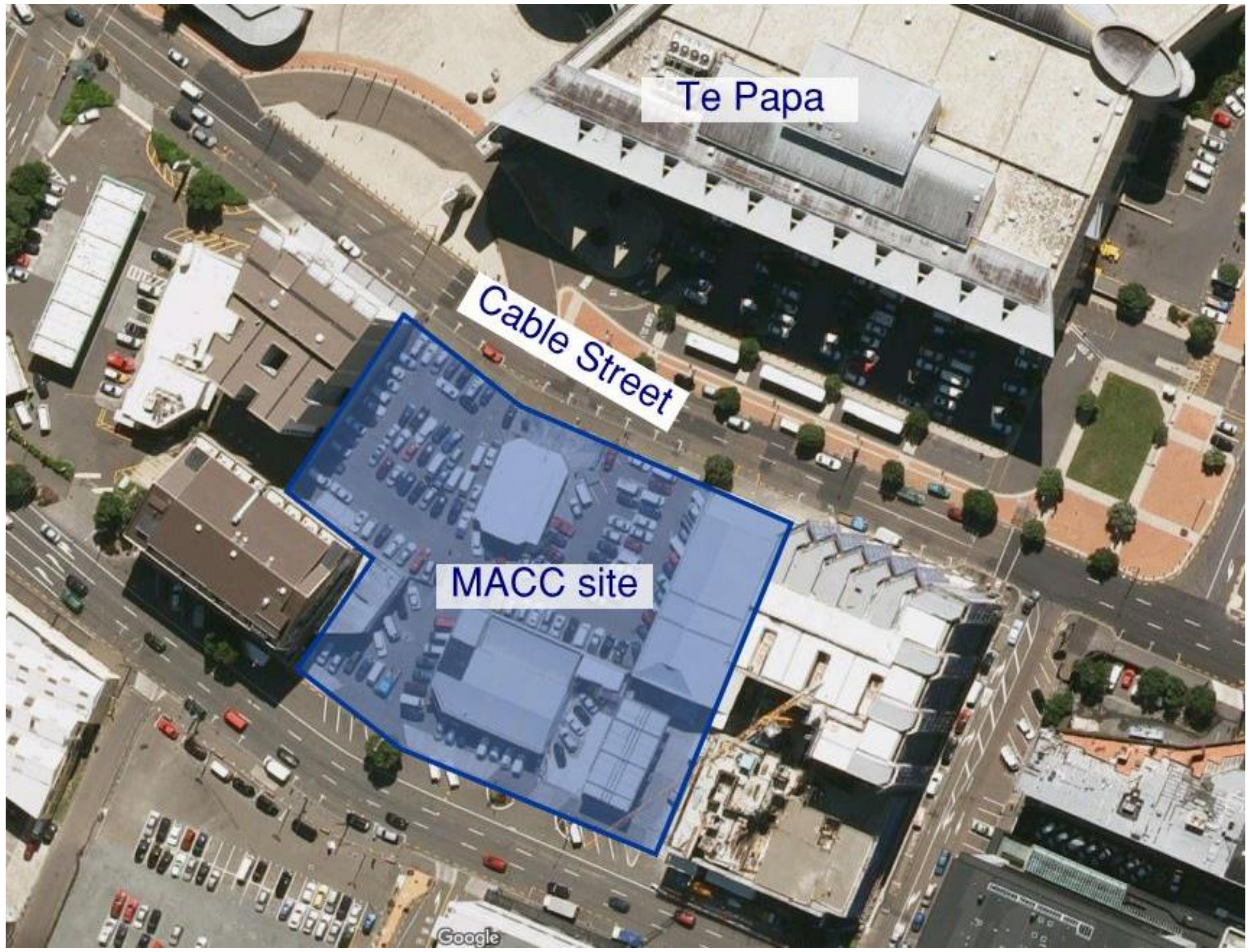
Report

MACC - EECA Programme 2A Energy Efficiency Review (Building Envelope)

Prepared for Wellington City Council

By Beca Ltd

3 June 2016



Revision History

Revision Nº	Prepared By	Description	Date
1	Shaan Cory	Issued for information	7 June 2016
2			
3			
4			
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Document Acceptance

Action	Name	Signed	Date
Prepared by	Shaan Cory		30 May 2016
Reviewed by	Ben Masters		3 June 2016
Approved by	Ben Masters		7 June 2016
on behalf of	Beca Ltd		

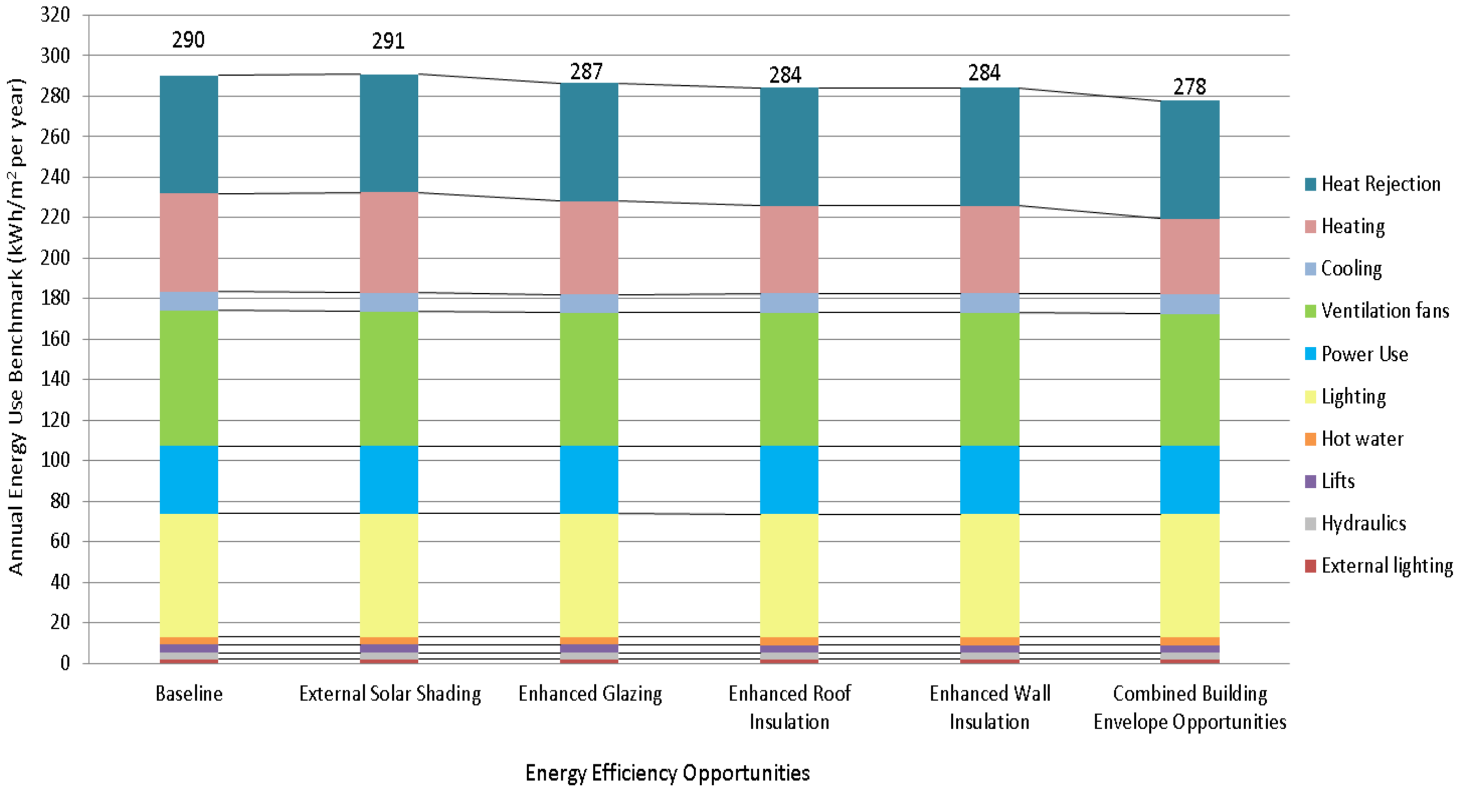
Executive Summary

The following is a summary overview of the selected energy efficiency opportunities assessed as part of the EECA Programme 2A energy efficiency advisory service for the proposed Museum and Convention Centre (MACC) project to assess building envelope opportunities. The energy efficiency review has used computer simulation modelling to benchmark annual energy use savings against a theoretical baseline building model.

Comparison of Building Envelope Energy Efficiency Opportunities

Attribute

Annual Energy Use Benchmark Comparison



The findings and recommendations are:

- Combining the energy efficiency opportunities which offer an energy reduction (enhanced glazing, roof, and wall insulation) indicates around 12kWh/m² per year energy savings compared to the NZBC baseline model. The energy savings of the combined energy efficiency options may reduce GHG emissions by more than 40 tonnes per year.
- The combination of implementing the enhanced glazing, wall and roof opportunities is indicated to provide approximately $11k of energy cost savings per year, which has an estimated payback period of 11 years, a NPV of $10k, and an IRR of 7.3% (20 year period). This indicates the assessed options would result in a favourable return on investment.
- Along with offering energy savings, the assessed enhanced glazing (IGU Low-e Solar Control) option is also recommended for improved occupancy thermal comfort due to improved summer and winter radiant surface temperatures in the occupied spaces. Likewise, the increased insulation level will result in improved winter thermal comfort.
- External solar shading and glazing performance criteria may also result in a reduced peak cooling load and resulting chiller plant capacity and required AHU sizes. Likewise increased thermal insulation will reduce the required boiler plant capacity. These potential capital cost savings have not been factored into the assessment
- It is indicated that installing additional solar shading increases energy consumption and GHG emissions, but would also improve summer comfort in the Level 4 FOH area.
- We recommend that WCC considers including the above combined opportunities subject to meeting their investment criteria and the project budget.

Annual Savings Benchmark Summary

Annual Energy and Emissions Savings Benchmark	Enhanced Energy Efficiency Opportunities				
	External solar shading	Enhanced Glazing	Enhanced Roof Insulation	Enhanced Wall Insulation	Combined Building Envelope Opportunities
kWh/m² per year	-0.5	4	6	6	12
kWh per year	-7,000	58,000	96,000	96,000	196,000
$ per year	$60	$4,000	$6,000	$6,000	$11,000
Tonnes CO_2-e/ year	-2	12	21	21	43

Performance Financial Analysis Summary

Financial Performance Indicator	Enhanced Energy Efficiency Opportunities				
	External Solar Shading	Enhanced Glazing (IGU Low-e Solar Control)	Enhanced Roof Insulation	Enhanced Wall Insulation	Combined Building Envelope Opportunities
Indicative Capital Cost[1]	$50K	$80K	$25K	$30K	$135K
Payback Period[2]	NA years	17 years	5 years	6 years	11 years
20 year NPV[3]	-$49,000	-$25,000	$49,000	$44,000	$10,000
20 year IRR	NA	2.4%	24.0%	20.1%	7.3%

[1] Based on indicative increased capital cost over baseline option. Order of capital costs TBC by Cost Consultant. Excluding GST, contractor P+G and margins, contingency allowance, and professional fees. These estimates are for comparison purposes only, and not to establish construction budget or estimate operating expenses.

[2] Based on WCC electricity rate of 10¢/kWh and gas rate of 5¢/kWh with a 2.5% annual inflation rate assumed

[3] Assumes a 6.5% discount rate

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Appendices

1 Introduction

This energy efficiency advisory service has been requested by Wellington City Council (WCC) to review selected energy efficiency opportunities available to the proposed Museum and Convention Centre (MACC). The scope of services provided aligns with the objectives of the Energy Efficiency & Conservation Authority (EECA) Programme 2A Advisory service requirements.

As summarised by EECA:

The objective of Programme 2A is to recommend energy efficient design features [building envelope] *when the building design is at the initial concept stage and to "lock in" energy efficiency before a significant amount of time and money has been spent on detailed drawings and designs.*

The EECA Programme 2B report has been carried out in parallel with this report and is focussed on energy efficient systems.

The energy efficiency review uses computer simulation modelling to benchmark the energy performance benefit of selected building envelope energy efficiency opportunities against a theoretical baseline model and the proposed design.

Each opportunity has been considered purely from an energy, Greenhouse Gas (GHG) emissions and energy cost perspective only. Other criteria including internal environmental quality (e.g. occupancy thermal comfort, air quality, daylight availability, access to external views etc), architectural, construction, cost, emissions, cleaning, safety in design and all other aspects which inform to the performance and aesthetic requirements of the building design should be considered separately by the project team.

Limitations

This study has been prepared for the purposes of helping to inform the development of the building design. The computer simulation models are only intended to help inform the building design and the predicted values may overestimate or underestimate the actual building performance in use. Note that the energy benchmark calculations use standard benchmarking criteria for occupancy, lighting, power and plant usage and benchmark weather data. Actual operating variables will differ in reality (e.g. weather, fitout and usage patterns, blinds control etc.). We point out that the weather files used for the computer simulations represent a typical weather year only and does not account for periods of unseasonably high (or low) temperature or humidity.

The energy benchmarks are not an estimate of predicted energy use and as such cannot be guaranteed that the actual building energy use will be within the target limits as this will be determined by many variables, including those listed above.

All costs are high level estimates only based on suppliers quotes and may not reflect the actual costs. These will need to be confirmed by further design and the project quantity surveyor.

2 Project Description

2.1 Museum and Convention Centre

WCC is planning to construct a new MACC with an approximate useable floor area of 15,751m^2. MACC is a 5 storey building. The lower four floors consist of two 10m high floor to ceiling mezzanine split levels that house the museum exhibits. The top floor houses the convention centre. MACC is comprised of:

- 11 large exhibition pieces
- 1,100 person convention centre,
- Kitchen,
- Offices, and
- Lobby area.

Figure 1 shows that MACC is located across the street from Te Papa and situated between three existing buildings.

Project summary details are as follows:

- Location: Cable Street, Wellington
- Client: Wellington City Council
- Design Stage: Preliminary Design

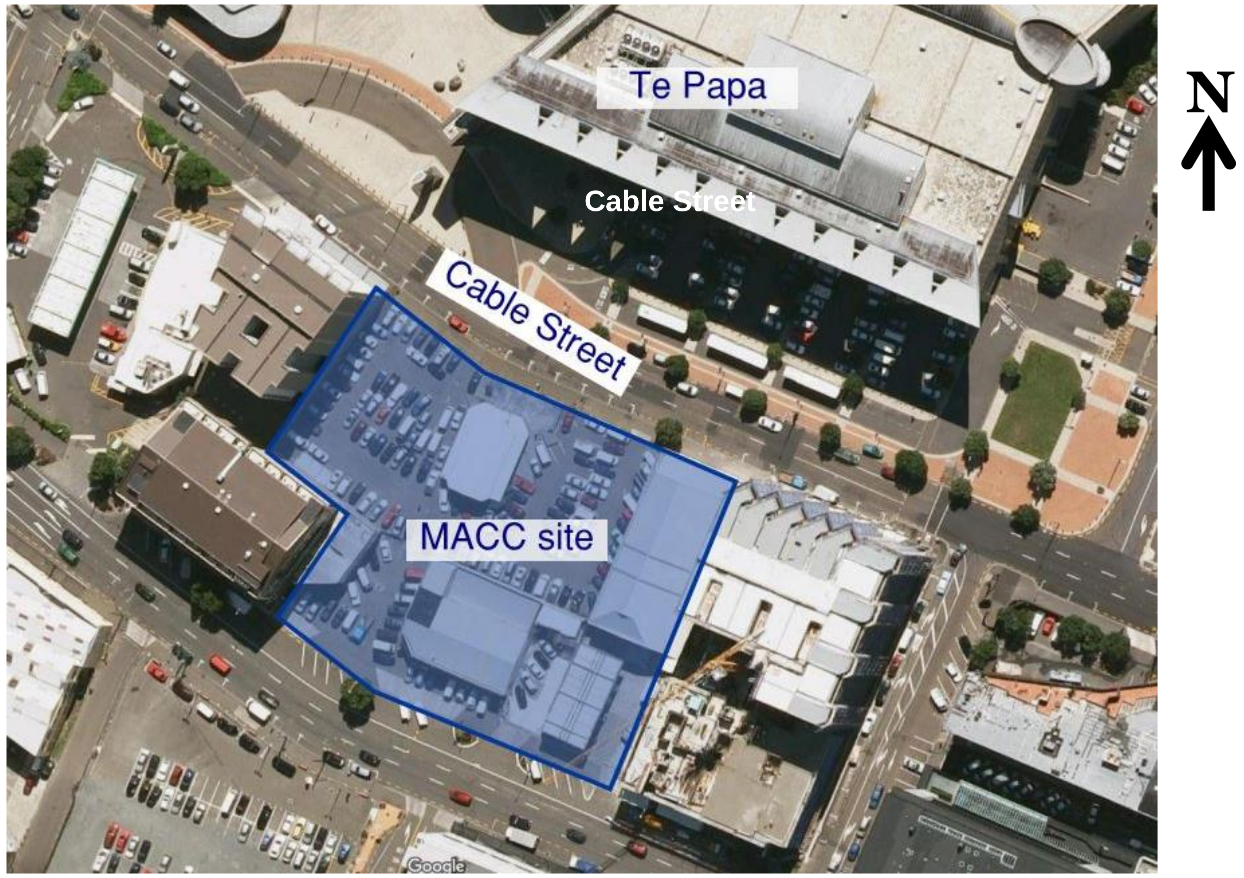

Figure 1 – Proposed site location on the existing Cable Street site

3 Energy Efficiency Overview

Commercial and industrial buildings account for around 8% of New Zealand's total energy consumption a year, and 5% of total CO_2 emissions.

Studies have shown there can be as much as a ten-fold difference in actual energy consumption between similar buildings with design and construction-related issues and operational issues the main contributors to the differences.

3.1 Efficiency Optimises Lifetime Costs

Designing energy-efficient buildings makes sense on a number of levels – not the least of which is the overall economics.

Typical costs relative to initial construction costs over the life of a typical building are:

- Environmental consultant fees 0.01 to 0.03
- Professional fees 0.10 to 0.15
- Construction costs 1.00
- Energy, operating and maintenance costs 3.00
- Business costs (salaries, rental/space) 200.00

Even taken together the design fees and costs of construction are a small portion of total lifetime costs of a building. Focusing on these initial construction costs alone will almost certainly result in a project that does not optimise its lifetime costs.

The extra initial cost of letting the architects and engineers evaluate the design thoroughly and determine an energy-efficient outcome is an investment that should repay itself many times over the life of the building.

Business costs are by far the most significant lifetime cost of a project, and to influence them, the potential effect of a building on the productivity and health of its users must be taken into account.

Energy-efficient design can also play a significant role in providing healthier, more productive environments. For example:

- Increased levels of thermal insulation results in improved winter thermal comfort
- External shading to control summer cooling loads also reduces direct solar gain which may cause discomfort for building occupants. Well-designed shading also means users do not need to use their blinds as much, allowing more access to daylight and exterior views.
- Energy-efficient high frequency lighting may reduce headache producing flicker

3.2 Energy Efficiency Adds Value

All stakeholders in the building stand to gain from more energy-efficient design.

Owners/occupiers and building users enjoy lower operating costs, and potentially greater operational flexibility and an environment that encourages greater productivity. The benefits also contribute to the long-term value of the asset for owners and portfolio holders.

The benefits of energy efficiency will become more obvious and more valuable as energy costs rise, employees' pressure for healthier environments increases, regulation becomes a more distinct possibility and overall environmental awareness improves.

4 Computer Simulation Models

A 3D computer simulation model was created for the building using IES Virtual Environment software. IES simulation software is of the dynamic thermal simulation type that is capable of predicting building thermal performance and estimating annual energy consumption in a building.

The program is based upon finite difference methods as recommended by CIBSE Part A for energy and environmental modelling to model the transmission and storage of heat in the building fabric.

The thermal model was created using IES Virtual Environment Version 2015. This has been independently verified to meet ANSI/ASHRAE Standard 140-2004 (Building Thermal Envelope and Fabric Test Loads) performance criteria. The *Apache HVAC* module has been used to simulate Heating, Ventilation, and Air-Conditioning (HVAC) energy.

4.1 Weather File

Each model has been simulated using the NIWA Wellington TMY2 weather file (Data Source - TMY2 NIWA 18234 D14482 WMO Station 934360). This represents a historical average year of Wellington weather data as recorded at the Kelburn weather station. It must be noted that the weather data does not account for any unseasonable weather conditions and does not account for any localised micro climate effects at the site location.

4.2 Baseline Model

A theoretical baseline model for the MACC building has been created which generally aligns with the New Zealand Building Code (NZBC) Clause H1 minimum energy efficiency requirements. The proposed building geometry has been modelled, with proposed areas and location of clear single glazing included on each façade. External wall, roof and suspended floor areas are all insulated to align with the Clause H1 R-value minimum. The baseline model includes the external solar shading which wraps around the building.

The baseline model has full air conditioning to all occupied areas with a combination of centralised Variable Air Volume (VAV) Air Handling Units (AHU) with zone reheat and a 4 pipe fan coil unit system providing heating and cooling via a water cooled chiller plant and gas boiler plant (condensing type). Mechanical ventilation is provided as per the current design provision. Internal lighting is assumed to be predominantly provided by LED lighting technology. HVAC plant and equipment efficiencies align with the Department of Building and Housing's Guidelines for Energy Efficient HVAC plant (MEPS).

The operating and occupancy profile used in the model has been set to align with the forecast average 10 year projection for movie museum usage from "Wellington City Council - Indicative business case for a new movie museum" document from November 2015 and projected year 5 convention centre usage from "Wellington City Council - Indicative business case for a new convention centre" document from December 2015.

Further details of the baseline computer model inputs are described in Appendix A.

Sample images of the 3D computer model can be seen in the following figures:

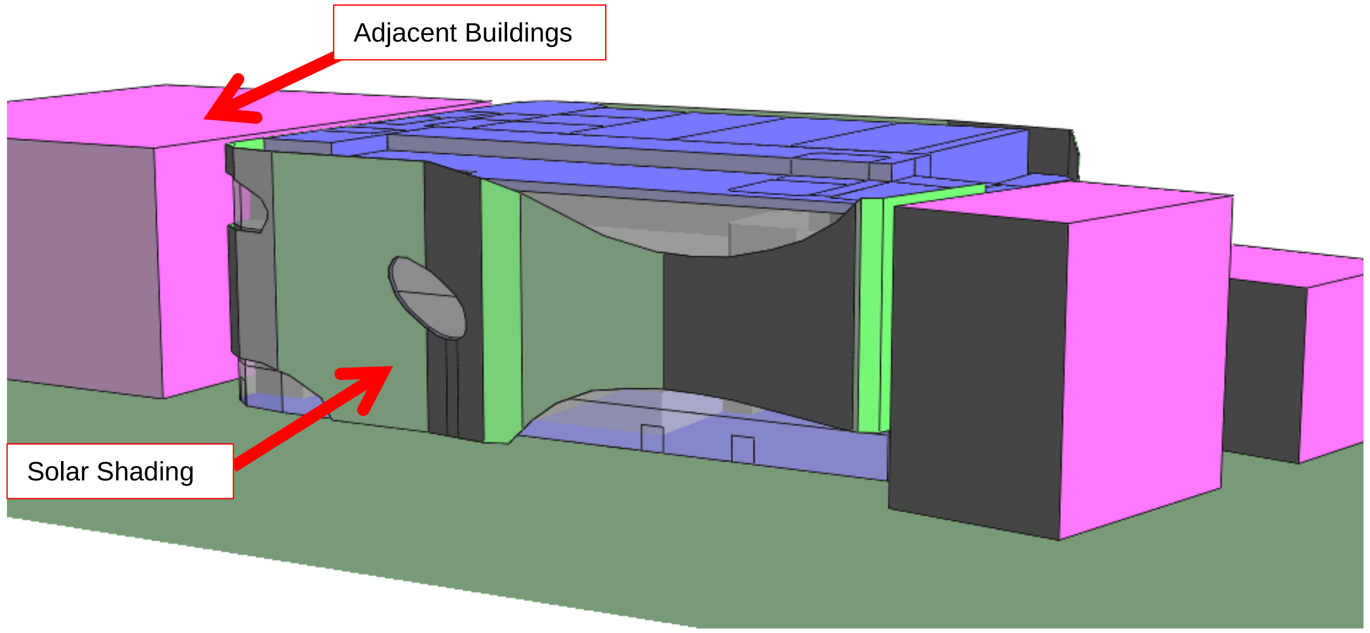

Figure 2 - Computer simulation model showing proposed façade design, view from north.

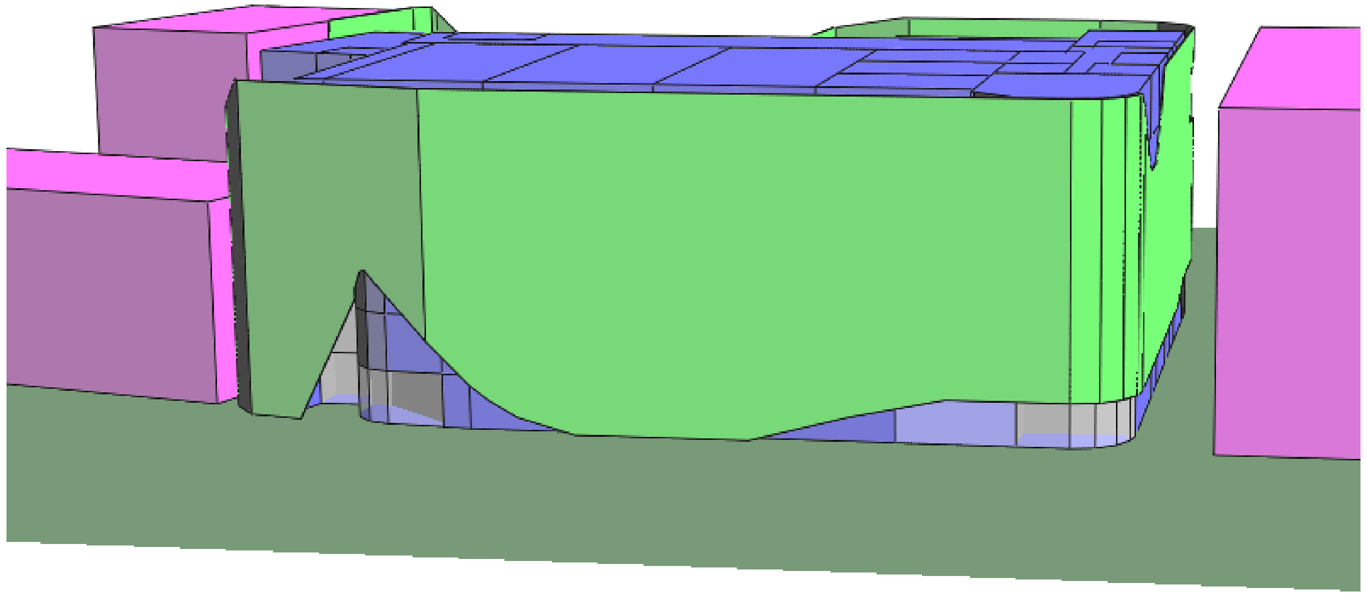

Figure 3 - Computer simulation model showing proposed façade design, view from south

Benchmark Energy End Use Breakdown

The benchmark annual energy end-use breakdown for the theoretical baseline model can be seen in the following figure:

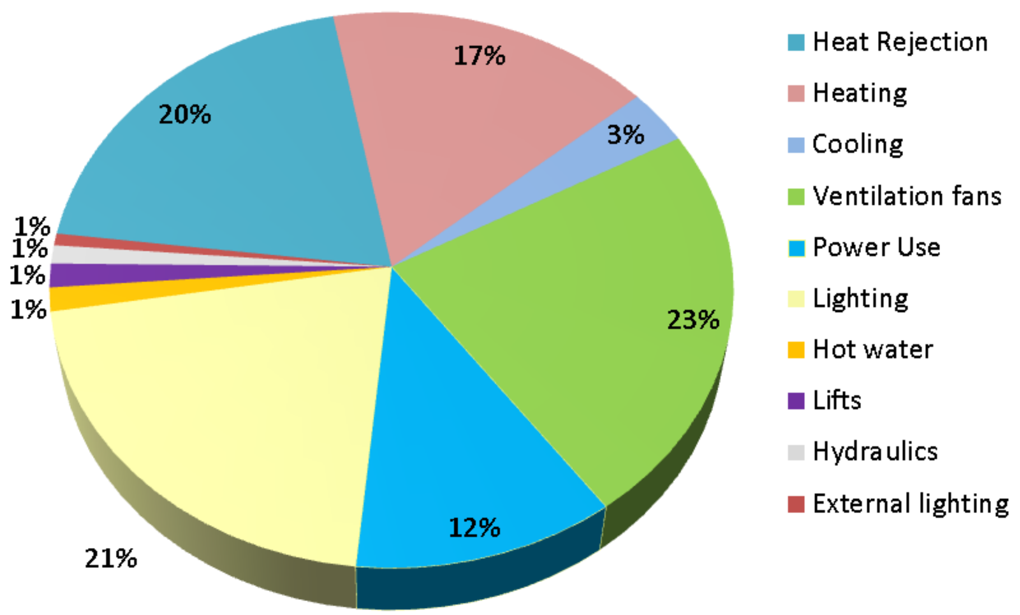

Figure 4 - Baseline Model, Benchmark Energy End Use Breakdown

It can be seen that heating, cooling, ventilation fans, and heat rejection energy makes up 63% of the annual energy use for the baseline model. Ventilation fans energy is the highest HVAC end use at 23% and is comprised of AHUs, supply air fans, fan coil units, and miscellaneous extract fans (e.g. toilets, kitchen exhaust, back of house etc). Heat rejection energy is the second largest energy user at 20% of overall energy and is comprised of the cooling tower fans and the condensing circuit's pumps. In the baseline model, the heat rejection operates at a constant speed, regardless of the cooling load. Heating energy is 17% and is comprised of outdoor air heating and space heating. Cooling energy accounts for only 3% due to the efficiency of the base case water cooled chiller.

The lighting and power (for computers, kitchen equipment and other equipment) makes up a further 33% of the annual energy usage. The baseline model assumes LED lighting and typical use of lighting and power with a low level of energy management being employed by building users. The energy use attributed to computers and other appliances can be a large variable and should be benchmarked as the design and Furniture, Fixtures and Equipment (FFE) stage progresses. The simulations have assumed equipment efficiency is not overly energy efficient at this stage but we recommend that an energy efficient equipment specification is targeted.

The remaining 4% of energy usage is for hydraulics, lifts, and external lighting.

5 Energy Efficiency Opportunities

The following Programme 2A energy efficiency opportunities were identified by Beca. The theoretical baseline model has been modified to represent each of the following energy efficiency opportunities (Refer to Appendix A for further details of computer model inputs):

- **External Solar Shading:** The addition of a theoretical solar shading element to level 4 north façade (refer to Figure 5). The shading has been modelled as a 2m overhang at roof level, but may also represent two 1m fins (one fin at roof level and the other at the midway point of the level 4 façade height). Shading of this configuration will shade from midday summer sun while allowing passive solar gain in winter.
- **Enhanced Roof Insulation:** The roofing option has an increased level of insulation and was modelled as follows:
  - Total R-value: R 3.0 m^2.K/W (including thermal bridging effects)
- **Enhanced Wall Insulation:** The wall option has an increased level of external wall insulation and was modelled as follows:
  - Total R-value: 2.0 m^2.K/W (including thermal bridging effects)
- **Enhanced Glazing:** Solar control Low-e Insulated Glazed Units (IGU) have a lower Shading Coefficient and G-value to reduce the amount of solar heat gain transmitted through the glazing and a higher thermal resistance to prevent heat loss through the glazed areas. The glazing was modelled as follows:
  - U_{window}: 3.0 W/m^2.K (including frame effect)
  - Shading Coefficient: 0.4
  - G value: 0.34
- **Combined Opportunities:** The following selected opportunities were simulated together:
  - Enhanced Roof Insulation
  - Enhanced Wall Insulation
  - Enhanced Glazing.

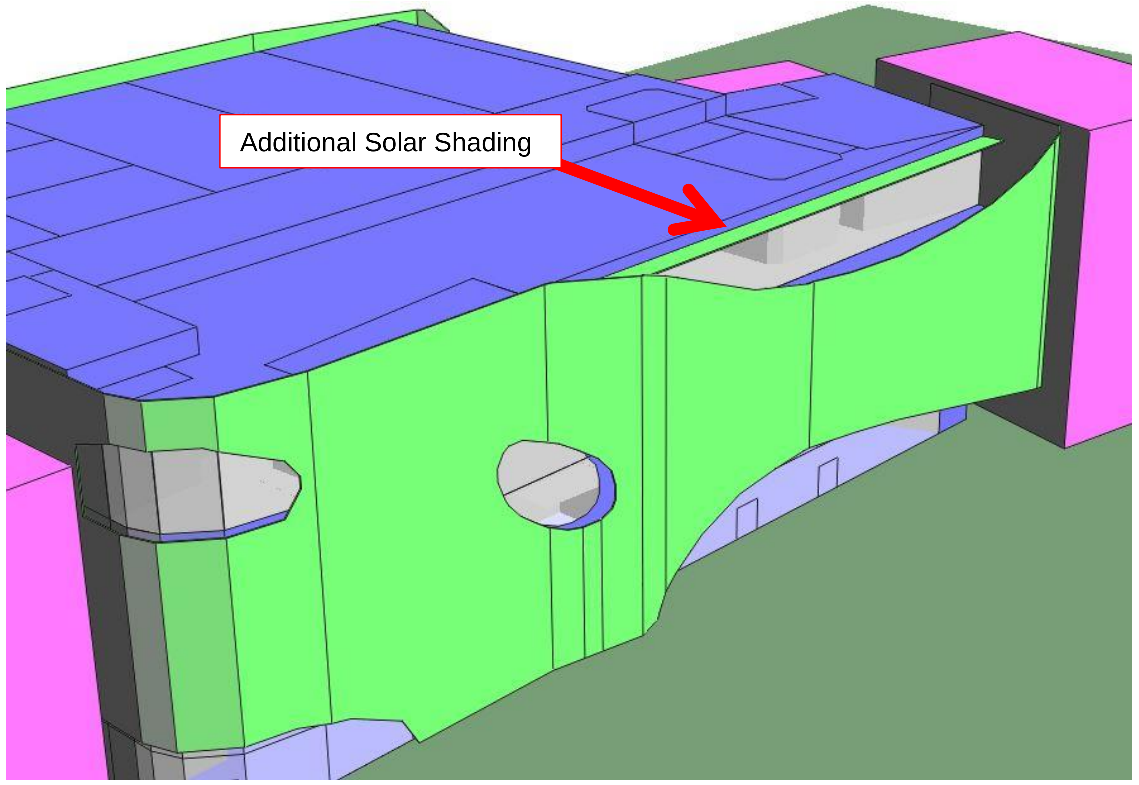

Figure 5 – Theoretical solar shading

6 Findings

Each computer model has been simulated over a typical Wellington weather year and the annual energy benefit of each energy efficiency opportunity is separately compared to the theoretical baseline model. The findings are as follows:

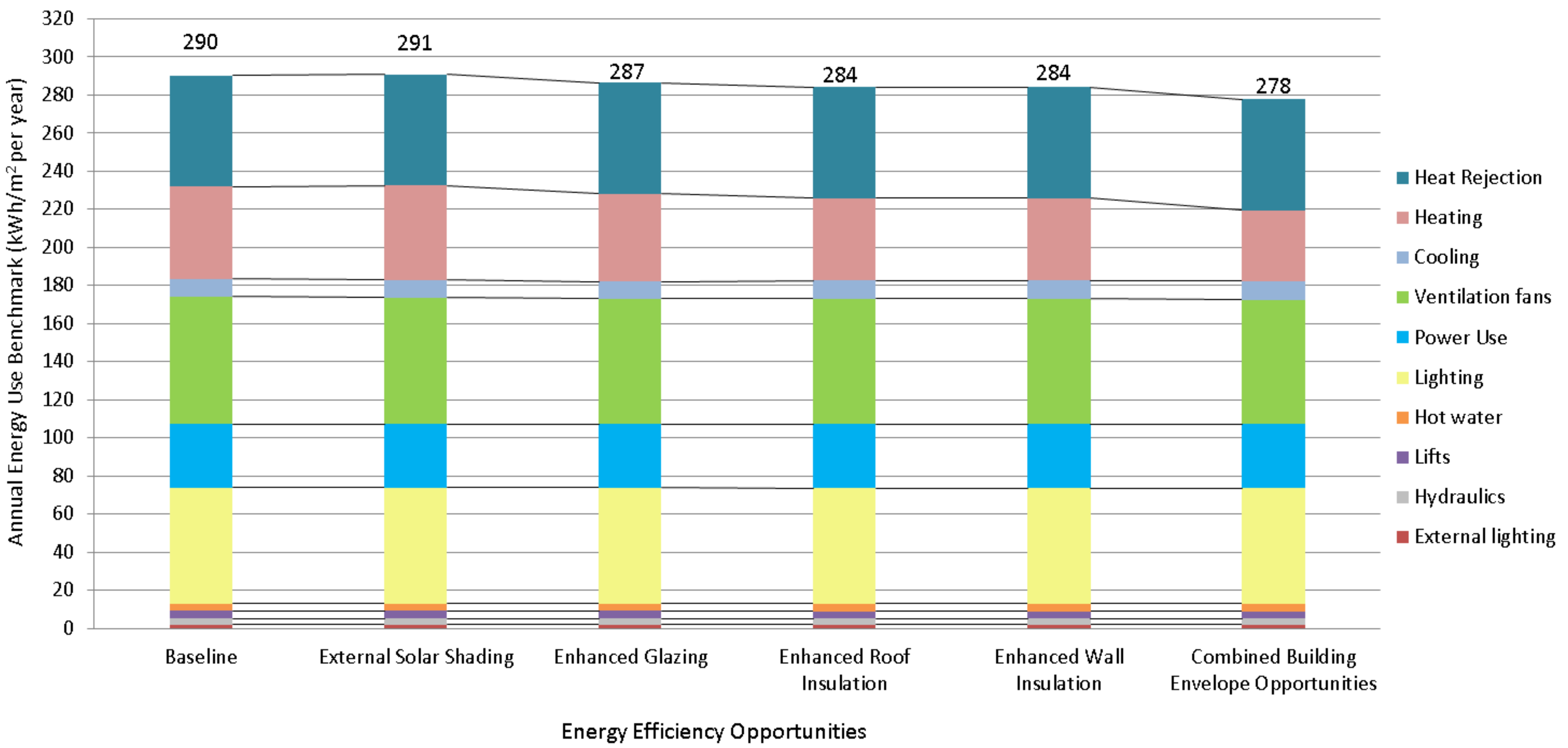

Figure 6 – Annual Energy Use Benchmark Comparison

- Installing solar shading increases energy consumption by 0.5kWh/m² per year due to the reduction in cooling energy being outweighed by an increase in heating energy consumption. However, due to the difference in the cost of gas and electricity, solar shading does achieve a $60 per year energy savings.

- Installing IGU Low-e Solar Control glazing is indicated to reduce energy consumption when compared to the baseline glazing. This is due to increased thermal resistance (increased U-value) and decreased heat loss through the glazed areas. It is indicated to decrease energy consumption by 4kWh/m² per year, as well as provide better thermal comfort due to a lower radiant effect in winter and summer.

- Increasing the roof and wall thermal resistance is indicated to reduce energy consumption by 6kWh/m² per year for each option.

- Combining the energy efficiency opportunities which offer an energy reduction (enhanced glazing, roof, and wall) is indicated to offer around 12kWh/m² per year energy savings compared to the NZBC baseline model. The energy savings of the combined energy efficiency options may reduce GHG emissions by more than 40 tonnes per year.

Table 1 – Annual Energy Savings Benchmark Summary

Annual Energy and Emissions Savings Benchmark	Enhanced Energy Efficiency Opportunities				
	External solar shading	Enhanced Glazing	Enhanced Roof Insulation	Enhanced Wall Insulation	Combined Building Envelope Opportunities
kWh/m² per year	-0.5	4	6	6	12
kWh per year	-7,000	58,000	96,000	96,000	196,000
$ per year	$60	$4,000	$6,000	$6,000	$11,000
Tonnes CO_2-e/ year	-2	12	21	21	43

7 Financial Performance Analysis

This section compares the financial performance of each energy efficiency opportunity. Please refer to Appendix B for detailed financial analysis of each enhanced energy efficiency opportunity identified over the NZBC baseline building.

The following indicative capital costs over the baseline have been estimated by Beca energy team generally based on previous project experience and supplier costs, however we recommend these are each confirmed by the project cost consultant:

- **Solar Shading ($50K):** Estimated based on a high level cost of adding a shading element above the glazing at the roof line of level 4.
- **Solar Control IGU Low-e ($80K):** Based on the NZBC minimum of clear single glazing @ $320/m² (8 mm clear toughened) compared to solar control low-e double glazing @ $385/m² (12.4mm clear toughened low-e + 8.4mm solar control toughened)
- **Roof Option ($25K):** Estimated based on a high level cost review comparing the lower insulation material cost @$58K compared to the proposed higher enhanced roof insulation (R 3.0 m².K/W)system @$83K.
- **Wall Option ($30K):** Estimated based on a high level cost review comparing the lower insulation material cost @$85.1K compared to the proposed higher enhanced wall insulation R 2.0 m².K/W)system @$115.1K.
- **Combined Opportunities ($135K):** The combined capital cost increase of the selected opportunities (enhance glazing, roof and wall).

The current WCC energy charge rates have been used as follows:

- Electricity: $0.10 per kWh
- Natural gas: $0.05 per kWh

The payback periods have been compared based on the following calculation while taking account of typical rates of inflation:

- Payback Period (in years) = Initial Investment Cost / Annual Operating Savings

Note that the following considerations have been allowed for in these calculations:

- Any reduction in heating or cooling plant or equipment costs as a result of each energy efficiency opportunity has not been considered
- An annual 2.5% inflation increase has been used as instructed by WCC
- A 6.5% discount rate has been used as instructed by WCC
- Maintenance costs have been excluded

A summary of the financial analysis can be seen in the following table:

Table 2 – Financial Analysis Summary

Financial Performance Indicator	Enhanced Energy Efficiency Opportunities				
	External Solar Shading	Enhanced Glazing (IGU Low-e Solar Control)	Enhanced Roof Insulation	Enhanced Wall Insulation	Combined Building Envelope Opportunities
Indicative Capital Cost[4]	$50K	$80K	$25K	$30K	$135K
Payback Period[5]	NA years	17 years	5 years	6 years	11 years
20 year NPV[6]	-$49,000	-$25,000	$49,000	$44,000	$10,000
20 year IRR	NA	2.4%	24.0%	20.1%	7.3%

[4] *Based on indicative increased capital cost over baseline option. Order of capital costs TBC by Cost Consultant. Excluding GST, contractor P+G and margins, contingency allowance, and professional fees. These estimates are for comparison purposes only, and not to establish construction budget or estimate operating expenses.*

[5] *Based on WCC electricity rate of 10¢/kWh and gas rate of 5¢/kWh with a 2.5% annual inflation rate assumed*

[6] *Assumes a 6.5% discount rate*

8 Comments & Recommendations

Each of the identified energy efficiency opportunities are indicated to offer energy cost savings compared to the baseline model, however solar shading increased energy consumption. Overall the combined opportunities (excluding the solar shading) are indicated to offer significant energy savings of approximately $11k per year (12kWh/$m^2$ per year) with a medium term payback period of 11 years. The medium term payback period is largely due to the relatively low energy rates WCC are currently paying. The payback period would be more favourable should energy rates increase in the future.

The highest level of energy savings is indicated to be offered by an enhanced level of external wall and roof insulation. The payback period is indicated as short-term at between 5 to 6 years.

The specification of an enhanced glazing performance is also indicated to offer a high level of energy savings with a long-term payback period of 17 years.

Along with offering energy savings the assessed building envelope opportunities are also recommended for improved occupancy thermal comfort to improve summer and winter radiant temperatures in the occupied spaces. External solar shading and glazing performance criteria may result in a reduced peak cooling load and resulting chiller plant capacity and required AHU sizes. Likewise increased thermal insulation will reduce the required boiler plant capacity. These potential capital cost savings have not been factored into the assessment.

The energy use attributed to computers and other appliances can be a large variable and should be benchmarked as the design and Furniture, Fixtures and Equipment (FFE) stage progresses. The simulations have assumed equipment efficiency is not overly energy efficient at this stage but we recommend that an energy efficient equipment specification is targeted.

We recommend that WCC considers including the above opportunities subject to meeting their investment criteria and the project budget.

9 Next Steps

We propose the following next steps:

1) Client team to review report & discuss with Beca
2) Project QS to review energy efficiency opportunities and confirm implementation cost
3) Project team to incorporate energy efficiency opportunities into building design subject to meeting WCC investment criteria and project budget
4) Beca to carry out Programme 2B Energy Efficiency Review to assess building services related energy efficiency opportunities (currently in progress)

Appendix A

Computer Simulation Model Inputs

Table 3 - Baseline Model Building Services inputs

Model Item	Baseline Energy Model Input	Model Input Reference	Comment
Building Documentation	▪ Based upon SPA architectural documents: dated 12 April 2016. ▪ Beca draft building services preliminary design as at 6 May 2016.		
Thermal simulation software	▪ IES Virtual Environment version 2015	▪ CIBSE	
Weather file for thermal simulation	▪ NIWA Wellington TMY2	▪ Assumed	▪ IWEC files have shown to contain errors in temperature data
Outdoor Design conditions	Summer: ▪ 23.6ºC DB ▪ 18.9ºC WB ▪ #hrs exceeded is 45 Winter ▪ 5.2ºC ▪ #hrs exceeded is 110	▪ NIWA	▪ 2.5% design day criteria
Ground solar reflectance	▪ 0.20	▪ (CIBSE) Assumed Asphalt	
Modelled spaces	▪ All conditioned and unconditioned spaces in the building ▪ Areas for each space taken from architectural drawings – 04/05/2016	▪ Architectural drawings ▪ Project mechanical engineer	
Assessed spaces	▪ Conditioned spaces	▪ Project Mechanical engineer	▪ Energy consumption of the retail areas is not considered.
Thermal zoning	▪ Spaces zoned to align with mechanical system design	▪ Project Mechanical engineer	
Manually controlled external shading device e.g. solar control blinds, external louvres etc	▪ Not modelled	▪ Project Mechanical engineer	
Automatically controlled shading device e.g. solar control blinds, external louvres	▪ Not modelled	▪ Project Mechanical engineer	
Design space temperature and humidity conditions	Convention Centre Space Plenary, Pre-Function, General Office, Meeting Rooms and Movie Museum Galleries: ▪ 23°C Cooling ▪ 20°C Heating Convention Centre BOH Circulation ▪ 18°C Heating Movie Museum BOH Circulation ▪ 18°C Heating Kitchen ▪ 16°C Heating Humidity: ▪ Not controlled	▪ Project Mechanical engineer	
Lighting power density	Convention Centre: ▪ Exhibition: 8 W/m² ▪ Plenary: 12 W/m² ▪ Pre-Function: 12 W/m² ▪ General Office Areas: 6 W/m² ▪ Meeting Rooms: 12 W/m² ▪ Circulation – Area FOH: 8 W/m² ▪ Circulation – Area BOH: 5 W/m² Movie Museum: ▪ Galleries: 8 W/m² ▪ Circulation – Area BOH: 4 W/m²	▪ Project Electrical Engineer.	▪ LED lighting design lighting power density
Lighting schedule	▪ Office and Museum: NABERS ▪ Convention Centre: Adapted NABERS for 9am to 10pm operation	▪ NABERS	
Peak equipment gains	Convention Centre: ▪ Exhibition: 5 W/m² ▪ Plenary: 15 W/m² ▪ Pre-Function: 15 W/m² ▪ General Office Areas: 11 W/m² ▪ Meeting Rooms: 11 W/m² ▪ Circulation – Area FOH: 5 W/m² ▪ Circulation – Area BOH: 5 W/m² Movie Museum: ▪ Galleries: 5 W/m² ▪ Circulation – Area BOH: 5 W/m²	▪ CIBSE Guide A Table 6.2 Assumptions ▪ NABERS	
Equipment schedule	▪ NABERS schedule for equipment is adapted similar to the lighting schedule	▪ NABERS	
Process load density	▪ Not modelled	▪ Project Mechanical engineer	▪ Covered under equipment gains

Model Item	Baseline Energy Model Input	Model Input Reference	Comment
Occupancy density	Convention Centre ▪ Kitchen/Cafe: 5m² / person ▪ Circulation – FOH and BOH: 5m²/ person ▪ Exhibition: 12m² / person ▪ Plenary: 12 m² / person ▪ Meeting Rooms: 12 m² / person ▪ Office: 15m² / person ▪ Lobby: 5m² / person Movie Museum: ▪ Gallery: 29m² / person ▪ Lobby: 5m² / person	▪ WCC movie museum business case	▪ Represent typical diversified density
Occupancy gains	▪ Exhibition, BOH, and Lobby : 75W sensible, 55W latent ▪ Kitchen:80W sensible 80W latent ▪ Plenary, Meeting, and Offices:70W sensible 35W latent	▪ CIBSE Guide A	
Occupancy schedule	▪ NABERS schedule for occupancy is adapted similar to the lighting schedule	▪ NABERS	
Infiltration rate	▪ 0.15 ACH all of the time (24hour occupancy)	▪ Project mechanical engineer	
Night purge ventilation	▪ Not modelled	▪ Project mechanical engineer	
Pressurisation requirements	▪ None	▪ Project mechanical engineer	
HVAC operating schedule	▪ Museum exhibition: 24/7 all year round ▪ Convention: 8am to 10pm, 7 days per week ▪ 1.5 hour optimum start period	▪ Project mechanical engineer	
Mechanical services control strategy	▪ Design room temperatures achieved during occupancy hours	▪ Project mechanical engineer	

Model Item	Baseline Energy Model Input	Model Input Reference	Comment
Outside air ventilation rate	Convention Centre: ▪ Exhibition: 8l/s.person ▪ Plenary: 8l/s.person ▪ Meeting Rooms: 10l/s.person General Offices: 10l/s.person ▪ Circulation – FOH and BOH: 1l/s.person ▪ Kitchen: 8l/s.person ▪ Cafe: 10l/s.person Movie Museum: ▪ Museum Gallery spaces: 8l/s.person ▪ Lobby/Circulation: 10l/s.person	▪ Beca design features report	
Outside air control	Movie Museum: ▪ 9am to 7pm, 7 days a week Convention Centre: ▪ 9am to 10pm, 7 days a week	▪ Project mechanical engineer	▪ No heat recovery or Demand Controlled Ventilation
Boiler SEER	▪ 90% (condensing gas fired boiler)	▪ Assumed ▪ NZBC Clause H1	▪ Outdoor air preheat and 4pipe FCU unit heating
Chiller SEER	▪ Full Load: 5.5 (water source chiller) ▪ Part load: 6.1	▪ New water cooled chiller plant	▪ Typical water cooled chiller efficiency
Heating Hot Water Loop	▪ HHW design flow temp: 60ºC -70ºC ▪ HHW design delta T: 10ºC ▪ HHW pump configuration: Constant Primary, Variable Secondary	▪ Project Mechanical Engineer	
Chilled Water Loop	▪ CHW design flow temp:6ºC -12ºC ▪ CHW design delta T: 6ºC ▪ CHW pump configuration: Constant Primary, Variable Secondary	▪ Project Mechanical Engineer	
Condensing Water Loop	▪ CDW design flow temp:29ºC -35ºC ▪ CDW design delta T: 6ºC ▪ CDW pump configuration: Constant Flow	▪ Project Mechanical Engineer	
Pipe/duct heat loss/gains	▪ 5% allowance	▪ Assumed	
Pumps	▪ Based on design flow rates	▪ Assumption	
AHU Fans	▪ 16°C preheat temperature ▪ Heating coil via HHW gas boiler circuit ▪ 10 no. AHU Variable Volume Fans: – Flow rates sized using IES ApacheHVAC – 2.5W/l.s	▪ Project mechanical engineer	▪ Typical fan efficiency

Model Item	Baseline Energy Model Input	Model Input Reference	Comment
Supply Air Fans	▪ 18°C preheat temperature ▪ Heating coil via HHW gas boiler circuit ▪ 2 no. fans: – SAF-01-01: 2,000l/s – SAF-05-01: 6,000l/s ▪ 2.5W/l.s	▪ Project mechanical engineer	▪ Typical fan efficiency
FCU fans	▪ 1 per FCU Zone ▪ 2.5W/l.s	▪ Project mechanical engineer	▪ Typical AC type FCU fan performance
Exhaust Air fans	▪ 7 no. fans: – EAF-01-01: 2,000 l/s – EAF-05-01: 4,000 l/s – EAF-05-02: 3,500 l/s – EAF-05-03: 2,500 l/s – EAF-05-04: 2,500 l/s – EAF-06-01: 2,000 l/s – EAF-06-02: 6,000 l/s ▪ 2.5W/l.s	▪ Project mechanical engineer	▪ Typical fan type performance
Lifts	▪ 4 kWh/m^2 per year	▪ GreenStar Office Design & Built 2009	
DHW	▪ 4 kWh/m^2 per year	▪ GreenStar Office Design & Built 2009	
External lighting	▪ 2 kWh/m^2 per year	▪ Assumed	

Table 4 - Baseline Model Architectural inputs

Model Item	Baseline Energy Model Input	Model Input Reference	Comment
Site location	▪ As site location ▪ Longitude = 174.80 E ▪ Latitude = 37.02 S	▪ Assumed	
Site Orientation	▪ As site location	▪ Architectural plan drawings	
Building Overshadowing	▪ Adjacent buildings modelled	▪ Architectural drawings	
Building Geometry	▪ As shown on architectural drawings	▪ Architectural drawings	
Building thermal envelope	▪ External walls: R 1.2 m^2.K/W (including thermal bridging effects) ▪ Roof: Total R-value: R 1.9 m^2.K/W (including thermal bridging effects) ▪ R 1.3 ground floor ▪ Glazing: – Uwindow: U 5.4 W/m2.K (including frame effect)	▪ H1 minimum values	▪ Clear 4mm single glazing reference
Glazing shading coefficient	▪ Vision glazing: – Shading Coefficient: 0.95 – G value: 0.82	▪ NZS4218	▪ 4mm single glazing reference
Internal walls	▪ 13mm plasterboard lining, 90mm timber framing, 13mm plasterboard lining	▪ Architectural drawings	
Intermediate floors	▪ Carpet +underlay, 150mm concrete slab, 1000mm ceiling cavity, 13mm plasterboard	▪ Architectural drawings	
External surface solar reflectance	▪ 0.5 (medium coloured) to be assigned to all external surfaces	▪ Assumed	
Area of glazing	▪ As per proposed design	▪ Architectural drawings	
Area of frame	▪ 10% glazing area	▪ Assumed	
Area of skylight/ clerestory	▪ None	▪ Architectural drawings	
Fixed external solar shading device	▪ Fixed Solar Shading modelled as per the proposed design.	▪ Architectural drawings	▪ Basecase allowance
Manually controlled curtains/blinds	▪ Blinds are not operated	▪ Assumed	
Manually controlled natural ventilation openings	▪ Not proposed	▪ Assumed	

Table 5 – NABERS lighting schedule

Museum and Office areas:

	12am-7am	7am-8am	8am-9am	9am-5pm	5pm-6pm	6pm-8pm	8pm-9pm	9pm-12am
Week	15%	40%	90%	100%	80%	60%	50%	15%
Saturday	15%	40%	90%	100%	80%	60%	50%	15%
Sunday	15%	40%	90%	100%	80%	60%	50%	15%

Convention Centre areas:

	12am-7am	7am-8am	8am-9am	9am-10pm	10pm-11pm	11pm-12pm
Week	15%	40%	90%	100%	80%	50%
Saturday	15%	40%	90%	100%	80%	50%
Sunday	15%	40%	90%	100%	80%	50%

Table 6 – NABERS equipment schedule

Museum and Office areas:

	12am-7am	7am-8am	8am-9am	9am-5pm	5pm-6pm	6pm-7pm	7pm-9pm	9pm-12am
Week	25%	65%	80%	100%	80%	65%	25%	25%
Saturday	25%	65%	80%	100%	80%	65%	25%	25%
Sunday	25%	65%	80%	100%	80%	65%	25%	25%

Convention Centre areas:

	12am-7am	7am-8am	8am-9am	9am-10pm	10pm-11pm	11pm-12pm
Week	25%	65%	80%	100%	80%	25%
Saturday	25%	65%	80%	100%	80%	25%
Sunday	25%	65%	80%	100%	80%	25%

Table 7 – NABERS occupancy schedule

Museum and Office areas:

	12am-7am	7am-8am	8am-9am	9am-5pm	5pm-6pm	6pm-7pm	7pm-9pm	9pm-12am
Week	0%	15%	60%	100%	50%	15%	5%	0%
Saturday	0%	15%	60%	100%	50%	15%	5%	0%
Sunday	0%	15%	60%	100%	50%	15%	5%	0%

Convention Centre areas:

	12am-7am	7am-8am	8am-9am	9am-10pm	10pm-11pm	11pm-12pm
Week	0%	15%	60%	100%	50%	15%
Saturday	0%	15%	60%	100%	50%	15%
Sunday	0%	15%	60%	100%	50%	15%

Table 8 – Energy Efficiency Opportunities

Model Item	Energy Model Input	Model Input Reference
Solar Shading	▪ 2m overhang at roof level above Level 4 north facade	
Enhanced Glazing	▪ IGU Low-e Solar Control – U_{window}: 3.0 W/m^2.K (including frame effect) – Shading Coefficient: 0.4 – G value: 0.34	
Enhanced Roof Insulation	▪ Total R-value: R 2.91 m^2.K/W (including thermal bridging effects)	
Enhanced Wall Insulation	▪ Total R-value: 2.0 m^2.K/W (including thermal bridging effects)	
Combined Energy Efficiency Opportunities	▪ Current Design proposal with the following opportunities combined: – Enhanced Glazing – Enhanced Roof – Enhanced Wall	▪ As above

Appendix B

Financial Performance Analysis

Solar Shading

Client Input Values	
Inflation Rate	2.5%
Discount Rate	6.5%

Assessment Inputs	
Capital Cost	$ 50,000
Secondary Capital Cost	$ -
Time of Secondary Capital Cost (Years)	0
Annual Savings	$60
Assessment Length (Years)	20

Assessment Results	
Payback Period (years)	NA
Total NPV	-$49,198
IRR	NA

Years	Annual Savings	Cummulative Savings	Payback	Capital Investment	Annual Cash Flow	Present Value of Saving	Net Present Value of Savings
0	$0	$0	-$50,000	$50,000	-$50,000	-$50,000	-$50,000
1	$60	$60	-$49,940	$0	$60	$56	-$49,944
2	$62	$122	-$49,879	$0	$62	$54	-$49,889
3	$63	$185	-$49,815	$0	$63	$52	-$49,837
4	$65	$249	-$49,751	$0	$65	$50	-$49,787
5	$66	$315	-$49,685	$0	$66	$48	-$49,739
6	$68	$383	-$49,617	$0	$68	$47	-$49,692
7	$70	$453	-$49,547	$0	$70	$45	-$49,647
8	$71	$524	-$49,476	$0	$71	$43	-$49,604
9	$73	$597	-$49,403	$0	$73	$41	-$49,563
10	$75	$672	-$49,328	$0	$75	$40	-$49,523
11	$77	$749	-$49,251	$0	$77	$38	-$49,484
12	$79	$828	-$49,172	$0	$79	$37	-$49,448
13	$81	$908	-$49,092	$0	$81	$36	-$49,412
14	$83	$991	-$49,009	$0	$83	$34	-$49,378
15	$85	$1,076	-$48,924	$0	$85	$33	-$49,345
16	$87	$1,163	-$48,837	$0	$87	$32	-$49,313
17	$89	$1,252	-$48,748	$0	$89	$31	-$49,282
18	$91	$1,343	-$48,657	$0	$91	$29	-$49,253
19	$94	$1,437	-$48,563	$0	$94	$28	-$49,225
20	$96	$1,533	-$48,467	$0	$96	$27	-$49,198
Total	$1,533		-$46,935				-$49,198

Glossary of Terms	
Discount Rate	The discount rate is the rate at which cash depreciates with time, hence the value of annual savings decreases.
Capital Cost	Capital costs are fixed one time expenses, typically the purchase of plant.
Present Value (PV)	PV is the present day value of the future returns from the investment.
Internal Rate Of Return (IRR)	IRR is the discount rate that make the NPV = 0 at the end of the assessment period. i.e. The Internal Rate of Return is the rate where if you discount all of the future cash flows, the present value of the flows is equal to the cost.
Net Present Value (NPV)	NPV is the sum of all previous PV's.

Enhanced Glazing (IGU Low-e Solar Control)

Client Input Values	
Inflation Rate	2.5%
Discount Rate	6.5%

Assessment Inputs	
Capital Cost	$ 80,000
Secondary Capital Cost	$ -
Time of Secondary Capital Cost (Years)	0
Annual Savings	$ 4,076
Assessment Length (Years)	20

Assessment Results	
Payback Period (years)	17.0
Total NPV	$ (25,487)
IRR	2.4%

Years	Annual Savings	Cummulative Savings	Payback	Capital Investment	Annual Cash Flow	Present Value of Saving	Net Present Value of Savings
0	$ -	$ -	$ (80,000)	$ 80,000	$ (80,000)	$ (80,000)	$ (80,000)
1	$ 4,076	$ 4,076	$ (75,924)	$ -	$ 4,076	$ 3,827	$ (76,173)
2	$ 4,178	$ 8,254	$ (71,746)	$ -	$ 4,178	$ 3,683	$ (72,489)
3	$ 4,282	$ 12,536	$ (67,464)	$ -	$ 4,282	$ 3,545	$ (68,944)
4	$ 4,389	$ 16,926	$ (63,074)	$ -	$ 4,389	$ 3,412	$ (65,532)
5	$ 4,499	$ 21,425	$ (58,575)	$ -	$ 4,499	$ 3,284	$ (62,248)
6	$ 4,612	$ 26,036	$ (53,964)	$ -	$ 4,612	$ 3,161	$ (59,088)
7	$ 4,727	$ 30,763	$ (49,237)	$ -	$ 4,727	$ 3,042	$ (56,046)
8	$ 4,845	$ 35,608	$ (44,392)	$ -	$ 4,845	$ 2,928	$ (53,118)
9	$ 4,966	$ 40,575	$ (39,425)	$ -	$ 4,966	$ 2,818	$ (50,301)
10	$ 5,090	$ 45,665	$ (34,335)	$ -	$ 5,090	$ 2,712	$ (47,589)
11	$ 5,218	$ 50,883	$ (29,117)	$ -	$ 5,218	$ 2,610	$ (44,979)
12	$ 5,348	$ 56,231	$ (23,769)	$ -	$ 5,348	$ 2,512	$ (42,467)
13	$ 5,482	$ 61,712	$ (18,288)	$ -	$ 5,482	$ 2,418	$ (40,050)
14	$ 5,619	$ 67,331	$ (12,669)	$ -	$ 5,619	$ 2,327	$ (37,723)
15	$ 5,759	$ 73,091	$ (6,909)	$ -	$ 5,759	$ 2,239	$ (35,484)
16	$ 5,903	$ 78,994	$ (1,006)	$ -	$ 5,903	$ 2,155	$ (33,328)
17	$ 6,051	$ 85,045	$ 5,045	$ -	$ 6,051	$ 2,074	$ (31,254)
18	$ 6,202	$ 91,247		$ -	$ 6,202	$ 1,996	$ (29,258)
19	$ 6,357	$ 97,604		$ -	$ 6,357	$ 1,921	$ (27,336)
20	$ 6,516	$ 104,120		$ -	$ 6,516	$ 1,849	$ (25,487)
Total	$ 104,120						$ (25,487)

Glossary of Terms	
Discount Rate	The discount rate is the rate at which cash depreciates with time, hence the value of annual savings decreases.
Capital Cost	Capital costs are fixed one time expenses, typically the purchase of plant.
Present Value (PV)	PV is the present day value of the future returns from the investment.
Internal Rate Of Return (IRR)	IRR is the discount rate that make the NPV = 0 at the end of the assessment period. i.e. The Internal Rate of Return is the rate where if you discount all of the future cash flows, the present value of the flows is equal to the cost.
Net Present Value (NPV)	NPV is the sum of all previous PV's.

Enhanced Roof Option

Client Input Values	
Inflation Rate	2.5%
Discount Rate	6.5%

Assessment Inputs	
Capital Cost	$ 25,000
Secondary Capital Cost	$ -
Time of Secondary Capital Cost (Years)	0
Annual Savings	$ 5,501
Assessment Length (Years)	20

Assessment Results	
Payback Period (years)	5.0
Total NPV	$ 48,571
IRR	24.0%

Years	Annual Savings	Cummulative Savings	Payback	Capital Investment	Annual Cash Flow	Present Value of Saving	Net Present Value of Savings
0	$ -	$ -	$ (25,000)	$ 25,000	$ (25,000)	$ (25,000)	$ (25,000)
1	$ 5,501	$ 5,501	$ (19,499)	$ -	$ 5,501	$ 5,165	$ (19,835)
2	$ 5,639	$ 11,140	$ (13,860)	$ -	$ 5,639	$ 4,971	$ (14,863)
3	$ 5,779	$ 16,919	$ (8,081)	$ -	$ 5,779	$ 4,785	$ (10,079)
4	$ 5,924	$ 22,843	$ (2,157)	$ -	$ 5,924	$ 4,605	$ (5,474)
5	$ 6,072	$ 28,915	$ 3,915	$ -	$ 6,072	$ 4,432	$ (1,042)
6	$ 6,224	$ 35,139		$ -	$ 6,224	$ 4,265	$ 3,223
7	$ 6,379	$ 41,518		$ -	$ 6,379	$ 4,105	$ 7,328
8	$ 6,539	$ 48,057		$ -	$ 6,539	$ 3,951	$ 11,280
9	$ 6,702	$ 54,760		$ -	$ 6,702	$ 3,803	$ 15,082
10	$ 6,870	$ 61,630		$ -	$ 6,870	$ 3,660	$ 18,742
11	$ 7,042	$ 68,672		$ -	$ 7,042	$ 3,522	$ 22,264
12	$ 7,218	$ 75,889		$ -	$ 7,218	$ 3,390	$ 25,654
13	$ 7,398	$ 83,288		$ -	$ 7,398	$ 3,263	$ 28,917
14	$ 7,583	$ 90,871		$ -	$ 7,583	$ 3,140	$ 32,057
15	$ 7,773	$ 98,644		$ -	$ 7,773	$ 3,022	$ 35,080
16	$ 7,967	$ 106,611		$ -	$ 7,967	$ 2,909	$ 37,988
17	$ 8,166	$ 114,777		$ -	$ 8,166	$ 2,799	$ 40,788
18	$ 8,370	$ 123,147		$ -	$ 8,370	$ 2,694	$ 43,482
19	$ 8,580	$ 131,727		$ -	$ 8,580	$ 2,593	$ 46,075
20	$ 8,794	$ 140,521		$ -	$ 8,794	$ 2,496	$ 48,571
Total	$ 140,521						$ 48,571

Glossary of Terms	
Discount Rate	The discount rate is the rate at which cash depreciates with time, hence the value of annual savings decreases.
Capital Cost	Capital costs are fixed one time expenses, typically the purchase of plant.
Present Value (PV)	PV is the present day value of the future returns from the investment.
Internal Rate Of Return (IRR)	IRR is the discount rate that make the NPV = 0 at the end of the assessment period. i.e. The Internal Rate of Return is the rate where if you discount all of the future cash flows, the present value of the flows is equal to the cost.
Net Present Value (NPV)	NPV is the sum of all previous PV's.

Enhanced Wall Option

Client Input Values	
Inflation Rate	2.5%
Discount Rate	6.5%

Assessment Inputs	
Capital Cost	$ 30,000
Secondary Capital Cost	$ -
Time of Secondary Capital Cost (Years)	0
Annual Savings	$ 5,501
Assessment Length (Years)	20

Assessment Results	
Payback Period (years)	6.0
Total NPV	$ 43,571
IRR	20.1%

Years	Annual Savings	Cummulative Savings	Payback	Capital Investment	Annual Cash Flow	Present Value of Saving	Net Present Value of Savings
0	$ -	$ -	$ (30,000)	$ 30,000	$ (30,000)	$ (30,000)	$ (30,000)
1	$ 5,501	$ 5,501	$ (24,499)	$ -	$ 5,501	$ 5,165	$ (24,835)
2	$ 5,639	$ 11,140	$ (18,860)	$ -	$ 5,639	$ 4,971	$ (19,863)
3	$ 5,779	$ 16,919	$ (13,081)	$ -	$ 5,779	$ 4,785	$ (15,079)
4	$ 5,924	$ 22,843	$ (7,157)	$ -	$ 5,924	$ 4,605	$ (10,474)
5	$ 6,072	$ 28,915	$ (1,085)	$ -	$ 6,072	$ 4,432	$ (6,042)
6	$ 6,224	$ 35,139	$ 5,139	$ -	$ 6,224	$ 4,265	$ (1,777)
7	$ 6,379	$ 41,518		$ -	$ 6,379	$ 4,105	$ 2,328
8	$ 6,539	$ 48,057		$ -	$ 6,539	$ 3,951	$ 6,280
9	$ 6,702	$ 54,760		$ -	$ 6,702	$ 3,803	$ 10,082
10	$ 6,870	$ 61,630		$ -	$ 6,870	$ 3,660	$ 13,742
11	$ 7,042	$ 68,672		$ -	$ 7,042	$ 3,522	$ 17,264
12	$ 7,218	$ 75,889		$ -	$ 7,218	$ 3,390	$ 20,654
13	$ 7,398	$ 83,288		$ -	$ 7,398	$ 3,263	$ 23,917
14	$ 7,583	$ 90,871		$ -	$ 7,583	$ 3,140	$ 27,057
15	$ 7,773	$ 98,644		$ -	$ 7,773	$ 3,022	$ 30,080
16	$ 7,967	$ 106,611		$ -	$ 7,967	$ 2,909	$ 32,988
17	$ 8,166	$ 114,777		$ -	$ 8,166	$ 2,799	$ 35,788
18	$ 8,370	$ 123,147		$ -	$ 8,370	$ 2,694	$ 38,482
19	$ 8,580	$ 131,727		$ -	$ 8,580	$ 2,593	$ 41,075
20	$ 8,794	$ 140,521		$ -	$ 8,794	$ 2,496	$ 43,571
Total	$ 140,521						$ 43,571

Glossary of Terms	
Discount Rate	The discount rate is the rate at which cash depreciates with time, hence the value of annual savings decreases.
Capital Cost	Capital costs are fixed one time expenses, typically the purchase of plant.
Present Value (PV)	PV is the present day value of the future returns from the investment.
Internal Rate Of Return (IRR)	IRR is the discount rate that make the NPV = 0 at the end of the assessment period. i.e. The Internal Rate of Return is the rate where if you discount all of the future cash flows, the present value of the flows is equal to the cost.
Net Present Value (NPV)	NPV is the sum of all previous PV's.

Combined Enhanced Envelope Options

Client Input Values	
Inflation Rate	2.5%
Discount Rate	6.5%

Assessment Inputs	
Capital Cost	$ 135,000
Secondary Capital Cost	$ -
Time of Secondary Capital Cost (Years)	0
Annual Savings	$ 10,829
Assessment Length (Years)	20

Assessment Results	
Payback Period (years)	11.0
Total NPV	$ 9,829
IRR	7.3%

Years	Annual Savings	Cummulative Savings	Payback	Capital Investment	Annual Cash Flow	Present Value of Saving	Net Present Value of Savings
0	$ -	$ -	$ (135,000)	$ 135,000	$ (135,000)	$ (135,000)	$ (135,000)
1	$ 10,829	$ 10,829	$ (124,171)	$ -	$ 10,829	$ 10,168	$ (124,832)
2	$ 11,100	$ 21,929	$ (113,071)	$ -	$ 11,100	$ 9,786	$ (115,046)
3	$ 11,377	$ 33,306	$ (101,694)	$ -	$ 11,377	$ 9,419	$ (105,627)
4	$ 11,662	$ 44,968	$ (90,032)	$ -	$ 11,662	$ 9,065	$ (96,562)
5	$ 11,953	$ 56,921	$ (78,079)	$ -	$ 11,953	$ 8,724	$ (87,838)
6	$ 12,252	$ 69,173	$ (65,827)	$ -	$ 12,252	$ 8,397	$ (79,441)
7	$ 12,558	$ 81,731	$ (53,269)	$ -	$ 12,558	$ 8,081	$ (71,360)
8	$ 12,872	$ 94,603	$ (40,397)	$ -	$ 12,872	$ 7,778	$ (63,582)
9	$ 13,194	$ 107,797	$ (27,203)	$ -	$ 13,194	$ 7,486	$ (56,096)
10	$ 13,524	$ 121,321	$ (13,679)	$ -	$ 13,524	$ 7,205	$ (48,892)
11	$ 13,862	$ 135,183	$ 183	$ -	$ 13,862	$ 6,934	$ (41,958)
12	$ 14,209	$ 149,392		$ -	$ 14,209	$ 6,674	$ (35,284)
13	$ 14,564	$ 163,956		$ -	$ 14,564	$ 6,423	$ (28,861)
14	$ 14,928	$ 178,884		$ -	$ 14,928	$ 6,182	$ (22,680)
15	$ 15,301	$ 194,185		$ -	$ 15,301	$ 5,949	$ (16,730)
16	$ 15,684	$ 209,868		$ -	$ 15,684	$ 5,726	$ (11,004)
17	$ 16,076	$ 225,944		$ -	$ 16,076	$ 5,511	$ (5,493)
18	$ 16,478	$ 242,422		$ -	$ 16,478	$ 5,304	$ (189)
19	$ 16,890	$ 259,311		$ -	$ 16,890	$ 5,105	$ 4,916
20	$ 17,312	$ 276,623		$ -	$ 17,312	$ 4,913	$ 9,829
Total	$ 276,623						$ 9,829

Glossary of Terms	
Discount Rate	The discount rate is the rate at which cash depreciates with time, hence the value of annual savings decreases.
Capital Cost	Capital costs are fixed one time expenses, typically the purchase of plant.
Present Value (PV)	PV is the present day value of the future returns from the investment.
Internal Rate Of Return (IRR)	IRR is the discount rate that make the NPV = 0 at the end of the assessment period. i.e. The Internal Rate of Return is the rate where if you discount all of the future cash flows, the present value of the flows is equal to the cost.
Net Present Value (NPV)	NPV is the sum of all previous PV's.