01 October 2021 Ref: IRC-2309

Dear

RE: Tākina Conference & Exhibition Centre.

Thank you for your email to the Council received on 27 August 2021 in which you asked a number of questions in respect of *"…the energy source used to power Tākina Wellington Convention and Exhibition Centre ('Tākina').*

The following overview of the project may provide some useful context in respect of your questions.

Prior to the commencement of work on the site in August 2019, there had been a number design stages, such as the Convention Centre and Film Museum preliminary design in 2016, and the Preliminary Design update for the Wellington Convention Centre and Exhibition Centre – Tākina in 2018.

Some of the key considerations in respect of the design of Tākina relate to resilience, climate change, managing energy demand, and reducing operational carbon emissions.

Resilience:

Tākina has been designed to very high standards of seismic resilience which enables a return to business as usual as quickly as possible after an emergency event. It is fully base isolated, which is the 'gold standard' in low damage design. The internal diagrid structure limits inter-story movement which is a major cause of fit-out damage. This design is estimated to reduce significant structural damage by up to 10 times that expected in a standard steel and concrete framed building.

Additionally, the ground floor sits 3.5m above sea level to ensure the risk of surface water flooding entering the building has been mitigated.

Energy efficiency:

In 2016, to inform the early design process, Wellington City Council engaged with the Energy Efficiency and Conservation Authority (EECA), who funded two studies through their energy efficiency advisory service. Please find copies attached.

The objective of the EECA reports was to provide the Council with energy efficiency advice which would allow the project team to make decisions regarding the building envelope design and the heating/ventilation/air-conditioning (HVAC) options at an early stage in the design process. ECCA Programme 2A and 2B technical reports were commissioned (attached).

EECA Programme 2A: Initial concept for a new building

This report reviewed the proposed plans and used thermal modelling of the building envelope to identify potential energy saving opportunities associated with the facade design. It also provided a payback period and financial performance assessment of the energy efficient design options.

EECA Programme 2B: Fit-out design and construction

This report provided further analysis of the baseline energy use of the building, including identifying and estimating the variables and factors that would affect the energy use baseline such as occupancy and operating conditions etc. The report also provided financial analysis of further potential energy saving opportunities available to the project such as improved HVAC plant and system efficiencies, and heat recovery devices. Each opportunity was considered from an energy, Greenhouse Gas emissions and energy cost perspective

The reports identified which options should be considered for inclusion into the design, including:

- Optimising the building envelope and systems to minimise heating requirements via:
  - double glazed and well-insulated thermal envelope
  - demand controlled ventilation systems
  - heat recovery from exhaust air
  - decentralised electric domestic hot water heating to remove circulation heat losses (with back up from heating system).

- Electric Heat pump heating for shoulder seasons
- Remaining heating for peak loads via high efficiency gas boilers (note: these also provide domestic hot water for the commercial kitchens).

Electrical Network Capacity:

During the project related discussions with Wellington Electricity (WE) it became apparent that the electrical utility network capacity in the area around Tākina had insufficient capacity to accommodate the anticipated diversified peak electrical load for the new building. WE indicated that if the new building required the anticipated capacity, they would need to significantly upgrade their network. This was not a situation that the Council wanted to induce, so a review was undertaken to determine what mitigation measures could be put in place that would reduce peak electrical load.

As a result, the building is being equipped with systems and components that will allow its peak electricity consumption to be managed within the existing network capacity. These systems/components include:

- an active electrical load monitoring and shedding system which will operate via the Building Management System (BMS)
- monitoring of the building post occupancy and during the first year of operation to fine tune the automated systems to manage the building load within the installed capacity without noticeable loss of building performance
- provision of connection points for installation of a portable temporary generator set for one-off large events
- the ability to install a Photovoltaic electricity generation system (electricity-generating solar panels) of up to 200kW capacity on the roof.

NZGBC Green Star Certification:

Tākina's design has been awarded a New Zealand Green Building Council 5 Green Star NZ Custom Tool Certified Rating, and upon completion, an As-built rating will be sought. Operational energy and greenhouse gas emissions modelling has been carried out as part of the Green Star submission.

Features include:

- Enhanced thermal insulation and high-performance double glazing
- Rainwater harvesting system (30,000 litres) for toilet flushing and evaporative cooling to reduce water consumption by 30 percent
- High efficiency LED lighting system and automatic controls for energy savings
- Adaptable and demand-controlled air conditioning system reducing energy use
- Predominantly heat pump heating to reduce reliance on fossil fuels
- The building is designed to operate efficiently at all levels of use, from large conference events to smaller events
- Decentralised domestic hot water system to reduce energy when the building is not in use
- Leading edge post occupancy energy optimisation systems to monitor and fine tune energy usage
- Future proofed to accommodate on-site renewable energy generation via roof mounted photovoltaic array
- Structural diagrid for building resiliency and reduced steel requirements
- Environmentally preferable materials specification to provide improved indoor air quality and reduced environmental impact
- Timber materials sourced from sustainable forestry

- Display screens located on the ground floor will communicate the green credentials of the building, with visitors able to see real-time building sustainability metrics such as water and energy consumption, as well as carbon emissions
- Regeneration of a former carpark site into a civic amenity.

I will now address each of your questions in the order of your email.

1) Will Tākina use fossil fuels as part of its energy/heating system?

Tākina's energy/heating system will use both electricity and gas. One of the aims of the design has been to reduce reliance on fossil fuels and on energy sources for heating generally.

2) Will gas boilers be used as part of Tākina energy/heating system?

The boilers will only be used for heating during peak loads, and are primarily used to provide domestic hot water in the commercial kitchens.

3) I understand Central Heating New Zealand Ltd are supplying NME Group Wellington with gas boilers to drive the Tākina energy/heating system, is this correct?

Central Heating New Zealand Ltd has supplied the project with gas boilers to provide hot water in the commercial kitchens and provide additional heating at peak times. The gas boilers do not drive the Tākina energy/heating system as this is led by the use of heat pumps which aim to reduce reliance on fossil fuels.

4) Was there any consideration of Wellington City Council policy or strategy for 'Energy Management and Strategy Plan-Gas Boiler Phase Out' in relation for the energy sources for Tākina, if so could information relating to this consideration be released?

The energy strategy for Tākina was extensive, incorporated a range of the factors outlined above, and culminated in the design being awarded 5* Green Star status.

Gas is a very small component of the overall energy strategy. When the gas boilers are at the end of their useful lives consideration will be given based on any constraints at the time.

5) Was there any consideration of 'Te Atakura' and Wellington City Council 'Sustainable Asset Policy' in relation to the energy sources for Tākina, if so could information relating to this consideration be released?

The Tākina design process included important factors that were later adopted within Te Atakura, such as energy efficiency, reducing carbon emissions and sustainable buildings. The design itself was finalised and construction had commenced, prior to the adoption of *Te Atakura.*

6) Was there any consideration of MBIE's 'Building for Climate Change policy' in relation to the energy sources for Tākina, if so could information relating to this consideration be released?

Again, the Tākina design had been finalised and construction commenced prior to the announcement of the *Building for Climate Change* programme, but it uses sustainable design features. Tākina is the first Conference Centre in NZ to attain a sustainability rating attested by the 5* Green Star certification. As noted above, the building has been designed with climate change and resilience at its heart incorporating features such as grey water collection and re-use, raising the building against floods, and energy efficiency.

7) Was there any consideration of the recent Climate Change Commission (He Pou a Rangi) Report/Advice 'Ināia tonu nei' and the IPCC '6th Assessment Report' in relation to the energy sources for Tākina, if so could information relating to this consideration be released?

The Tākina design had been finalised and construction commenced prior to the announcement of the Climate Change Commission *(He Pou a Rangi) Report/Advice 'Ināia tonu nei'* and the IPCC *'6th Assessment Report'.* However, Takina has subsequently achieved 5* Green Star certification.

8) I understand the building concept design behind Tākina is to invoke/summon the wind as powerful force in and identity of Te Whanganui a Tara, were alternative sustainable/green energies such as wind power considered in relation to the energy sources for Tākina, if so could information relating to this consideration be released?

The building has infrastructure in place so that on-site renewable energy generation via a roof mounted photovoltaic array (electricity-generating solar panels) can be accommodated in the future.

Kind regards,
Ian

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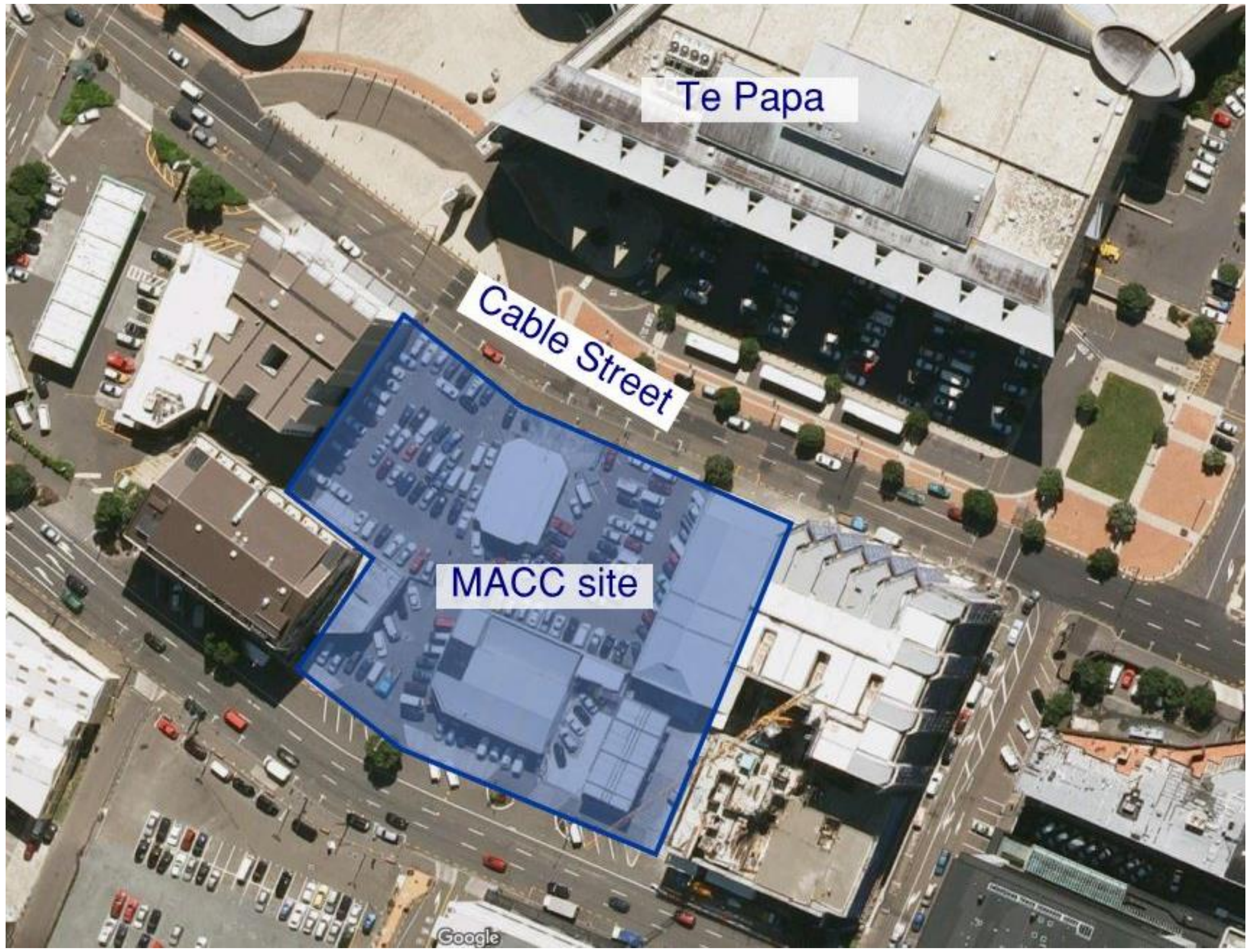
Report

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			
5			

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		

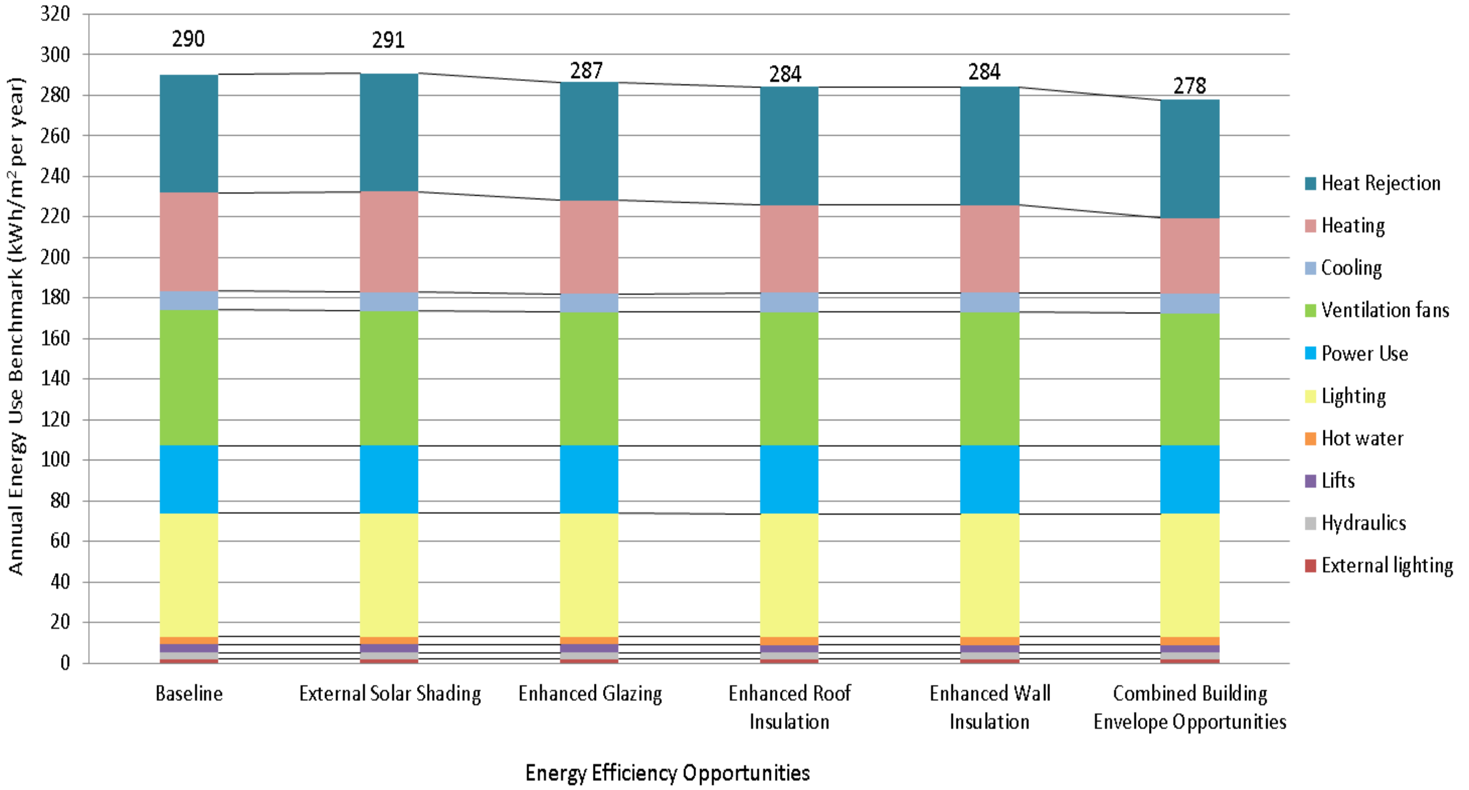
Executive Summary

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*

Contents

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

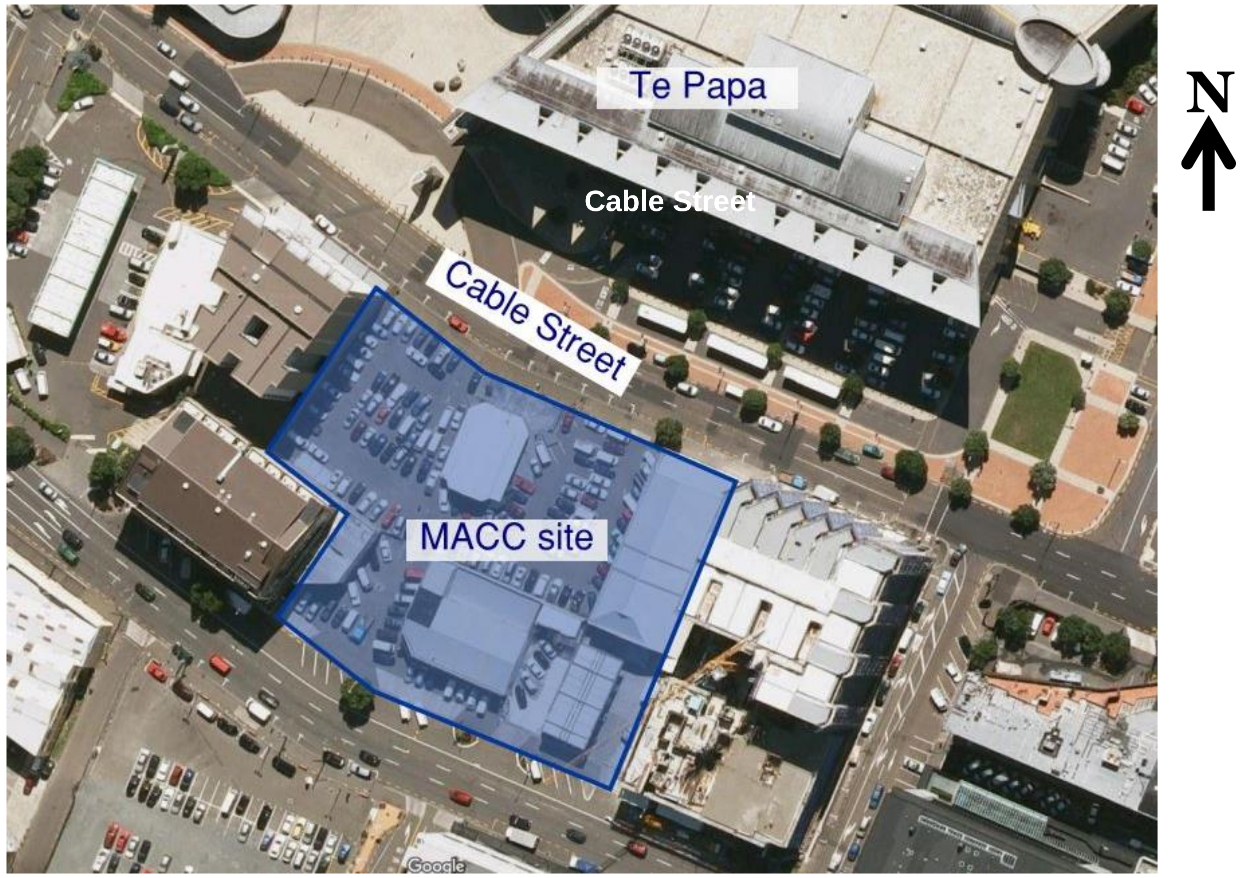


Figure 1 – Proposed site location on the existing Cable Street site

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:

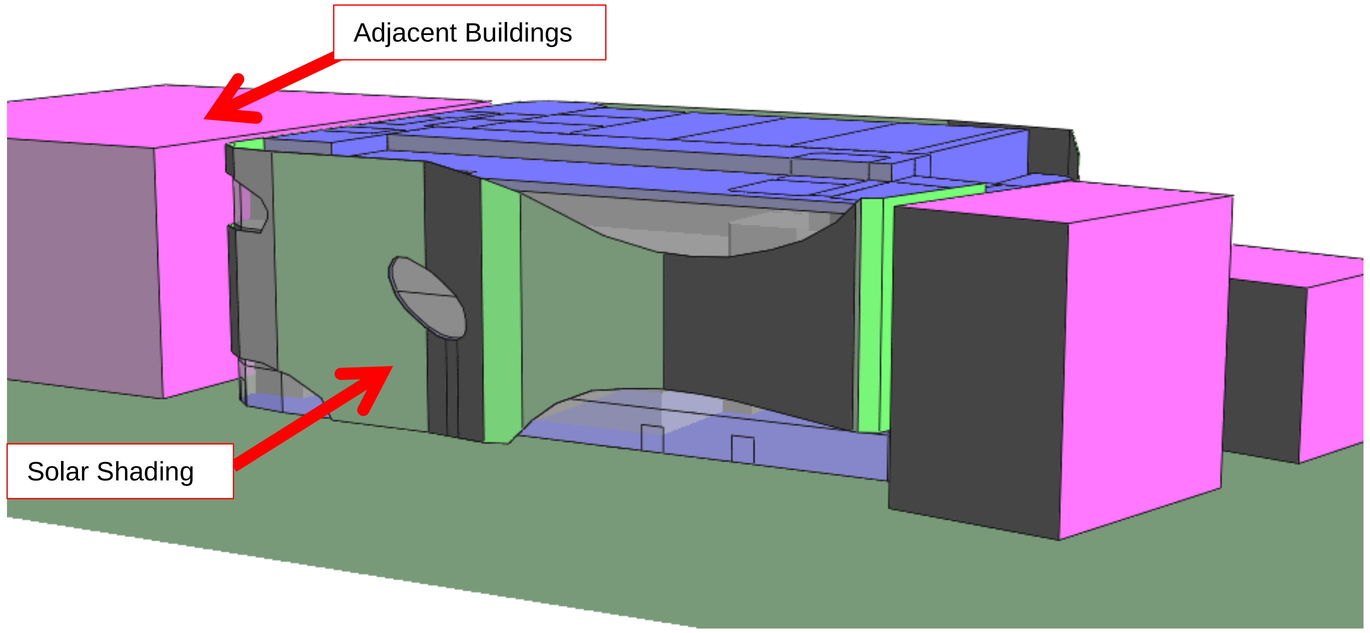


Figure 2 - Computer simulation model showing proposed façade design, view from north.

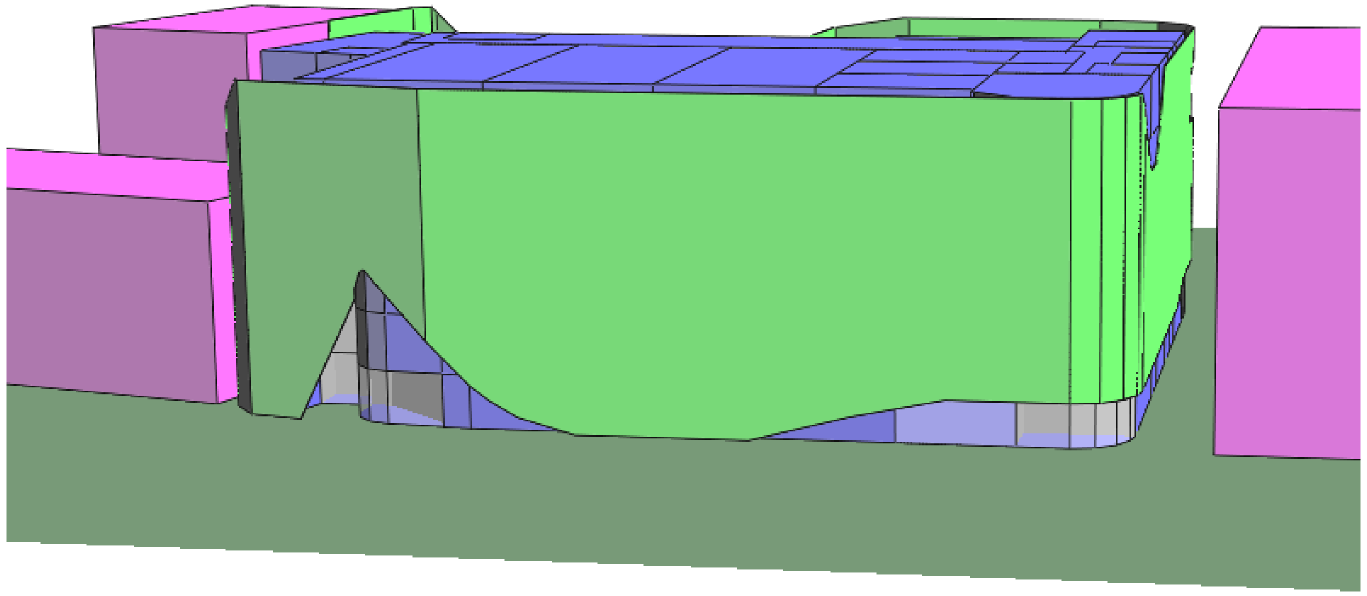


Figure 3 - Computer simulation model showing proposed façade design, view from south

Benchmark Energy End Use Breakdown

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

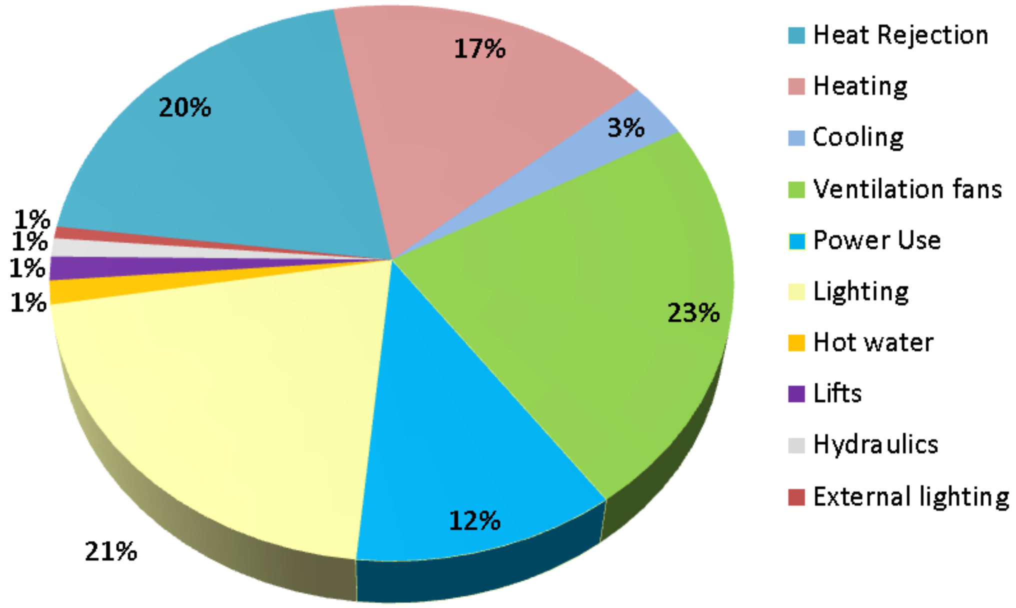


Figure 4 - Baseline Model, Benchmark Energy End Use Breakdown

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.

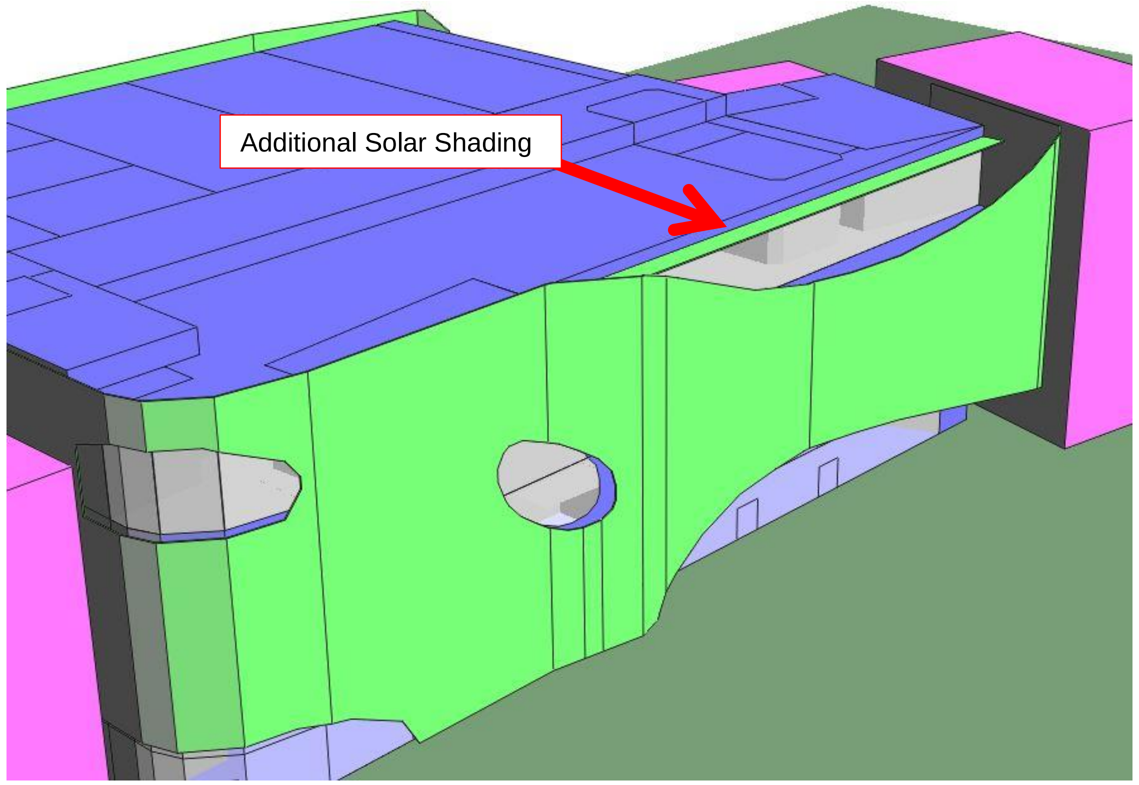


Figure 5 – Theoretical solar shading

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:

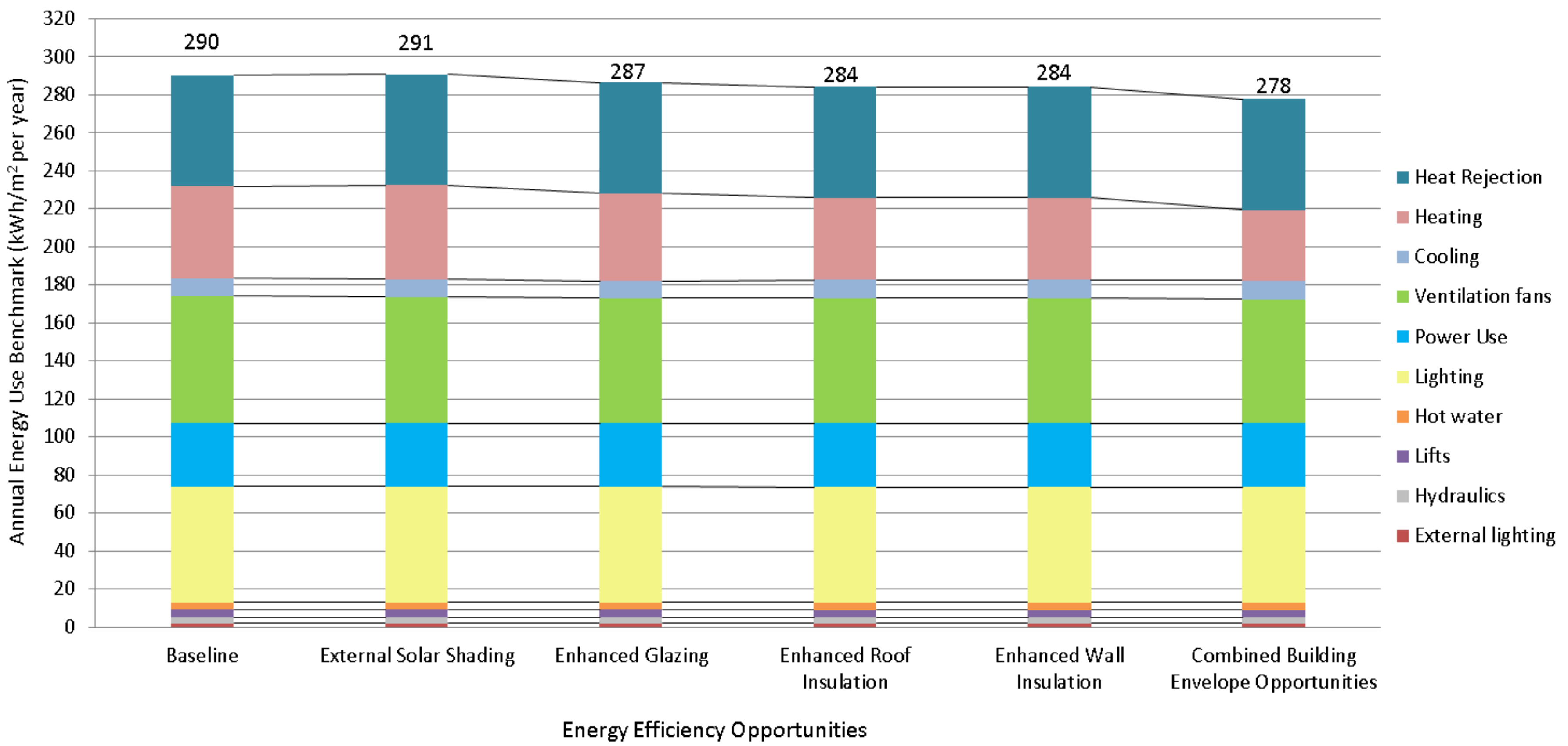


Figure 6 – Annual Energy Use Benchmark Comparison

- Installing solar shading increases energy consumption by 0.5kWh/m^2 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/m^2 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/m^2 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/m^2 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/m^2 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	

Model Item	Baseline Energy Model Input	Model Input Reference	Comment
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: 5m^2 / person ■ Circulation – FOH and BOH: 5m^2/ person ■ Exhibition: 12m^2 / person ■ Plenary: 12 m^2 / person ■ Meeting Rooms: 12 m^2 / person ■ Office: 15m^2 / person ■ Lobby: 5m^2 / person Movie Museum: ■ Gallery: 29m^2 / person ■ Lobby: 5m^2 / 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.

Beca

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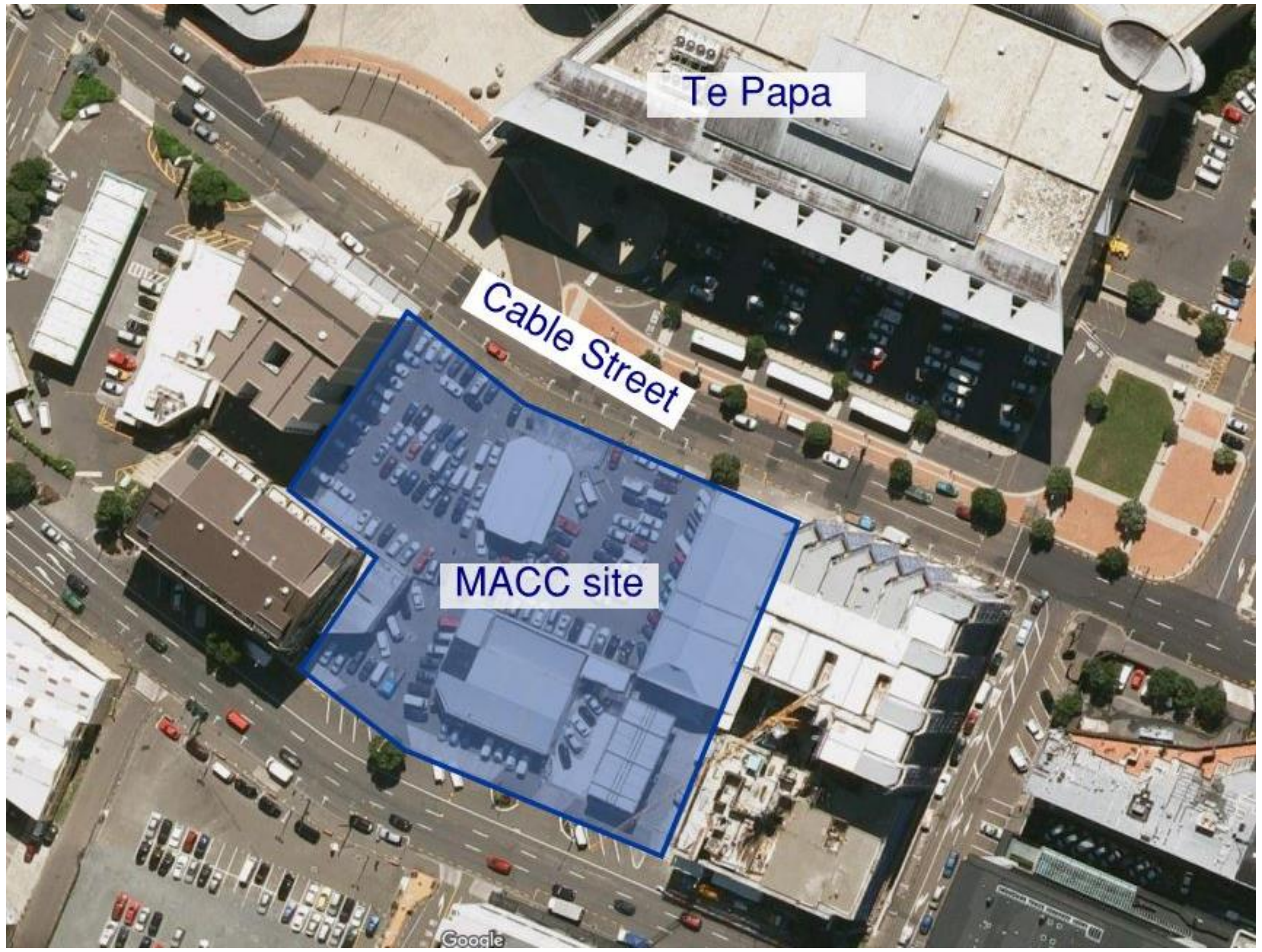
Report

MACC - EECA Programme 2B Energy Efficiency Review (Building Services)

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			
5			

Document Acceptance

Action	Name	Signed	Date
Prepared by	Shaan Cory		2 June 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 building services energy efficiency opportunities assessed as part of the EECA Programme 2B energy efficiency advisory service for the proposed Museum and Convention Centre (MACC) project. The energy efficiency review has used computer simulation modelling to benchmark annual energy use savings against a theoretical baseline building model.

Table 1 - Comparison of Building Services Energy Efficiency Opportunities

Scenario		Description	Annual Energy and Emissions Savings Benchmark					Financial Performance Indicator			
			Energy Use (kWh/m^2)	kWh/m^2 per yr	kWh per yr	$ per year	Tonnes CO2-e/ year	Indicative Capital Cost[1]	Payback Period[2]	20 year NPV[3]	20 year IRR
1	Enhanced HVAC Control Opportunities	Baseline: EECA 2A report Combined Enhanced Envelope	278	-	-	-	-	-	-	-	-
2		Baseline + Daylight Harvesting in FOH Areas	277	1	12,000	$ 1,600	2	$21k	12 years	$800	7.0%
3		Baseline + Economiser	274	3	51,000	$ 7,000	7	$5k	1 years	$89,000	142.5%
4		Baseline + Exhaust Air Heat Recovery	272	6	96,000	$ 5,000	22	$20k	5 years	$42,000	25.2%
5		Baseline + Demand Control Ventilation (DCV)	258	20	312,000	$ 14,000	71	$15k	2 years	$174,000	96.8%
6		Baseline + Movie Museum Gallery HVAC Off Overnight	250	27	429,000	$ 42,000	78	$0k	0 years	$561,000	NA
7		Combined HVAC Control Opportunities (Baseline + Scenarios 2, 3, 4, 5 and 6)	233	44	700,000	$ 60,000	134	$61k	2 years	$742,000	101.0%
8	Enhanced Energy Efficient Design Opportunities	Scenario 7 + Condensing Loop Heat Pump	232	1	13,000	$ 500	3	$40k	80 years	-$34,000	-9.0%
9		Scenario 7 + Magnetic Bearing Water Cooled Chiller	231	2	38,000	$ 4,000	7	$118k	30 years	-$67,000	-1.7%
10		Scenario 7 + Low Specific Fan Power (SFP) Central Air Handling	225	9	136,000	$ 15,000	23	$17k	1 years	$284,000	134.9%
11		Scenario 7 + Variable Speed Cooling Tower	216	18	278,000	$ 28,000	50	$10k	1 years	$361,000	280.1%
12		Scenario 7 + Air Sourced Heat Pump	216	18	278,000	$ 5,000	44	$39k	7 years	$31,000	14.4%
13		Scenario 7 + Waste Water Heat Pump	215	19	293,000	$ 7,000	47	$264k	38 years	-$174,000	-3.5%
14		Scenario 7 + Variable Volume Condensing Water Loop	211	22	351,000	$ 35,000	62	$50k	2 years	$419,000	72.6%
15		Scenario 7 + Energy Piles	203	30	475,000	$ 47,000	85	$303k	6 years	$338,000	17.2%
16		Combined Efficient Design Opportunities (Scenario 7 + Scenarios 10, 11, 12, 13, and 15)	165	69	1,079,000	$ 86,000	188	$419k	6 years	$495,000	17.8%
17		Scenario 16 + Roof Mounted Photovoltaics	149	16	250,000	$ 25,000	45	$344k	12 years	-$10,000	6.2%

The findings are as follows:

- The combined savings of implementing Daylight Harvesting, Economiser, DCV, Exhaust Air Heat Recovery, and switching the Movie Museum Galleries HVAC Off overnight is indicated as a substantial reduction of 44kWh/m^2 per year and 134 tonnes of associated Greenhouse Gas (GHG) emissions per year. The opportunities indicate a payback period of 2 years, with a NPV of approximately $740K and an IRR of 101% across a 20 year period.

- Further energy reductions can be achieved by installing Variable Speed Cooling Tower Fans, a Variable Volume Condensing Water Loop, an Air Sourced Heat Pump, Energy Piles and designing for a Low SFP central air handling (includes efficient motors). The combination of the these opportunities is indicated to reduce energy consumption by 69kWh/m^2 per year, $86K of cost savings per year, and a reduction of 188 tonnes of associated GHG emissions per year. They are indicated to have a short payback period of 6 years, even with the low energy rates WCC are currently paying. The 20 year NPV is indicated to be just under $500K with an IRR of 17.8%, which suggests these options would result in a favourable return on investment.

- Incorporating the combined envelope measures outlined in the EECA 2A report, the combined HVAC controls and combined HVAC design opportunities is indicated to reduce energy consumption by approximately 40% (125kWh/m^2 per year, $150k of cost savings per year, and a reduction of 365 tonnes of associated GHG emissions per year). The 40% reduction in energy consumption is indicated to have a short payback period of under 5 years and an indicative 20 year NPV of over $1 million dollars with an IRR of over 20%. All suggesting that the combination of the building envelope and system options would result in a favourable return on investment. These figures exclude roof mounted PV which should be considered given the visual statement and marketing opportunity a PV installation would represent.

- High efficiency motors will be specified during the selection process. For example, selections with EC motors will be undertaken as EC motors have mid-high 90% efficiencies. Note: the 60-70% efficiency displayed on the AHU fan data sheets provided by suppliers represent the total efficiency of the entire fan assembly, which takes into account the EC motor efficiency, the fan scroll efficiency and any losses.

[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*

Contents

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 2B Advisory service requirements.

As summarised by EECA:

The objective of Programme 2B is to ensure that energy efficiency features [Building Services] *are incorporated into the more detailed design and construction of the Building. Where the Building has been part of a Programme 2A Project, it will be important that the recommendations from the Programme 2A report are included in the detailed design and construction (if possible).*

The EECA Programme 2A report has been carried out in parallel with this report and is focussed on an energy efficient building envelope.

The energy efficiency review uses computer simulation modelling to benchmark the energy performance benefit of selected 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 MACC

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

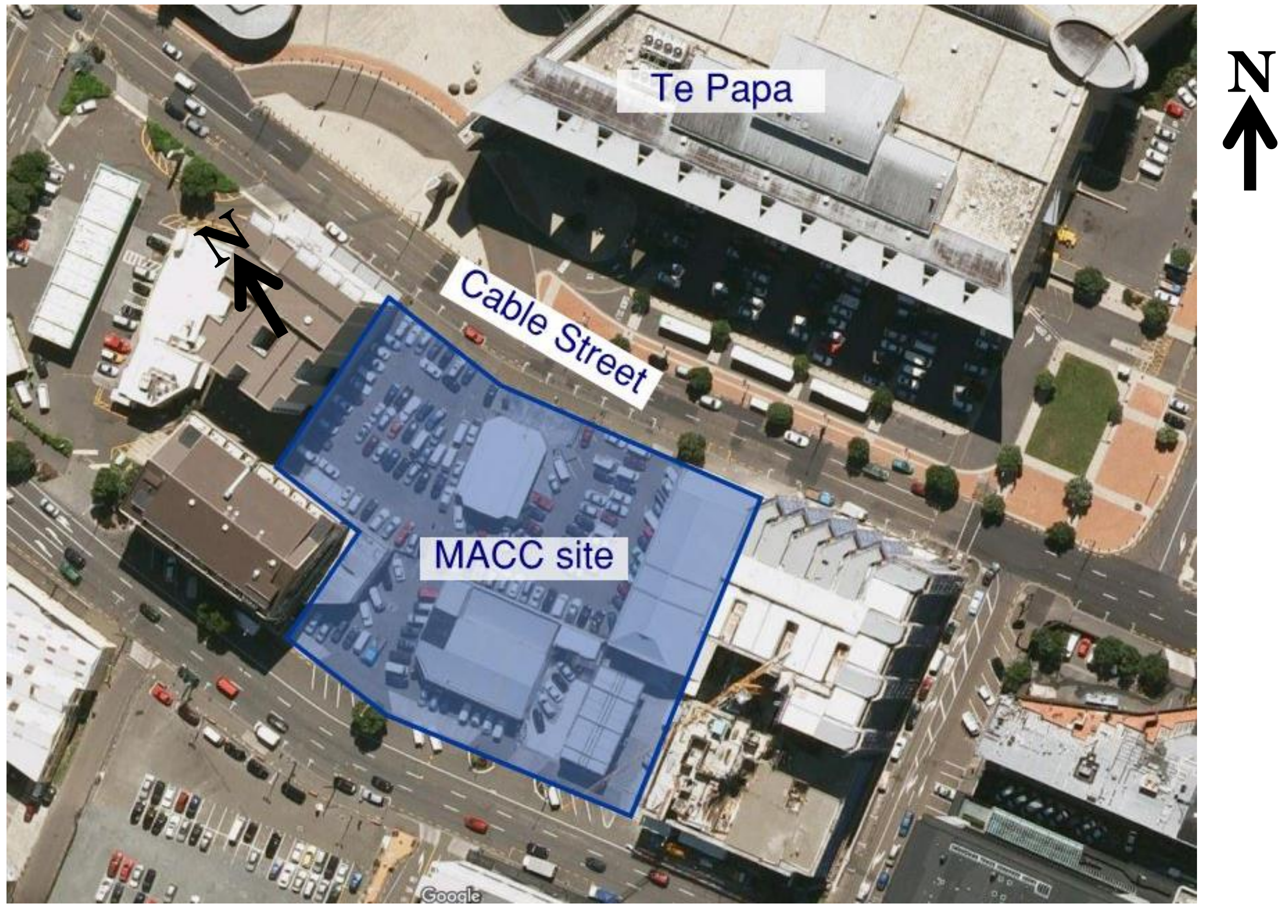


Figure 1 – Proposed site location on the existing Cable Street site

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 accurately 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

The thermal envelope has been modelled to represent the combined EECA 2A proposed building thermal envelope performance:

- External walls: R 2 m2.K/W (including thermal bridging effects)
- Roof: Total R-value: R 3 m2.K/W (including thermal bridging effects)
- R 1.3 ground floor
- Vision Glazing:
  - Uwindow: U 3.0 W/m2.K (including frame effect)
  - Shading Coefficient: 0.40
  - G value: 0.35

The baseline model includes the external solar shading surrounding the building and the adjacent buildings.

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:

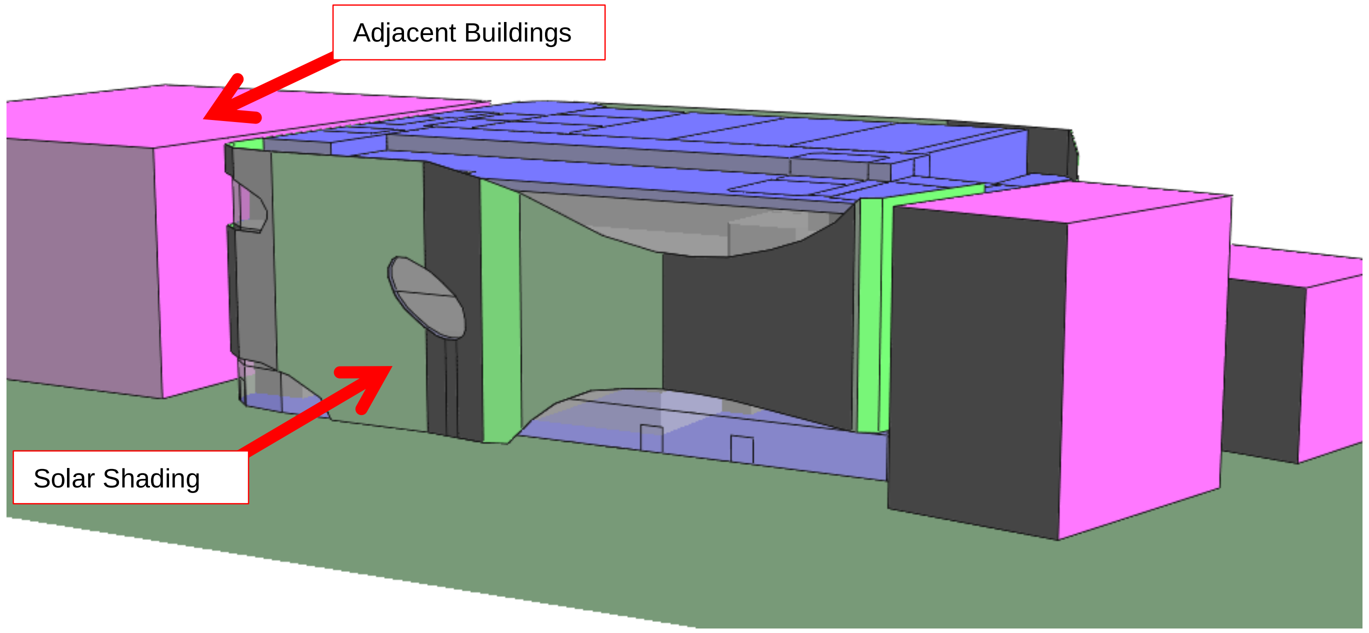


Figure 2 - Computer simulation model showing proposed façade design, view from north.

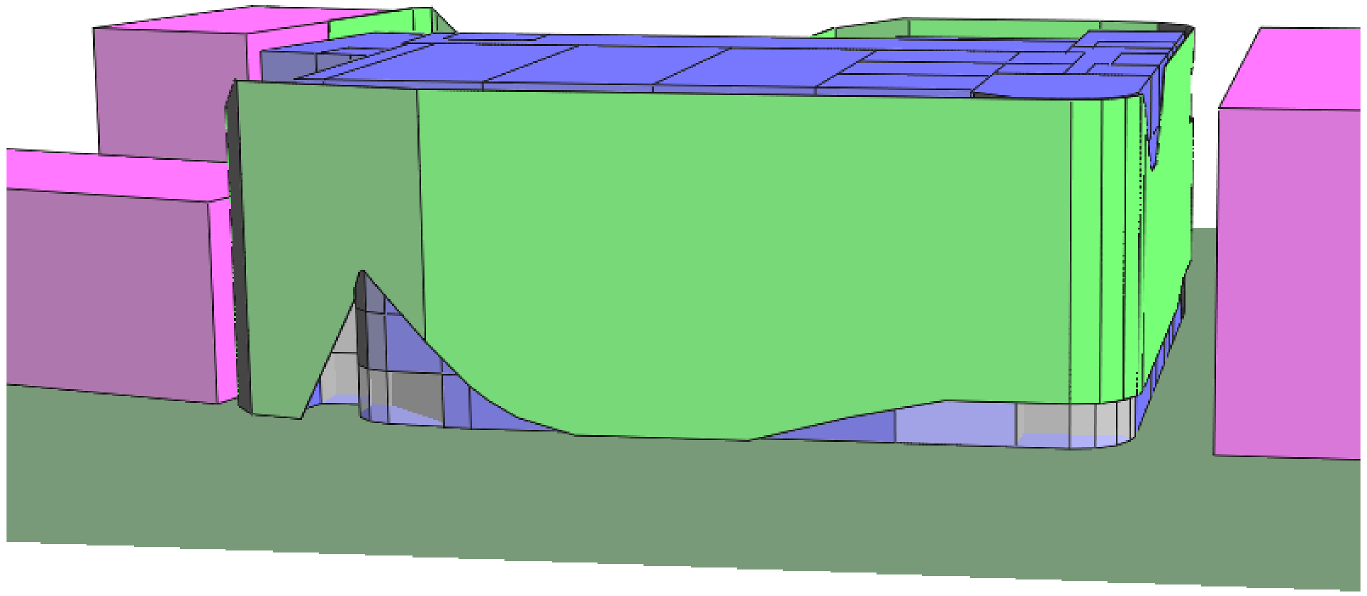


Figure 3 - Computer simulation model showing proposed façade design, view from south

Benchmark Energy End Use Breakdown

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

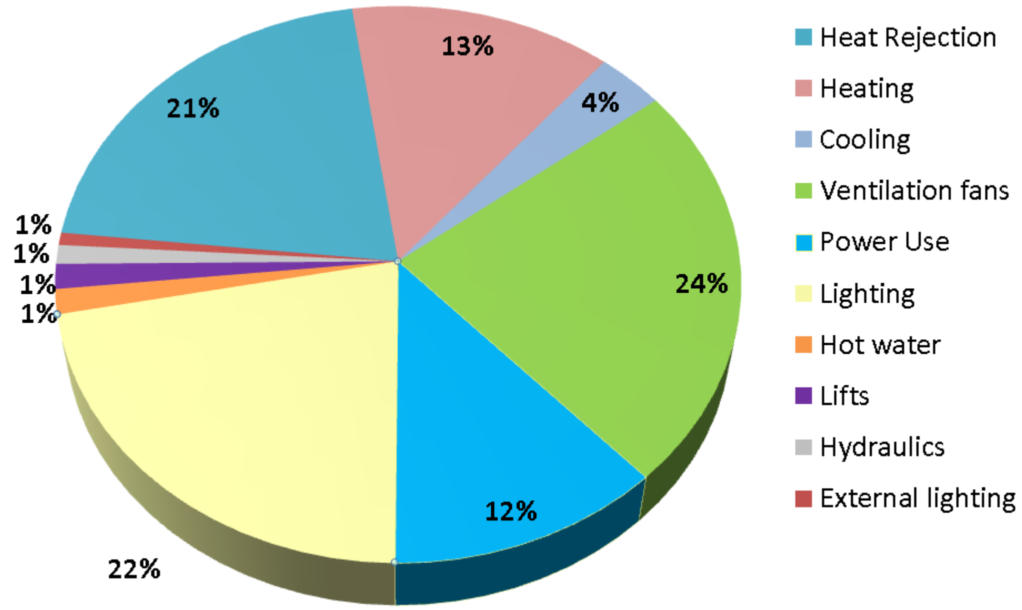


Figure 4 - Baseline Model, Benchmark Energy End Use Breakdown

It can be seen that heating, cooling, ventilation fans, and heat rejection energy makes up 62% of the annual energy use for the baseline model. Ventilation fans energy is the highest HVAC end use at 24% 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 21% 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 13% and is comprised of outdoor air heating and space heating. Cooling energy accounts for only 4% due to the efficiency of the Baseline water cooled chiller.

The lighting and power (for computers, kitchen equipment and other equipment) makes up a further 34% 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 2B energy efficiency opportunities were identified by WCC and Beca.

5.1 Control Opportunities

The potential energy saving performance of a number of energy efficient HVAC controls opportunities were initially assessed against the baseline model as follows:

- **Demand Controlled Ventilation (DCV):** Outside air supply is delivered only as required to achieve the required level of air quality (as opposed to 100% of design capacity during all occupied hours). Air quality sensors monitor air quality levels to determine the level of outdoor air rate required.
- **Economiser:** The Economiser is used if the HVAC system zone is requesting cooling and the outdoor air temperature is cool enough to directly provide the zone cooling requirements.
- **HVAC Off Overnight:** Switch the HVAC off overnight in the Movie Museum Galleries and let the temperature drift outside of the heating and cooling temperature set points. The Convention Centre already switches off overnight.
- **Exhaust Air Heat Recovery:** Install a run around coil to recover heat from exhausted air to preheat incoming outdoor air which is supplied to the Fan Coil Unit system (Lobby areas). Additional pipework connected from the exhaust duct to the supply air duct before the Air Handling Units heating coil is required.
- **Daylight harvesting to FOH areas:** Install electric light dimming in perimeter lobby and convention centre exhibition areas. Lighting energy use has been reduced to account for daylight levels in FOH perimeter areas to simulate automated light dimming controls
- **Combined HVAC Control Opportunities:** All of the five opportunities above were simulated together.

5.2 Design Opportunities

The above Combined Control Opportunities form a new scenario which the potential energy saving performance of a number of additional enhanced building services design opportunities were separately assessed against, as follows:

- **Magnetic Bearing Water Cooled High Efficiency Chillers:** The efficiency gains in a magnetic bearing chiller are attained from a reduction in the energy losses associated with friction. The reduced energy losses increase the heat transfer efficiency of the chiller. This is because no oil is used in the chiller. Also, a variable speed drive on the motor allows the compressor to operate much more efficiently at partial loads than standard compressors.
- **Waste Water Sourced Heat Pump:** A Waste Water Sourced Heat Pump absorbs heat from waste water (sewage) and transfers the heat to the building through the refrigerant cycle in a heat pump. The Waste Water Heat Pump scenario has a Sewage SHARC to remove solid waste and makes the waste water usable as a heat source.
- **Condenser loop water sourced Heat Pump:** Similar to the Waste Water Sourced Heat Pump, the condensing loop water is used to absorb heat and transfer the heat to the building through the refrigerant cycle in a heat pump. A condensing loop Heat Pump can only be used when there is a coincident cooling load equal to or greater than the heating load.
- **Air Sourced Heat Pump:** Similar to the waste water sourced heat pump, the outside air is used to extract heat and transfer the heat to the building through the refrigerant cycle in a heat pump.
- **Energy Piles (Ground sourced heat rejection through piles):** Energy Piles use the ground as an energy transfer medium, in this case as a medium to reject heat. Energy Piles reduce the cooling energy consumption because it uses the ground as a means to cool the condensing water for free without requiring cooling tower fans (pumps for water circulation through piles are still required). If the ground cannot cool the condensing water entirely, the cooling tower would be used. The assessment has assumed that 2 loops of piping were run through the 37 piles that are 1m or larger in diameter with an estimate heat rejection capacity of 110kW.
- **Variable speed cooling tower fans:** Cooling tower fans which run constantly can over cool the condenser water. A variable speed drive is installed and varies the cooling tower fan speed to only cool the condensing water to the temperature the chiller is requesting. This in turn reduces the cooling tower fan energy consumption.
- **Variable volume condenser water loop:** Condensing water loop pumps which run constantly can over cool the condenser water. A variable speed drive is installed and varies the Condensing water loop pumps to only cool the condensing water to the temperature the chiller is requesting. This in turn reduces the condensing water loop pump energy consumption.
- **Low Specific fan power central air handling:** Specific fan power is a measurement of the electric power that is needed to drive a fan, relative to the air volume that is circulated through the fan. SFP is measured in Watts per litre per second (W/l.s). Fan energy consumption will reduce by designing the ventilation system which has lower static pressure. The design takes advantage of larger duct sizes to reduce friction. As an example, the table below displays the impact having a lower static pressure has on fan power.

Fan Static	Power Input
800 Pa	3.7 kW
900 Pa	4.2 kW
1000 Pa	4.6 kW

  High efficiency motors will be specified during the selection process. For example, selections with EC motors will be undertaken as EC motors have mid-high 90% efficiencies. Note: the 60-70% efficiency displayed on the AHU fan data sheets provided by suppliers represent the total efficiency of the entire fan assembly, which takes into account the EC motor efficiency, the fan scroll efficiency and any losses. This is for a total system, not just the motor only.
- **Combined Opportunities:** The following selected opportunities were simulated together:
  - Air Sourced Heat Pump
  - Energy Piles
  - Variable Speed Cooling Towers
  - Variable Volume Condensing Water Loop
  - Low Specific Fan Power Central Air Handling
- **Roof Mounted Photovoltaic Array:** Photovoltaics are a renewable energy generation source which converts solar radiation into electricity. It is proposed to install a 160kW array over 50% of the MACC roof area.

6 Findings

Each computer model scenario has been simulated over a typical Wellington weather year and the annual energy benefit of each energy efficiency opportunity is separately compared to either the baseline model or the proposed Combined Load and Controls Opportunities scenario which forms a new baseline to measure the energy efficient design opportunities against. The findings are as follows:

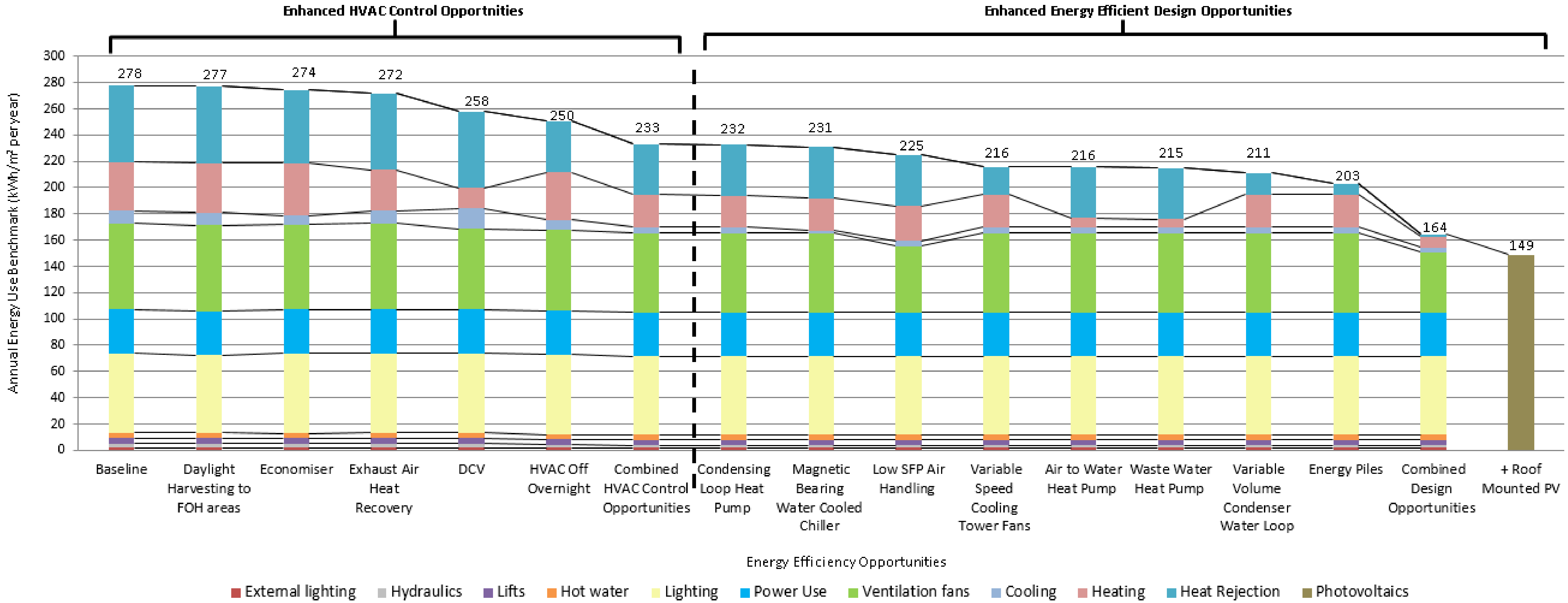


Figure 5 – Annual Energy Use Benchmark Comparison

- DCV and Switching the Movie Museum Gallery HVAC Off overnight are indicated to produce the largest energy savings from a controls perspective. DCV is indicated to save 20kWh/m² a year, and switching the HVAC Off overnight 27kWh/m² a year.
- Combining the HVAC control opportunities is indicated to reduce energy consumption by 44kWh/m² a year, lower GHG emissions by 134 tonnes per year, and reduce energy costs by approximately $60K per year.
- The various heat pump options all reduce energy consumption, with the Air Sourced (18kWh/m².yr) and Waste Water (19kWh/m².yr) Heat Pumps being indicated to provide a large amount of annual energy savings. Both the air sourced and waste water heat pumps have the potential to reduce GHG emissions by over 40 tonnes per year.
- Upgrading the water cooled chiller to a magnetic bearing option may reduce energy by only 2kWh/m² per year largely due to the already high efficiency of standard water cooled chillers.
- By designing the central ventilation systems to minimise pressure loss can lead to 9kWh/m² per year worth of energy savings. This equates to 23 tonnes of GHG emissions.
- It is indicated that large energy savings are offered by designing the heat rejection system to be more energy efficient:
  - Variable speed cooling towers is suggested to reduce energy consumption by 18kWh/m² a year and GHG emissions by 50 tonnes per year.
  - A Variable volume condensing water loop is indicated to reduce energy consumption by 19kWh/m² a year and GHG emissions by 62 tonnes per year.
- It is indicated that installing Energy Piles would be the single largest energy saver. Energy piles reduce energy consumption by 30kWh/m² a year and GHG emissions by 80 tonnes per year.
- Combining the design options which provide a favourable return on investment (Low SFP, Variable Speed Cooling Tower Fans, Variable Volume Condensing Water Loop, Air Sourced Heat Pump, and Energy Piles) is indicated to reduce energy consumption by 69kWh/m² per year and GHG emissions by 188 tonnes per year.
- A roof mounted PV system covering 50% of the MACC roof area can generate 16kWh/m² per year and equates to approximately 45 tonnes of GHG emissions. Installing PV presents a visual statement that WCC and the MACC development is sustainability and environmentally focussed.

Table 2 – Annual Energy Savings Benchmark Summary

Annual Energy and Emissions Savings Benchmark	Enhanced HVAC Control Opportunities						Enhanced Energy Efficient Design Opportunities									
	Daylight Harvesting to FOH areas	Economiser	Exhaust Air Heat Recovery	DCV	HVAC Off Overnight	Combined HVAC Control Opportunities	Condensing Loop Heat Pump	Magnetic Bearing Water Cooled Chiller	Low SFP Air Handling	Variable Speed Cooling Tower Fans	Air to Water Heat Pump	Waste Water Heat Pump	Variable Volume Condenser Water Loop	Energy Piles	Combined Design Opportunities	Roof Mounted PV
kWh/m^2 per year	1	3	6	20	27	44	1	2	9	18	18	19	22	30	69	16
kWh per year	12,000	51,000	96,000	312,000	429,000	700,000	13,000	38,000	136,000	278,000	278,000	293,000	351,000	475,000	1,079,000	250,000
$ per year	$1,600	$7,000	$5,000	$14,000	$42,000	$60,000	$500	$4,000	$15,000	$28,000	$5,000	$7,000	$35,000	$47,000	$86,000	$25,000
Tonnes CO_2-e/ year	2	7	22	71	78	134	3	7	23	50	44	47	62	85	188	45

7 Financial 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 baseline.

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

- **Daylight Harvesting to FOH Areas ($21K):** This allows for the installation of daylight sensors, wiring, controllers and associated controls programming
- **Economisers ($5K):** This allows for the inclusion of wiring and associated BMS programming to the VAV AHUs.
- **Exhaust Air Heat Recovery ($20K):** Additional costs of run around coils, piping and extra pumps of additional circuit, and larger fans to compensate for higher pressure drop across the additional heat recovery coils.
- **Demand Controlled Ventilation (DCV) ($15K):** This allows for the installation of air quality sensors, wiring and associated BMS programming
- **HVAC Off overnight ($0):** No additional cost for switching off HVAC overnight as it is a Building Management System (BMS) schedule change.
- **Combined HVAC Control Opportunities ($61K):** The combined capital cost increase of the selected opportunities: Daylight Harvesting, DCV, Exhaust Air Heat Recovery, Economiser, and HVAC Off Overnight.
- **Condensing Loop Heat Pump ($40K):** Based on additional costs of purchasing 62kW Water Sourced Heat Pump @ $30K and associated pipework and controls @$10k.
- **Magnetic Bearing Water Cooled Chillers ($118):** Based on additional costs of purchasing two 1200kW magnetic bearing water cooled chillers @ $277K each compared to two typical York centrifugal 1200kW water cooled chillers @$218K each. No maintenance cost savings have been incorporated.
- **Low SFP ($16K):** Based on additional costs of purchasing larger duct sizes @ $426K to reduce static pressure by 20% to achieve a SFP of 2W/l.s compared to smaller duct sizes @$410K which have 20% higher static pressure and have a SFP of 2.5W/l.s.
- **Variable Speed Cooling Tower Fans ($10K):** This allows for the installation of VSDs, to include wiring and associated BMS programming.
- **Variable Volume Condenser Water loop ($50K):** This allows for the installation of VSDs to Condensing Water pumps and includes wiring, associated BMS programming, and additional cost of indirect cooling towers versus direct cooling tower.
- **Air Sourced Heat Pump ($39K):** Based on additional costs of purchasing a 150kW air sourced heat pump @ $40K, minus the cost of the 150kW boiler it is replacing @$11K, and an additional hot water circuit for Domestic Hot Water @$10K.
- **Waste Water Heat Pump ($264K):** Based on additional costs of purchasing a 150kW water sourced heat pump @ $42K, minus the cost of the 150kW boiler it is replacing @$11K, an additional hot water circuit for Domestic Hot Water @$10K, and the additional cost of the Sewage SHARC component @$223K.
- **Energy Piles ($303K):** Based on additional costs of piping, pumps, pile detailing, and additional non-steel casing concrete pile construction costs for the 39 proposed piles greater than 1m in diameter @ $303K (contractor's estimate of an additional 20% to pile construction costs).
- **Combined Design Opportunities ($419K):** The combined capital cost increase of the selected opportunities: Low SFP, Variable Speed Cooling Tower Fans, Variable Volume Condensing Water Loop, Air Sourced Heat Pump, and Energy Piles.
- **Roof Mounted PV ($344K):** Based on installation costs of purchasing a 160kW PV system @ $2,150 per kW.

The current WCC energy 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
- Potential to send any excess power generated by PVs back to the electrical grid

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

Table 3 – Financial Analysis Summary

Financial Performance Indicator	Enhanced HVAC Control Opportunities						Enhanced Energy Efficient Design Opportunities									
	Daylight Harvesting to FOH areas	Economiser	Exhaust Air Heat Recovery	DCV	HVAC Off Overnight	Combined HVAC Control Opportunities	Condensing Loop Heat Pump	Magnetic Bearing Water Cooled Chiller	Low SFP Air Handling	Variable Speed Cooling Tower Fans	Air to Water Heat Pump	Waste Water Heat Pump	Variable Volume Condenser Water Loop	Energy Piles	Combined Design Opportunities	Roof Mounted PV
Indicative Capital Cost[4]	$21k	$5k	$20k	$15k	$0k	$61k	$40k	$118k	$17k	$10k	$39k	$264k	$50k	$303k	$419k	$344k
Payback Period[5]	12 years	1 years	5 years	2 years	0 years	2 years	80 years	31 years	1 years	1 years	7 years	39 years	2 years	6 years	6 years	12 years
20 year NPV[6]	$800	$89,000	$42,000	$174,000	$561,000	$742,000	-$34,000	-$67,000	$284,000	$361,000	$31,000	-$174,000	$419,000	$338,000	$495,000	-$10,000
~~20 year IRR~~	~~7.0%~~	~~142.5%~~	25.2%	96.8%	NA	101.0%	-9.0%	-1.7%	134.9%	280.1%	14.4%	-3.5%	72.6%	17.2%	17.8%	6.2%

[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

We recommend that WCC considers including the HVAC controls and design opportunities subject to meeting their investment criteria and the project budget. Consideration should be given to the visual statement and marketing opportunity a PV installation would represent

8.1 Controls Opportunities

Implementing energy efficient HVAC control opportunities in the building services design are indicated to offer significant energy savings when compared to the baseline. The combined savings of implementing Daylight Harvesting, Economiser, DCV, Exhaust Air Heat Recovery, and switching the Movie Museum Galleries HVAC Off is indicated to offer 44kWh/m^2 per year with a reduction of 134 tonnes of associated Greenhouse Gas (GHG) emissions. This represents good practice and improves on the baseline (which represents a minimal level of energy performance). The HVAC controls opportunities have a payback period of 2 years, an NPV of $740K across a 20 year period and an IRR of 101%. It suggests the options would result in a favourable return on investment.

8.1.1 HVAC scheduling

A high energy saving opportunity is indicated to be offered by switching off HVAC in the Movie Museum galleries. The payback period for the option is 0 years because it does not require any additional costs.

8.2 Design opportunities

Further energy reductions can be achieved by installing Variable Speed Cooling Tower Fans, Variable Volume Condensing Water Loop, Air Sourced Heat Pump, Energy Piles and designing for central air handling to have a Low SFP. The combination of the these energy efficient design opportunities is indicated to provide a further energy reduction of 69kWh/m^2 per year, $86K of cost savings per year, and a reduction of 188 tonnes of associated GHG emissions. The combined opportunities have a short payback period of 6 years, even with the low energy rates WCC are currently paying. The 20 year NPV of the combined design opportunities is indicated to be over $500K with an IRR of 19.8%, which suggests the options would again result in a favourable return on investment.

8.2.1 Heating source

Of the three different heat pump options (Condensing Water Loop, Air Sourced and Waste Water), the Air sourced heat pump is the only option that provides a positive NPV over a 20 year period. The Air Sourced Heat Pump is indicated to have a 7 year payback, a 20 year NPV of approximately $31K and an IRR of 14.6%. The reason the condensing loop Heat Pump does not financially stack up, with a payback of 64 years, is due to the limited energy savings it could provide as there is a minimal occurrence of coincident heating and cooling load. Conversely, the Waste Water Heat Pump offers high energy savings, but the payback is indicated to be 39 years and is due to the very high capital cost investment required of approximately $263.5K (primarily due to the Sewage SHARC cost of approximately $223K).

8.2.2 Cooling source

The magnetic bearing water cooled chiller does not provide a favourable return on investment with a payback of 31 years. This is largely due to the low cooling energy load and the low WCC energy costs. The financial assessment of the magnetic bearing water cooled chiller does not include any cost savings from lower maintenance costs.

8.2.3 Heat rejection

The largest single energy saving option, and also the largest capital cost investment, is indicated to be the installation of Energy Piles. Energy Piles use the ground as an energy transfer medium, in this case as a medium to reject heat. Energy Piles reduce the cooling energy consumption because it uses the ground as a means to cool the condensing water. Energy Piles would initially cost approximately $300K and offer an annual energy cost reduction over $40K per year. Energy Piles are indicated to have a payback period of 6 years, a 20 year NPV of over $337K and an IRR of 17.2%. This suggests Energy Piles would offer a good return on investment. If this option is to be pursued, it is recommended to undertake a detailed feasibility study which determines the make-up of the ground conditions and potentially use a test pile as a means to assess the performance of a potential Energy Pile system

8.3 Photovoltaics

Installing a roof mounted PV system would represent a visual statement that WCC and MACC development are sustainability and environmentally focussed. The potential energy generation from the system is indicated to reduce energy and GHG emissions substantially at 16kWh/m^2 and 45 tonnes of GHG per year respectively. The payback for installing a PV system is 12 years. The large reduction in emissions and the visual aspect of the solar collectors on the roof provides a great marketing statement. It is assumed all energy generated is used onsite.

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) Project team to ensure energy efficient plant and equipment selection is retained throughout the design and construction phase on the project
5) WCC and MACC to consider implementing a comprehensive 2 year building tuning programme (in conjunction with the main contractor and design team) to ensure the building is operating as per the design intent

   We recommend WCC and MACC apply for EECA Programme 2C (Commissioning) and 2D (Assessing energy performance after occupation) to provide funding assistance with this.

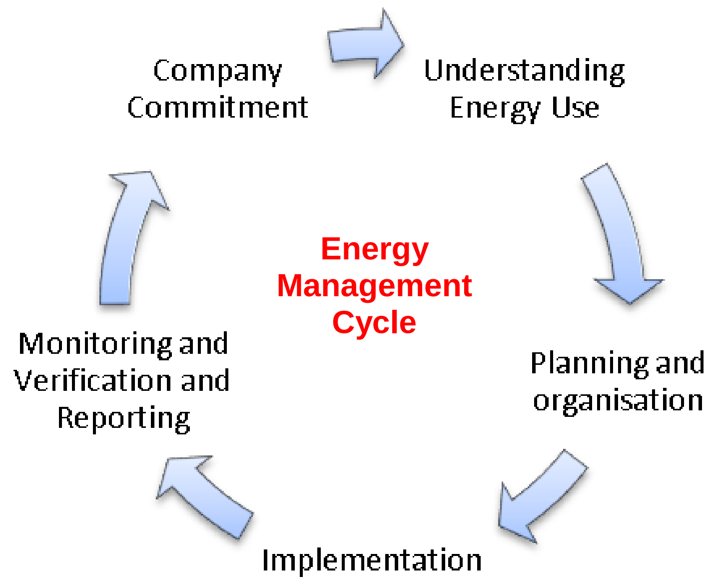
10 Energy Management

While the energy efficiency opportunities identified may offer significant energy savings, it is the operational stage of a building where energy savings are realised. Implementing an energy management system and organisational plan that meets/exceeds ISO 50-001 (Energy Management) standards will aid in targeting a reduced energy consumption, carbon emissions and energy costs.

An energy management system enables an organisation to follow a systematic approach in achieving continual improvement of energy performance.

Having an effective energy management system offers several important opportunities:

- Lower operating costs
- Improved environmental performance
- Longer equipment life
- Better risk management
- More effective, lower cost maintenance (Proactive)
- Improved thermal comfort and indoor air quality, and
- Enhance public image



Energy Management system initiatives include:

- Creating a Plan
  - Energy Policy
  - Objectives and Targets
- Reviewing the current systems
- Identifying improvements
- Implementing improvements
- Measuring and Verifying improvements
- Reviewing the energy management system

The Energy Efficiency and Conservation Authority (EECA) have various funding schemes which help to implement an effective energy management system:

- Energy Management Plan: EECA can potentially fund up to 40% of costs (up to $100,000) for this work
  - Setting up a system to manage your energy, including development of an energy policy
  - Identifying your main areas of energy use
  - Setting an energy-savings target
  - Creating plans to prioritise energy-saving opportunities.
- Systems Optimisation: EECA can potentially fund up to 40% of costs (up to $100,000) for this work
  - Identifying areas for improved energy efficiency
  - Tuning and recalibrating existing equipment
- Monitoring & Targeting: EECA can potentially fund up to 40% of costs (up to $100,000) for this work
  - Implementing a monitoring & targeting system
  - Analysing, comparing and benchmarking energy use
  - Target setting
  - Reporting

Appendix A

Computer Simulation Model Inputs

Table 4 - 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	

Model Item	Baseline Energy Model Input	Model Input Reference	Comment
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/m^2 ▪ Plenary: 12 W/m^2 ▪ Pre-Function: 12 W/m^2 ▪ General Office Areas: 6 W/m^2 ▪ Meeting Rooms: 12 W/m^2 ▪ Circulation – Area FOH: 8 W/m^2 ▪ Circulation – Area BOH: 5 W/m^2 Movie Museum: ▪ Galleries: 8 W/m^2 ▪ Circulation – Area BOH: 4 W/m^2	▪ 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/m^2 ▪ Plenary: 15 W/m^2 ▪ Pre-Function: 15 W/m^2 ▪ General Office Areas: 11 W/m^2 ▪ Meeting Rooms: 11 W/m^2 ▪ Circulation – Area FOH: 5 W/m^2 ▪ Circulation – Area BOH: 5 W/m^2 Movie Museum: ▪ Galleries: 5 W/m^2 ▪ Circulation – Area BOH: 5 W/m^2	▪ CIBSE Guide A Table 6.2 Assumptions ▪ NABERS	
Equipment schedule	▪ NABERS schedule for equipment is adapted similar to the lighting schedule	▪ NABERS	

Model Item	Baseline Energy Model Input	Model Input Reference	Comment
Process load density	■ Not modelled	■ Project Mechanical engineer	■ Covered under equipment gains
Occupancy density	Convention Centre ■ Kitchen/Cafe: 5m^2 / person ■ Circulation – FOH and BOH: 5m^2/ person ■ Exhibition: 12m^2 / person ■ Plenary: 12 m^2 / person ■ Meeting Rooms: 12 m^2 / person ■ Office: 15m^2 / person ■ Lobby: 5m^2 / person Movie Museum: ■ Gallery: 29m^2 / person ■ Lobby: 5m^2 / person	■ Project 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	Museum: ■ 9am to 7pm, 365 Days a year Convention Centre: ■ 9am to 10pm, 7 days per 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 5 - 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 2 m^2.K/W (including thermal bridging effects) ▪ Roof: Total R-value: R 3 m^2.K/W (including thermal bridging effects) ▪ R 1.3 ground floor ▪ Vision Glazing: – Uwindow: U 3.0 W/m2.K (including frame effect)	▪ H1 minimum values	▪ Refer to EECA 2A report
Glazing shading coefficient	▪ Vision glazing: – Shading Coefficient: 0.40 – G value: 0.35	▪ NZS4218	▪ Refer to EECA 2A report
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 opening	▪ Not proposed	▪ Assumed	

Table 6 – 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 7 – 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 8 – 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 9 – Energy Efficiency Opportunities

Model Item	Energy Model Input	Model Input Reference
Switch Movie Museum HVAC Off overnight	▪ HVAC only operates from 8am to 7pm. ▪ A 1.5 hour optimum start period	▪ Project mechanical engineer
Exhaust air heat recovery	▪ Run around coil ▪ 50% heat recovery effectiveness	▪ Project mechanical engineer
Demand Control Ventilation	▪ Outside air supply reduces to as a percentage based on diversified design occupant density	▪ Estimated based on European studies. Actual requirement will be dependent on the project and building occupancy rates
Economiser cycles (free cooling)	▪ Up to 20ºC outdoor air temperature: when outside air temperature is lower than indoor air temperature, the economiser cycle is used.	
Daylight harvesting to FOH areas	▪ Reduced NABERS office lighting schedule by 20% in FOF perimeters areas	▪ NABERS
Combined HVAC Control Opportunities	▪ All of the above	
Waste Water Sourced Heat Pump SEER	▪ 3.73 (Water sourced heat pump) ▪ 150kW	▪ Based on York water sourced heat pump selection with Evaporator water in temperature of 15ºC and supplying 50ºC/45ºC hot water
Air sourced Heat Pump SEER	▪ 3.0 (Air cooled heat pump) ▪ 150kW – equates to 90th percentile heat load.	▪ Based on typical air sourced heat pump selection
Condensing circuit water sourced Heat Pump SEER	▪ 3.86 (water cooled heat pump) ▪ 62kW – is maximum coincident heating and cooling load.	▪ Based on York water sourced heat pump selection with Evaporator water in temperature of 22ºC and supplying 50ºC/45ºC hot water

Model Item	Energy Model Input	Model Input Reference
(Energy Piles) Ground Sourced heat coupling through piles	▪ 25W/m of heat rejection through water loop circulating through buildings piles. ▪ 2 loops of piping per pile ▪ Pile details: – 15 piles at 29m – 17 piles at 29.5m – 7 piles at 24.5m ▪ Equates to approximately 100kW of heat rejection capacity ▪ Increased Pump energy was included	▪ Ground sourced cooling and energy pile literature.
Magnetic Bearing Water Cooled High Efficiency Chiller	▪ 1200kW chiller ▪ Magnetic Bearing water cooled chiller 10 point part load COPs: – 1150kW: 5.81 COP – 1035 kW: 6.63 COP – 920kW: 7.56 COP – 805kW: 8.66 COP – 690kW: 10.07 COP – 575kW: 11.96 COP – 460kW: 12.33 COP – 345kW: 12.47 COP – 230kW: 13.23 COP ▪ 115kW: 13.86 COP ▪ Magnetic Bearing water cooled chiller 10 point part load COPs: – 1150kW: 5. 5 COP – 1035 kW: 6.1 COP – 115kW: 6.1 COP	▪ Based on a Powerpax 1200kW water cooling chiller selection supplying 6ºC/12ºC.
Variable speed cooling tower fans	▪ Fans vary speed based on outdoor air temperature: – 100% fan speed at 24.8ºC outdoor air temperature ▪ Does not account for reduced fan speed requirements due to low cooling load.	
Variable volume condenser water loop (Open versus closed towers)	▪ Pumps vary speed proportionally to cooling load: – 10% to 40% cooling load: 6% pump speed – 50% cooling load: 13% pump power – 60% cooling load: 22% pump power – 70% cooling load: 34% pump power – 80% cooling load: 51% pump power – 90% cooling load: 73% pump power – 100% cooling load: 100% pump power	
Low specific fan power Central Air Handling	▪ A 20% improvement on baseline SFP: – 2.0W/l.s – Supply and return air fans	▪ Typical fan efficiency

Model Item	Energy Model Input	Model Input Reference
Combined Energy Efficient Design Opportunities	▪ Current Design proposal with the following opportunities combined: – Air Sourced Heat Pump – Energy Piles – Variable Speed Cooling Towers – Variable Volume Condensing Water Loop – Low Specific Fan Power Central Air Handling	▪ As above
Roof-mounted photovoltaic array	▪ $10m^2$ per kW of install PV: 160kW ▪ 26% efficiency drop due to inclination and orientation and system losses. ▪ 50% of roof area available for PV to be installed: – Roof area: $1600m^2$ – Effective PV panel area: $955m^2$ ▪ NIWA Mean monthly total sunshine (hours) for Wellington	▪ Based on NIWA Sunshine hours for Wellington and SolarKing PV 260W (per panel) selection.

Appendix B

Financial Performance Analysis

Daylight Harvesting to FOH areas

Client Input Values	
Inflation Rate	2.5%
Discount Rate	6.5%

Assessment Inputs	
Capital Cost	$ 21,000
Secondary Capital Cost	$ -
Time of Secondary Capital Cost (Years)	0
Annual Savings	$1,633
Assessment Length (Years)	20

Assessment Results	
Payback Period (years)	12.0
Total NPV	$840
IRR	7.0%

Years	Annual Savings	Cummulative Savings	Payback	Capital Investment	Annual Cash Flow	Present Value of Saving	Net Present Value of Savings
0	$0	$0	-$21,000	$21,000	-$21,000	-$21,000	-$21,000
1	$1,633	$1,633	-$19,367	$0	$1,633	$1,533	-$19,467
2	$1,674	$3,307	-$17,693	$0	$1,674	$1,476	-$17,991
3	$1,716	$5,022	-$15,978	$0	$1,716	$1,420	-$16,571
4	$1,759	$6,781	-$14,219	$0	$1,759	$1,367	-$15,204
5	$1,803	$8,584	-$12,416	$0	$1,803	$1,316	-$13,888
6	$1,848	$10,431	-$10,569	$0	$1,848	$1,266	-$12,622
7	$1,894	$12,325	-$8,675	$0	$1,894	$1,219	-$11,403
8	$1,941	$14,266	-$6,734	$0	$1,941	$1,173	-$10,230
9	$1,990	$16,256	-$4,744	$0	$1,990	$1,129	-$9,101
10	$2,039	$18,295	-$2,705	$0	$2,039	$1,086	-$8,015
11	$2,090	$20,386	-$614	$0	$2,090	$1,046	-$6,969
12	$2,143	$22,528	$1,528	$0	$2,143	$1,006	-$5,963
13	$2,196	$24,724		$0	$2,196	$969	-$4,994
14	$2,251	$26,975		$0	$2,251	$932	-$4,062
15	$2,307	$29,283		$0	$2,307	$897	-$3,165
16	$2,365	$31,648		$0	$2,365	$863	-$2,302
17	$2,424	$34,072		$0	$2,424	$831	-$1,471
18	$2,485	$36,557		$0	$2,485	$800	-$671
19	$2,547	$39,104		$0	$2,547	$770	$99
20	$2,611	$41,714		$0	$2,611	$741	$840
Total	$41,714						$840

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.

Economiser

Client Input Values	
Inflation Rate	2.5%
Discount Rate	6.5%

Assessment Inputs	
Capital Cost	$ 5,000
Secondary Capital Cost	$ -
Time of Secondary Capital Cost (Years)	0
Annual Savings	$ 7,001
Assessment Length (Years)	20

Assessment Results	
Payback Period (years)	1.0
Total NPV	$ 88,632
IRR	142.5%

Years	Annual Savings	Cummulative Savings	Payback	Capital Investment	Annual Cash Flow	Present Value of Saving	Net Present Value of Savings
0	$ -	$ -	$ (5,000)	$ 5,000	$ (5,000)	$ (5,000)	$ (5,000)
1	$ 7,001	$ 7,001	$ 2,001	$ -	$ 7,001	$ 6,574	$ 1,574
2	$ 7,176	$ 14,177		$ -	$ 7,176	$ 6,327	$ 7,901
3	$ 7,355	$ 21,532		$ -	$ 7,355	$ 6,089	$ 13,990
4	$ 7,539	$ 29,072		$ -	$ 7,539	$ 5,860	$ 19,850
5	$ 7,728	$ 36,800		$ -	$ 7,728	$ 5,640	$ 25,491
6	$ 7,921	$ 44,721		$ -	$ 7,921	$ 5,429	$ 30,919
7	$ 8,119	$ 52,840		$ -	$ 8,119	$ 5,225	$ 36,144
8	$ 8,322	$ 61,162		$ -	$ 8,322	$ 5,028	$ 41,172
9	$ 8,530	$ 69,692		$ -	$ 8,530	$ 4,840	$ 46,012
10	$ 8,743	$ 78,435		$ -	$ 8,743	$ 4,658	$ 50,669
11	$ 8,962	$ 87,397		$ -	$ 8,962	$ 4,483	$ 55,152
12	$ 9,186	$ 96,583		$ -	$ 9,186	$ 4,314	$ 59,467
13	$ 9,416	$ 105,998		$ -	$ 9,416	$ 4,152	$ 63,619
14	$ 9,651	$ 115,649		$ -	$ 9,651	$ 3,996	$ 67,616
15	$ 9,892	$ 125,541		$ -	$ 9,892	$ 3,846	$ 71,462
16	$ 10,140	$ 135,681		$ -	$ 10,140	$ 3,702	$ 75,164
17	$ 10,393	$ 146,074		$ -	$ 10,393	$ 3,563	$ 78,727
18	$ 10,653	$ 156,727		$ -	$ 10,653	$ 3,429	$ 82,156
19	$ 10,919	$ 167,646		$ -	$ 10,919	$ 3,300	$ 85,456
20	$ 11,192	$ 178,838		$ -	$ 11,192	$ 3,176	$ 88,632
Total	$ 178,838						$ 88,632

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.

Exhaust Air Heat Recovery (FCU system only)

Client Input Values	
Inflation Rate	2.5%
Discount Rate	6.5%

Assessment Inputs	
Capital Cost	$ 20,000
Secondary Capital Cost	$ -
Time of Secondary Capital Cost (Years)	0
Annual Savings	$ 4,634
Assessment Length (Years)	20

Assessment Results	
Payback Period (years)	5.0
Total NPV	$ 41,976
IRR	25.2%

Years	Annual Savings	Cummulative Savings	Payback	Capital Investment	Annual Cash Flow	Present Value of Saving	Net Present Value of Savings
0	$ -	$ -	$ (20,000)	$ 20,000	$ (20,000)	$ (20,000)	$ (20,000)
1	$ 4,634	$ 4,634	$ (15,366)	$ -	$ 4,634	$ 4,351	$ (15,649)
2	$ 4,750	$ 9,384	$ (10,616)	$ -	$ 4,750	$ 4,188	$ (11,461)
3	$ 4,869	$ 14,252	$ (5,748)	$ -	$ 4,869	$ 4,030	$ (7,431)
4	$ 4,990	$ 19,243	$ (757)	$ -	$ 4,990	$ 3,879	$ (3,552)
5	$ 5,115	$ 24,358	$ 4,358	$ -	$ 5,115	$ 3,733	$ 182
6	$ 5,243	$ 29,601		$ -	$ 5,243	$ 3,593	$ 3,775
7	$ 5,374	$ 34,975		$ -	$ 5,374	$ 3,458	$ 7,233
8	$ 5,508	$ 40,483		$ -	$ 5,508	$ 3,328	$ 10,562
9	$ 5,646	$ 46,129		$ -	$ 5,646	$ 3,203	$ 13,765
10	$ 5,787	$ 51,916		$ -	$ 5,787	$ 3,083	$ 16,848
11	$ 5,932	$ 57,848		$ -	$ 5,932	$ 2,967	$ 19,815
12	$ 6,080	$ 63,929		$ -	$ 6,080	$ 2,856	$ 22,671
13	$ 6,232	$ 70,161		$ -	$ 6,232	$ 2,749	$ 25,419
14	$ 6,388	$ 76,549		$ -	$ 6,388	$ 2,645	$ 28,065
15	$ 6,548	$ 83,097		$ -	$ 6,548	$ 2,546	$ 30,611
16	$ 6,711	$ 89,808		$ -	$ 6,711	$ 2,450	$ 33,061
17	$ 6,879	$ 96,687		$ -	$ 6,879	$ 2,358	$ 35,419
18	$ 7,051	$ 103,738		$ -	$ 7,051	$ 2,270	$ 37,689
19	$ 7,227	$ 110,966		$ -	$ 7,227	$ 2,184	$ 39,873
20	$ 7,408	$ 118,374		$ -	$ 7,408	$ 2,102	$ 41,976
Total	$ 118,374						$ 41,976

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.

Demand Controlled Ventilation

Client Input Values	
Inflation Rate	2.5%
Discount Rate	6.5%

Assessment Inputs	
Capital Cost	$ 15,000
Secondary Capital Cost	$ -
Time of Secondary Capital Cost (Years)	0
Annual Savings	$ 14,147
Assessment Length (Years)	20

Assessment Results	
Payback Period (years)	2.0
Total NPV	$ 174,204
IRR	96.8%

Years	Annual Savings	Cummulative Savings	Payback	Capital Investment	Annual Cash Flow	Present Value of Saving	Net Present Value of Savings
0	$ -	$ -	$ (15,000)	$ 15,000	$ (15,000)	$ (15,000)	$ (15,000)
1	$ 14,147	$ 14,147	$ (853)	$ -	$ 14,147	$ 13,284	$ (1,716)
2	$ 14,501	$ 28,648	$ 13,648	$ -	$ 14,501	$ 12,785	$ 11,068
3	$ 14,863	$ 43,511		$ -	$ 14,863	$ 12,304	$ 23,373
4	$ 15,235	$ 58,746		$ -	$ 15,235	$ 11,842	$ 35,215
5	$ 15,616	$ 74,361		$ -	$ 15,616	$ 11,398	$ 46,613
6	$ 16,006	$ 90,367		$ -	$ 16,006	$ 10,969	$ 57,582
7	$ 16,406	$ 106,773		$ -	$ 16,406	$ 10,557	$ 68,140
8	$ 16,816	$ 123,590		$ -	$ 16,816	$ 10,161	$ 78,301
9	$ 17,237	$ 140,827		$ -	$ 17,237	$ 9,779	$ 88,080
10	$ 17,668	$ 158,494		$ -	$ 17,668	$ 9,412	$ 97,492
11	$ 18,109	$ 176,604		$ -	$ 18,109	$ 9,059	$ 106,550
12	$ 18,562	$ 195,166		$ -	$ 18,562	$ 8,718	$ 115,269
13	$ 19,026	$ 214,192		$ -	$ 19,026	$ 8,391	$ 123,660
14	$ 19,502	$ 233,694		$ -	$ 19,502	$ 8,076	$ 131,735
15	$ 19,989	$ 253,683		$ -	$ 19,989	$ 7,772	$ 139,508
16	$ 20,489	$ 274,172		$ -	$ 20,489	$ 7,480	$ 146,988
17	$ 21,001	$ 295,173		$ -	$ 21,001	$ 7,200	$ 154,188
18	$ 21,526	$ 316,700		$ -	$ 21,526	$ 6,929	$ 161,117
19	$ 22,064	$ 338,764		$ -	$ 22,064	$ 6,669	$ 167,786
20	$ 22,616	$ 361,380		$ -	$ 22,616	$ 6,418	$ 174,204
Total	$ 361,380						$ 174,204

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.

Switch Movie Museum HVAC Off Overnight

Client Input Values	
Inflation Rate	2.5%
Discount Rate	6.5%

Assessment Inputs	
Capital Cost	$ -
Secondary Capital Cost	$ -
Time of Secondary Capital Cost (Years)	0
Annual Savings	$ 41,913
Assessment Length (Years)	20

Assessment Results	
Payback Period (years)	0.0
Total NPV	$ 560,550
IRR	NA

Years	Annual Savings	Cummulative Savings	Payback	Capital Investment	Annual Cash Flow	Present Value of Saving	Net Present Value of Savings
0	$ -	$ -	$ -	$ -	$ -	$ -	$ -
1	$ 41,913	$ 41,913	$ 41,913	$ -	$ 41,913	$ 39,355	$ 39,355
2	$ 42,961	$ 84,874		$ -	$ 42,961	$ 37,877	$ 77,232
3	$ 44,035	$ 128,909		$ -	$ 44,035	$ 36,454	$ 113,686
4	$ 45,136	$ 174,044		$ -	$ 45,136	$ 35,085	$ 148,771
5	$ 46,264	$ 220,308		$ -	$ 46,264	$ 33,767	$ 182,538
6	$ 47,421	$ 267,729		$ -	$ 47,421	$ 32,499	$ 215,037
7	$ 48,606	$ 316,335		$ -	$ 48,606	$ 31,278	$ 246,316
8	$ 49,821	$ 366,157		$ -	$ 49,821	$ 30,104	$ 276,419
9	$ 51,067	$ 417,224		$ -	$ 51,067	$ 28,973	$ 305,392
10	$ 52,344	$ 469,567		$ -	$ 52,344	$ 27,885	$ 333,277
11	$ 53,652	$ 523,220		$ -	$ 53,652	$ 26,837	$ 360,115
12	$ 54,993	$ 578,213		$ -	$ 54,993	$ 25,829	$ 385,944
13	$ 56,368	$ 634,581		$ -	$ 56,368	$ 24,859	$ 410,803
14	$ 57,778	$ 692,359		$ -	$ 57,778	$ 23,926	$ 434,729
15	$ 59,222	$ 751,581		$ -	$ 59,222	$ 23,027	$ 457,756
16	$ 60,703	$ 812,283		$ -	$ 60,703	$ 22,162	$ 479,918
17	$ 62,220	$ 874,503		$ -	$ 62,220	$ 21,330	$ 501,248
18	$ 63,776	$ 938,279		$ -	$ 63,776	$ 20,529	$ 521,777
19	$ 65,370	$ 1,003,649		$ -	$ 65,370	$ 19,758	$ 541,535
20	$ 67,004	$ 1,070,653		$ -	$ 67,004	$ 19,016	$ 560,550
Total	$ 1,070,653						$ 560,550

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 HVAC Control Opportunities

Client Input Values	
Inflation Rate	2.5%
Discount Rate	6.5%

Assessment Inputs	
Capital Cost	$ 61,000
Secondary Capital Cost	$ -
Time of Secondary Capital Cost (Years)	0
Annual Savings	$ 60,076
Assessment Length (Years)	20

Assessment Results	
Payback Period (years)	2.0
Total NPV	$ 742,465
IRR	101.0%

Years	Annual Savings	Cummulative Savings	Payback	Capital Investment	Annual Cash Flow	Present Value of Saving	Net Present Value of Savings
0	$ -	$ -	$ (61,000)	$ 61,000	$ (61,000)	$ (61,000)	$ (61,000)
1	$ 60,076	$ 60,076	$ (924)	$ -	$ 60,076	$ 56,409	$ (4,591)
2	$ 61,578	$ 121,654	$ 60,654	$ -	$ 61,578	$ 54,291	$ 49,700
3	$ 63,117	$ 184,771		$ -	$ 63,117	$ 52,252	$ 101,952
4	$ 64,695	$ 249,467		$ -	$ 64,695	$ 50,289	$ 152,241
5	$ 66,313	$ 315,779		$ -	$ 66,313	$ 48,400	$ 200,641
6	$ 67,970	$ 383,750		$ -	$ 67,970	$ 46,582	$ 247,224
7	$ 69,670	$ 453,419		$ -	$ 69,670	$ 44,833	$ 292,057
8	$ 71,411	$ 524,831		$ -	$ 71,411	$ 43,149	$ 335,206
9	$ 73,197	$ 598,028		$ -	$ 73,197	$ 41,528	$ 376,734
10	$ 75,027	$ 673,054		$ -	$ 75,027	$ 39,969	$ 416,703
11	$ 76,902	$ 749,957		$ -	$ 76,902	$ 38,468	$ 455,170
12	$ 78,825	$ 828,782		$ -	$ 78,825	$ 37,023	$ 492,193
13	$ 80,796	$ 909,577		$ -	$ 80,796	$ 35,632	$ 527,825
14	$ 82,815	$ 992,393		$ -	$ 82,815	$ 34,294	$ 562,119
15	$ 84,886	$ 1,077,278		$ -	$ 84,886	$ 33,006	$ 595,125
16	$ 87,008	$ 1,164,286		$ -	$ 87,008	$ 31,766	$ 626,891
17	$ 89,183	$ 1,253,470		$ -	$ 89,183	$ 30,573	$ 657,464
18	$ 91,413	$ 1,344,882		$ -	$ 91,413	$ 29,425	$ 686,889
19	$ 93,698	$ 1,438,580		$ -	$ 93,698	$ 28,320	$ 715,209
20	$ 96,041	$ 1,534,621		$ -	$ 96,041	$ 27,256	$ 742,465
Total	$ 1,534,621						$ 742,465

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.

Condensing Water Loop Heat Pump

Client Input Values	
Inflation Rate	2.5%
Discount Rate	6.5%

Assessment Inputs	
Capital Cost	$ 40,000
Secondary Capital Cost	$ -
Time of Secondary Capital Cost (Years)	0
Annual Savings	$ 469
Assessment Length (Years)	20

Assessment Results	
Payback Period (years)	80.0
Total NPV	$ (33,728)
IRR	-9.0%

Years	Annual Savings	Cummulative Savings	Payback	Capital Investment	Annual Cash Flow	Present Value of Saving	Net Present Value of Savings
0	$ -	$ -	$ (40,000)	$ 40,000	$ (40,000)	$ (40,000)	$ (40,000)
1	$ 469	$ 469	$ (39,531)	$ -	$ 469	$ 440	$ (39,560)
2	$ 481	$ 950	$ (39,050)	$ -	$ 481	$ 424	$ (39,136)
3	$ 493	$ 1,442	$ (38,558)	$ -	$ 493	$ 408	$ (38,728)
4	$ 505	$ 1,948	$ (38,052)	$ -	$ 505	$ 393	$ (38,335)
5	$ 518	$ 2,465	$ (37,535)	$ -	$ 518	$ 378	$ (37,957)
6	$ 531	$ 2,996	$ (37,004)	$ -	$ 531	$ 364	$ (37,594)
7	$ 544	$ 3,540	$ (36,460)	$ -	$ 544	$ 350	$ (37,244)
8	$ 557	$ 4,097	$ (35,903)	$ -	$ 557	$ 337	$ (36,907)
9	$ 571	$ 4,669	$ (35,331)	$ -	$ 571	$ 324	$ (36,583)
10	$ 586	$ 5,254	$ (34,746)	$ -	$ 586	$ 312	$ (36,271)
11	$ 600	$ 5,855	$ (34,145)	$ -	$ 600	$ 300	$ (35,970)
12	$ 615	$ 6,470	$ (33,530)	$ -	$ 615	$ 289	$ (35,681)
13	$ 631	$ 7,101	$ (32,899)	$ -	$ 631	$ 278	$ (35,403)
14	$ 647	$ 7,747	$ (32,253)	$ -	$ 647	$ 268	$ (35,135)
15	$ 663	$ 8,410	$ (31,590)	$ -	$ 663	$ 258	$ (34,878)
16	$ 679	$ 9,089	$ (30,911)	$ -	$ 679	$ 248	$ (34,630)
17	$ 696	$ 9,786	$ (30,214)	$ -	$ 696	$ 239	$ (34,391)
18	$ 714	$ 10,499	$ (29,501)	$ -	$ 714	$ 230	$ (34,161)
19	$ 731	$ 11,231	$ (28,769)	$ -	$ 731	$ 221	$ (33,940)
20	$ 750	$ 11,980	$ (28,020)	$ -	$ 750	$ 213	$ (33,728)
Total	$ 11,980		$ (16,039)				$ (33,728)

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.

Magnetic Bearing Water Cooled Chiller

Client Input Values	
Inflation Rate	2.5%
Discount Rate	6.5%

Assessment Inputs	
Capital Cost	$ 118,000
Secondary Capital Cost	$ -
Time of Secondary Capital Cost (Years)	0
Annual Savings	$ 3,780
Assessment Length (Years)	20

Assessment Results	
Payback Period (years)	31.0
Total NPV	$ (67,446)
IRR	-1.7%

Years	Annual Savings	Cummulative Savings	Payback	Capital Investment	Annual Cash Flow	Present Value of Saving	Net Present Value of Savings
0	$ -	$ -	$ (118,000)	$ 118,000	$ (118,000)	$ (118,000)	$ (118,000)
1	$ 3,780	$ 3,780	$ (114,220)	$ -	$ 3,780	$ 3,549	$ (114,451)
2	$ 3,875	$ 7,655	$ (110,346)	$ -	$ 3,875	$ 3,416	$ (111,035)
3	$ 3,971	$ 11,626	$ (106,374)	$ -	$ 3,971	$ 3,288	$ (107,747)
4	$ 4,071	$ 15,697	$ (102,303)	$ -	$ 4,071	$ 3,164	$ (104,583)
5	$ 4,172	$ 19,869	$ (98,131)	$ -	$ 4,172	$ 3,045	$ (101,537)
6	$ 4,277	$ 24,146	$ (93,854)	$ -	$ 4,277	$ 2,931	$ (98,606)
7	$ 4,384	$ 28,529	$ (89,471)	$ -	$ 4,384	$ 2,821	$ (95,786)
8	$ 4,493	$ 33,023	$ (84,977)	$ -	$ 4,493	$ 2,715	$ (93,071)
9	$ 4,606	$ 37,628	$ (80,372)	$ -	$ 4,606	$ 2,613	$ (90,458)
10	$ 4,721	$ 42,349	$ (75,651)	$ -	$ 4,721	$ 2,515	$ (87,943)
11	$ 4,839	$ 47,188	$ (70,812)	$ -	$ 4,839	$ 2,420	$ (85,522)
12	$ 4,960	$ 52,147	$ (65,853)	$ -	$ 4,960	$ 2,329	$ (83,193)
13	$ 5,084	$ 57,231	$ (60,769)	$ -	$ 5,084	$ 2,242	$ (80,951)
14	$ 5,211	$ 62,442	$ (55,558)	$ -	$ 5,211	$ 2,158	$ (78,793)
15	$ 5,341	$ 67,783	$ (50,217)	$ -	$ 5,341	$ 2,077	$ (76,716)
16	$ 5,475	$ 73,257	$ (44,743)	$ -	$ 5,475	$ 1,999	$ (74,718)
17	$ 5,611	$ 78,869	$ (39,131)	$ -	$ 5,611	$ 1,924	$ (72,794)
18	$ 5,752	$ 84,620	$ (33,380)	$ -	$ 5,752	$ 1,851	$ (70,943)
19	$ 5,896	$ 90,516	$ (27,484)	$ -	$ 5,896	$ 1,782	$ (69,161)
20	$ 6,043	$ 96,559	$ (21,441)	$ -	$ 6,043	$ 1,715	$ (67,446)
Total	$ 96,559		$ 75,118				$ (67,446)

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.

Low Specific Fan Power

Client Input Values	
Inflation Rate	2.5%
Discount Rate	6.5%

Assessment Inputs	
Capital Cost	$ 17,000
Secondary Capital Cost	$ -
Time of Secondary Capital Cost (Years)	0
Annual Savings	$ 22,511
Assessment Length (Years)	20

Assessment Results	
Payback Period (years)	1.0
Total NPV	$ 284,065
IRR	134.9%

Years	Annual Savings	Cummulative Savings	Payback	Capital Investment	Annual Cash Flow	Present Value of Saving	Net Present Value of Savings
0	$ -	$ -	$ (17,000)	$ 17,000	$ (17,000)	$ (17,000)	$ (17,000)
1	$ 22,511	$ 22,511	$ 5,511	$ -	$ 22,511	$ 21,137	$ 4,137
2	$ 23,074	$ 45,585		$ -	$ 23,074	$ 20,343	$ 24,480
3	$ 23,651	$ 69,235		$ -	$ 23,651	$ 19,579	$ 44,059
4	$ 24,242	$ 93,477		$ -	$ 24,242	$ 18,844	$ 62,903
5	$ 24,848	$ 118,325		$ -	$ 24,848	$ 18,136	$ 81,039
6	$ 25,469	$ 143,794		$ -	$ 25,469	$ 17,455	$ 98,494
7	$ 26,106	$ 169,900		$ -	$ 26,106	$ 16,799	$ 115,293
8	$ 26,759	$ 196,659		$ -	$ 26,759	$ 16,168	$ 131,462
9	$ 27,427	$ 224,086		$ -	$ 27,427	$ 15,561	$ 147,023
10	$ 28,113	$ 252,199		$ -	$ 28,113	$ 14,977	$ 161,999
11	$ 28,816	$ 281,015		$ -	$ 28,816	$ 14,414	$ 176,413
12	$ 29,536	$ 310,552		$ -	$ 29,536	$ 13,873	$ 190,286
13	$ 30,275	$ 340,826		$ -	$ 30,275	$ 13,352	$ 203,638
14	$ 31,032	$ 371,858		$ -	$ 31,032	$ 12,850	$ 216,488
15	$ 31,807	$ 403,666		$ -	$ 31,807	$ 12,368	$ 228,856
16	$ 32,603	$ 436,268		$ -	$ 32,603	$ 11,903	$ 240,759
17	$ 33,418	$ 469,686		$ -	$ 33,418	$ 11,456	$ 252,215
18	$ 34,253	$ 503,939		$ -	$ 34,253	$ 11,026	$ 263,241
19	$ 35,109	$ 539,049		$ -	$ 35,109	$ 10,612	$ 273,852
20	$ 35,987	$ 575,036		$ -	$ 35,987	$ 10,213	$ 284,065
Total	$ 575,036						$ 284,065

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.

Variable Speed Cooling Tower Fans

Client Input Values	
Inflation Rate	2.5%
Discount Rate	6.5%

Assessment Inputs	
Capital Cost	$ 10,000
Secondary Capital Cost	$ -
Time of Secondary Capital Cost (Years)	0
Annual Savings	$ 27,757
Assessment Length (Years)	20

Assessment Results	
Payback Period (years)	1.0
Total NPV	$ 361,226
IRR	280.1%

Years	Annual Savings	Cummulative Savings	Payback	Capital Investment	Annual Cash Flow	Present Value of Saving	Net Present Value of Savings
0	$ -	$ -	$ (10,000)	$ 10,000	$ (10,000)	$ (10,000)	$ (10,000)
1	$ 27,757	$ 27,757	$ 17,757	$ -	$ 27,757	$ 26,063	$ 16,063
2	$ 28,451	$ 56,208		$ -	$ 28,451	$ 25,084	$ 41,147
3	$ 29,162	$ 85,370		$ -	$ 29,162	$ 24,142	$ 65,289
4	$ 29,891	$ 115,261		$ -	$ 29,891	$ 23,235	$ 88,524
5	$ 30,639	$ 145,900		$ -	$ 30,639	$ 22,362	$ 110,886
6	$ 31,404	$ 177,304		$ -	$ 31,404	$ 21,523	$ 132,409
7	$ 32,190	$ 209,494		$ -	$ 32,190	$ 20,714	$ 153,123
8	$ 32,994	$ 242,488		$ -	$ 32,994	$ 19,936	$ 173,059
9	$ 33,819	$ 276,308		$ -	$ 33,819	$ 19,187	$ 192,247
10	$ 34,665	$ 310,972		$ -	$ 34,665	$ 18,467	$ 210,714
11	$ 35,531	$ 346,504		$ -	$ 35,531	$ 17,773	$ 228,487
12	$ 36,420	$ 382,923		$ -	$ 36,420	$ 17,106	$ 245,593
13	$ 37,330	$ 420,253		$ -	$ 37,330	$ 16,463	$ 262,056
14	$ 38,263	$ 458,517		$ -	$ 38,263	$ 15,845	$ 277,901
15	$ 39,220	$ 497,736		$ -	$ 39,220	$ 15,250	$ 293,150
16	$ 40,200	$ 537,937		$ -	$ 40,200	$ 14,677	$ 307,827
17	$ 41,205	$ 579,142		$ -	$ 41,205	$ 14,126	$ 321,953
18	$ 42,236	$ 621,378		$ -	$ 42,236	$ 13,595	$ 335,548
19	$ 43,291	$ 664,669		$ -	$ 43,291	$ 13,085	$ 348,633
20	$ 44,374	$ 709,043		$ -	$ 44,374	$ 12,593	$ 361,226
Total	$ 709,043						$ 361,226

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.

Air Sourced Heat Pump

Client Input Values	
Inflation Rate	2.5%
Discount Rate	6.5%

Assessment Inputs	
Capital Cost	$ 39,000
Secondary Capital Cost	$ -
Time of Secondary Capital Cost (Years)	0
Annual Savings	$ 5,228
Assessment Length (Years)	20

Assessment Results	
Payback Period (years)	7.0
Total NPV	$ 30,921
IRR	14.4%

Years	Annual Savings	Cummulative Savings	Payback	Capital Investment	Annual Cash Flow	Present Value of Saving	Net Present Value of Savings
0	$ -	$ -	$ (39,000)	$ 39,000	$ (39,000)	$ (39,000)	$ (39,000)
1	$ 5,228	$ 5,228	$ (33,772)	$ -	$ 5,228	$ 4,909	$ (34,091)
2	$ 5,359	$ 10,587	$ (28,413)	$ -	$ 5,359	$ 4,725	$ (29,366)
3	$ 5,493	$ 16,080	$ (22,920)	$ -	$ 5,493	$ 4,547	$ (24,819)
4	$ 5,630	$ 21,710	$ (17,290)	$ -	$ 5,630	$ 4,376	$ (20,443)
5	$ 5,771	$ 27,481	$ (11,519)	$ -	$ 5,771	$ 4,212	$ (16,231)
6	$ 5,915	$ 33,396	$ (5,604)	$ -	$ 5,915	$ 4,054	$ (12,177)
7	$ 6,063	$ 39,459	$ 459	$ -	$ 6,063	$ 3,902	$ (8,275)
8	$ 6,215	$ 45,673		$ -	$ 6,215	$ 3,755	$ (4,520)
9	$ 6,370	$ 52,043		$ -	$ 6,370	$ 3,614	$ (906)
10	$ 6,529	$ 58,572		$ -	$ 6,529	$ 3,478	$ 2,572
11	$ 6,692	$ 65,265		$ -	$ 6,692	$ 3,348	$ 5,920
12	$ 6,860	$ 72,124		$ -	$ 6,860	$ 3,222	$ 9,141
13	$ 7,031	$ 79,156		$ -	$ 7,031	$ 3,101	$ 12,242
14	$ 7,207	$ 86,363		$ -	$ 7,207	$ 2,984	$ 15,227
15	$ 7,387	$ 93,750		$ -	$ 7,387	$ 2,872	$ 18,099
16	$ 7,572	$ 101,322		$ -	$ 7,572	$ 2,764	$ 20,864
17	$ 7,761	$ 109,083		$ -	$ 7,761	$ 2,661	$ 23,524
18	$ 7,955	$ 117,038		$ -	$ 7,955	$ 2,561	$ 26,085
19	$ 8,154	$ 125,192		$ -	$ 8,154	$ 2,465	$ 28,549
20	$ 8,358	$ 133,550		$ -	$ 8,358	$ 2,372	$ 30,921
Total	$ 133,550						$ 30,921

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.

Waste Water Heat Pump

Client Input Values	
Inflation Rate	2.5%
Discount Rate	6.5%

Assessment Inputs	
Capital Cost	$ 264,000
Secondary Capital Cost	$ -
Time of Secondary Capital Cost (Years)	0
Annual Savings	$ 6,763
Assessment Length (Years)	20

Assessment Results	
Payback Period (years)	39.0
Total NPV	$ (173,551)
IRR	-3.5%

Years	Annual Savings	Cummulative Savings	Payback	Capital Investment	Annual Cash Flow	Present Value of Saving	Net Present Value of Savings
0	$ -	$ -	$ (264,000)	$ 264,000	$ (264,000)	$ (264,000)	$ (264,000)
1	$ 6,763	$ 6,763	$ (257,237)	$ -	$ 6,763	$ 6,350	$ (257,650)
2	$ 6,932	$ 13,695	$ (250,305)	$ -	$ 6,932	$ 6,112	$ (251,538)
3	$ 7,105	$ 20,800	$ (243,200)	$ -	$ 7,105	$ 5,882	$ (245,656)
4	$ 7,283	$ 28,083	$ (235,917)	$ -	$ 7,283	$ 5,661	$ (239,995)
5	$ 7,465	$ 35,549	$ (228,451)	$ -	$ 7,465	$ 5,449	$ (234,546)
6	$ 7,652	$ 43,200	$ (220,800)	$ -	$ 7,652	$ 5,244	$ (229,302)
7	$ 7,843	$ 51,043	$ (212,957)	$ -	$ 7,843	$ 5,047	$ (224,255)
8	$ 8,039	$ 59,082	$ (204,918)	$ -	$ 8,039	$ 4,857	$ (219,398)
9	$ 8,240	$ 67,322	$ (196,678)	$ -	$ 8,240	$ 4,675	$ (214,722)
10	$ 8,446	$ 75,768	$ (188,232)	$ -	$ 8,446	$ 4,499	$ (210,223)
11	$ 8,657	$ 84,426	$ (179,574)	$ -	$ 8,657	$ 4,330	$ (205,893)
12	$ 8,874	$ 93,299	$ (170,701)	$ -	$ 8,874	$ 4,168	$ (201,725)
13	$ 9,095	$ 102,395	$ (161,605)	$ -	$ 9,095	$ 4,011	$ (197,714)
14	$ 9,323	$ 111,718	$ (152,282)	$ -	$ 9,323	$ 3,861	$ (193,853)
15	$ 9,556	$ 121,274	$ (142,726)	$ -	$ 9,556	$ 3,716	$ (190,137)
16	$ 9,795	$ 131,068	$ (132,932)	$ -	$ 9,795	$ 3,576	$ (186,561)
17	$ 10,040	$ 141,108	$ (122,892)	$ -	$ 10,040	$ 3,442	$ (183,120)
18	$ 10,291	$ 151,399	$ (112,601)	$ -	$ 10,291	$ 3,312	$ (179,807)
19	$ 10,548	$ 161,947	$ (102,053)	$ -	$ 10,548	$ 3,188	$ (176,619)
20	$ 10,812	$ 172,759	$ (91,241)	$ -	$ 10,812	$ 3,068	$ (173,551)
Total	$ 172,759		$ 81,517				$ (173,551)

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.

Variable Volume Condending Water Loop

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	$ 35,059
Assessment Length (Years)	20

Assessment Results	
Payback Period (years)	2.0
Total NPV	$ 418,884
IRR	72.6%

Years	Annual Savings	Cummulative Savings	Payback	Capital Investment	Annual Cash Flow	Present Value of Saving	Net Present Value of Savings
0	$ -	$ -	$ (50,000)	$ 50,000	$ (50,000)	$ (50,000)	$ (50,000)
1	$ 35,059	$ 35,059	$ (14,941)	$ -	$ 35,059	$ 32,919	$ (17,081)
2	$ 35,935	$ 70,994	$ 20,994	$ -	$ 35,935	$ 31,683	$ 14,602
3	$ 36,834	$ 107,828		$ -	$ 36,834	$ 30,493	$ 45,095
4	$ 37,755	$ 145,583		$ -	$ 37,755	$ 29,348	$ 74,443
5	$ 38,699	$ 184,282		$ -	$ 38,699	$ 28,245	$ 102,688
6	$ 39,666	$ 223,948		$ -	$ 39,666	$ 27,184	$ 129,872
7	$ 40,658	$ 264,605		$ -	$ 40,658	$ 26,163	$ 156,036
8	$ 41,674	$ 306,279		$ -	$ 41,674	$ 25,181	$ 181,217
9	$ 42,716	$ 348,995		$ -	$ 42,716	$ 24,235	$ 205,452
10	$ 43,784	$ 392,779		$ -	$ 43,784	$ 23,325	$ 228,777
11	$ 44,878	$ 437,658		$ -	$ 44,878	$ 22,449	$ 251,225
12	$ 46,000	$ 483,658		$ -	$ 46,000	$ 21,606	$ 272,831
13	$ 47,150	$ 530,809		$ -	$ 47,150	$ 20,794	$ 293,625
14	$ 48,329	$ 579,138		$ -	$ 48,329	$ 20,013	$ 313,638
15	$ 49,537	$ 628,675		$ -	$ 49,537	$ 19,261	$ 332,900
16	$ 50,776	$ 679,451		$ -	$ 50,776	$ 18,538	$ 351,438
17	$ 52,045	$ 731,497		$ -	$ 52,045	$ 17,842	$ 369,280
18	$ 53,346	$ 784,843		$ -	$ 53,346	$ 17,172	$ 386,451
19	$ 54,680	$ 839,523		$ -	$ 54,680	$ 16,527	$ 402,978
20	$ 56,047	$ 895,570		$ -	$ 56,047	$ 15,906	$ 418,884
Total	$ 895,570						$ 418,884

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.

Energy Piles (Ground Source Heat Rejection Through Piles)

Client Input Values	
Inflation Rate	2.5%
Discount Rate	6.5%

Assessment Inputs	
Capital Cost	$ 303,000
Secondary Capital Cost	$ -
Time of Secondary Capital Cost (Years)	0
Annual Savings	$ 47,921
Assessment Length (Years)	20

Assessment Results	
Payback Period (years)	6.0
Total NPV	$ 337,902
IRR	17.2%

Years	Annual Savings	Cummulative Savings	Payback	Capital Investment	Annual Cash Flow	Present Value of Saving	Net Present Value of Savings
0	$ -	$ -	$ (303,000)	$ 303,000	$ (303,000)	$ (303,000)	$ (303,000)
1	$ 47,921	$ 47,921	$ (255,079)	$ -	$ 47,921	$ 44,996	$ (258,004)
2	$ 49,119	$ 97,040	$ (205,960)	$ -	$ 49,119	$ 43,306	$ (214,698)
3	$ 50,347	$ 147,387	$ (155,613)	$ -	$ 50,347	$ 41,680	$ (173,018)
4	$ 51,606	$ 198,993	$ (104,007)	$ -	$ 51,606	$ 40,114	$ (132,904)
5	$ 52,896	$ 251,889	$ (51,111)	$ -	$ 52,896	$ 38,608	$ (94,296)
6	$ 54,218	$ 306,107	$ 3,107	$ -	$ 54,218	$ 37,158	$ (57,138)
7	$ 55,574	$ 361,680		$ -	$ 55,574	$ 35,762	$ (21,376)
8	$ 56,963	$ 418,643		$ -	$ 56,963	$ 34,419	$ 13,043
9	$ 58,387	$ 477,030		$ -	$ 58,387	$ 33,126	$ 46,169
10	$ 59,847	$ 536,877		$ -	$ 59,847	$ 31,882	$ 78,051
11	$ 61,343	$ 598,220		$ -	$ 61,343	$ 30,684	$ 108,735
12	$ 62,877	$ 661,097		$ -	$ 62,877	$ 29,532	$ 138,267
13	$ 64,448	$ 725,545		$ -	$ 64,448	$ 28,423	$ 166,690
14	$ 66,060	$ 791,605		$ -	$ 66,060	$ 27,355	$ 194,045
15	$ 67,711	$ 859,316		$ -	$ 67,711	$ 26,328	$ 220,373
16	$ 69,404	$ 928,720		$ -	$ 69,404	$ 25,339	$ 245,712
17	$ 71,139	$ 999,859		$ -	$ 71,139	$ 24,387	$ 270,099
18	$ 72,917	$ 1,072,776		$ -	$ 72,917	$ 23,471	$ 293,571
19	$ 74,740	$ 1,147,517		$ -	$ 74,740	$ 22,590	$ 316,161
20	$ 76,609	$ 1,224,126		$ -	$ 76,609	$ 21,741	$ 337,902
Total	$ 1,224,126						$ 337,902

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 Efficient Design Opportunities

Client Input Values	
Inflation Rate	2.5%
Discount Rate	6.5%

Assessment Inputs	
Capital Cost	$ 419,000
Secondary Capital Cost	$ -
Time of Secondary Capital Cost (Years)	0
Annual Savings	$ 68,314
Assessment Length (Years)	20

Assessment Results	
Payback Period (years)	6.0
Total NPV	$ 494,641
IRR	17.8%

Years	Annual Savings	Cummulative Savings	Payback	Capital Investment	Annual Cash Flow	Present Value of Saving	Net Present Value of Savings
0	$ -	$ -	$ (419,000)	$ 419,000	$ (419,000)	$ (419,000)	$ (419,000)
1	$ 68,314	$ 68,314	$ (350,686)	$ -	$ 68,314	$ 64,145	$ (354,855)
2	$ 70,022	$ 138,336	$ (280,664)	$ -	$ 70,022	$ 61,735	$ (293,120)
3	$ 71,772	$ 210,108	$ (208,892)	$ -	$ 71,772	$ 59,417	$ (233,703)
4	$ 73,567	$ 283,675	$ (135,325)	$ -	$ 73,567	$ 57,185	$ (176,518)
5	$ 75,406	$ 359,081	$ (59,919)	$ -	$ 75,406	$ 55,037	$ (121,481)
6	$ 77,291	$ 436,372	$ 17,372	$ -	$ 77,291	$ 52,970	$ (68,511)
7	$ 79,223	$ 515,595		$ -	$ 79,223	$ 50,981	$ (17,530)
8	$ 81,204	$ 596,799		$ -	$ 81,204	$ 49,066	$ 31,536
9	$ 83,234	$ 680,033		$ -	$ 83,234	$ 47,223	$ 78,759
10	$ 85,315	$ 765,348		$ -	$ 85,315	$ 45,449	$ 124,208
11	$ 87,448	$ 852,796		$ -	$ 87,448	$ 43,742	$ 167,951
12	$ 89,634	$ 942,429		$ -	$ 89,634	$ 42,100	$ 210,050
13	$ 91,875	$ 1,034,304		$ -	$ 91,875	$ 40,518	$ 250,569
14	$ 94,172	$ 1,128,476		$ -	$ 94,172	$ 38,996	$ 289,565
15	$ 96,526	$ 1,225,002		$ -	$ 96,526	$ 37,532	$ 327,097
16	$ 98,939	$ 1,323,941		$ -	$ 98,939	$ 36,122	$ 363,219
17	$ 101,413	$ 1,425,353		$ -	$ 101,413	$ 34,765	$ 397,985
18	$ 103,948	$ 1,529,301		$ -	$ 103,948	$ 33,460	$ 431,444
19	$ 106,547	$ 1,635,848		$ -	$ 106,547	$ 32,203	$ 463,647
20	$ 109,210	$ 1,745,058		$ -	$ 109,210	$ 30,994	$ 494,641
Total	$ 1,745,058						$ 494,641

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.

Roof Mounted Photovoltaics

Client Input Values	
Inflation Rate	2.5%
Discount Rate	6.5%

Assessment Inputs	
Capital Cost	$ 344,000
Secondary Capital Cost	$ -
Time of Secondary Capital Cost (Years)	0
Annual Savings	$ 24,987
Assessment Length (Years)	20

Assessment Results	
Payback Period (years)	12.0
Total NPV	$ (9,820)
IRR	6.2%

Years	Annual Savings	Cummulative Savings	Payback	Capital Investment	Annual Cash Flow	Present Value of Saving	Net Present Value of Savings
0	$ -	$ -	$ (344,000)	$ 344,000	$ (344,000)	$ (344,000)	$ (344,000)
1	$ 24,987	$ 24,987	$ (319,013)	$ -	$ 24,987	$ 23,462	$ (320,538)
2	$ 25,612	$ 50,599	$ (293,401)	$ -	$ 25,612	$ 22,581	$ (297,957)
3	$ 26,252	$ 76,851	$ (267,149)	$ -	$ 26,252	$ 21,733	$ (276,225)
4	$ 26,908	$ 103,759	$ (240,241)	$ -	$ 26,908	$ 20,916	$ (255,308)
5	$ 27,581	$ 131,340	$ (212,660)	$ -	$ 27,581	$ 20,131	$ (235,177)
6	$ 28,270	$ 159,610	$ (184,390)	$ -	$ 28,270	$ 19,375	$ (215,803)
7	$ 28,977	$ 188,588	$ (155,412)	$ -	$ 28,977	$ 18,647	$ (197,156)
8	$ 29,702	$ 218,289	$ (125,711)	$ -	$ 29,702	$ 17,947	$ (179,209)
9	$ 30,444	$ 248,734	$ (95,266)	$ -	$ 30,444	$ 17,273	$ (161,936)
10	$ 31,205	$ 279,939	$ (64,061)	$ -	$ 31,205	$ 16,624	$ (145,312)
11	$ 31,985	$ 311,924	$ (32,076)	$ -	$ 31,985	$ 16,000	$ (129,313)
12	$ 32,785	$ 344,709	$ 709	$ -	$ 32,785	$ 15,399	$ (113,914)
13	$ 33,605	$ 378,314		$ -	$ 33,605	$ 14,820	$ (99,094)
14	$ 34,445	$ 412,759		$ -	$ 34,445	$ 14,264	$ (84,830)
15	$ 35,306	$ 448,065		$ -	$ 35,306	$ 13,728	$ (71,102)
16	$ 36,189	$ 484,254		$ -	$ 36,189	$ 13,212	$ (57,890)
17	$ 37,093	$ 521,347		$ -	$ 37,093	$ 12,716	$ (45,174)
18	$ 38,021	$ 559,368		$ -	$ 38,021	$ 12,238	$ (32,936)
19	$ 38,971	$ 598,339		$ -	$ 38,971	$ 11,779	$ (21,157)
20	$ 39,945	$ 638,284		$ -	$ 39,945	$ 11,336	$ (9,820)
Total	$ 638,284						$ (9,820)

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.