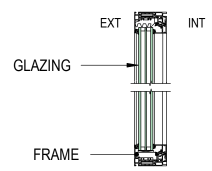
TRIPLE



NOMINAL THICKNESS (mm)	U VALUE	SHGC	FRAME TYPE	GLAZING TYPE
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6 + 12 + 6 + 12 + 6	1.61	0.40	THERMALLY BROKEN ALUMINIUM	TINT LOW - E

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Drawing Originator: Beca

Original Scale (A1) 1 : 20
Reduced Scale (A3) Half A1

Design
Drawn
Dsg Verifier
Dwg Check

Client: MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HIKINA WHAKATUTUKI

Project: NZBC H1 - R-VALUE PERFORMANCE REVIEW, LARGE BUILDINGS
TYPICAL H1 SKETCHES

Title: CONSTRUCTION BUILD-UPS
GLAZING

Discipline: ARCHITECTURE

Drawing No. 5137501-AR-7006

Rev.

Document No. P:\513\5137501\CAD\BIM\5137501-AR-2020-MBIE (Latest).rvt

DO NOT SCALE

IF IN DOUBT ASK.

D

Appendix D: Financial Analysis Dashboard

Financial Analysis Dashboard

Dashboard Interface

The following illustrates the interactive dashboard developed to process the large volumes of data. As noted, there are multiple inputs, sectors, and sliders to filter the results and draw conclusions from.