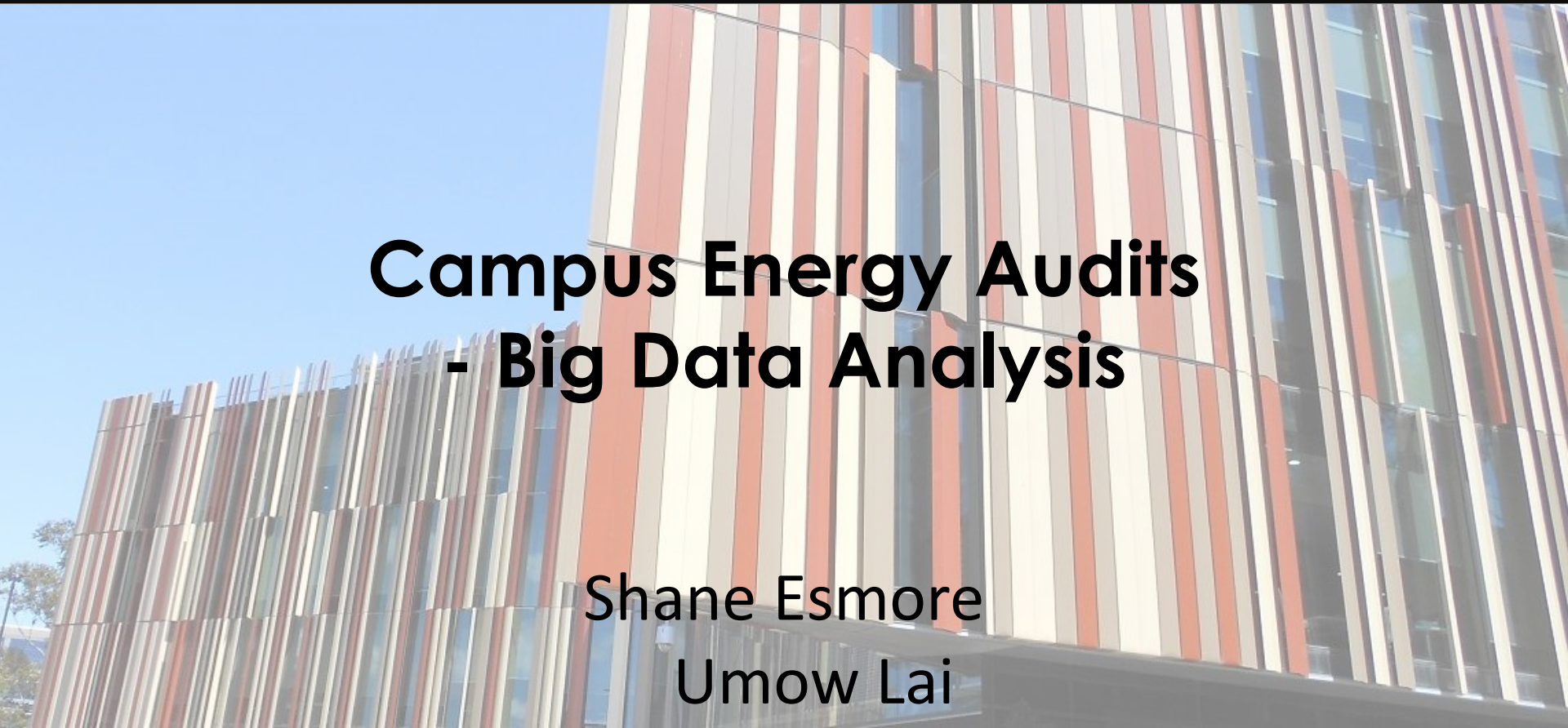


Campus Energy Audits - Big Data Analysis

Shane Esmore
Umow Lai

MACQUARIE UNIVERSITY
SYDNEY ~ AUSTRALIA

Umow Lai

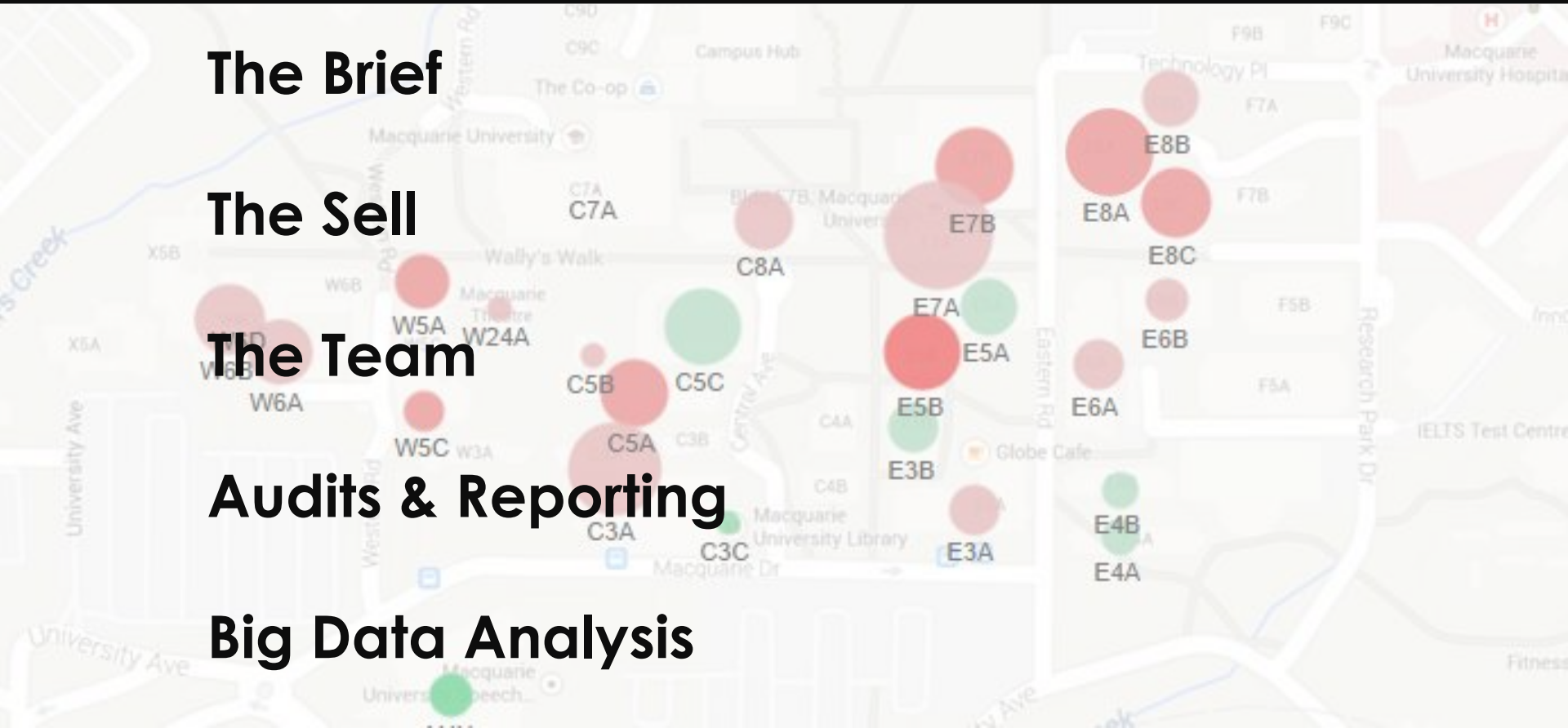
The Brief

The Sell

The Team

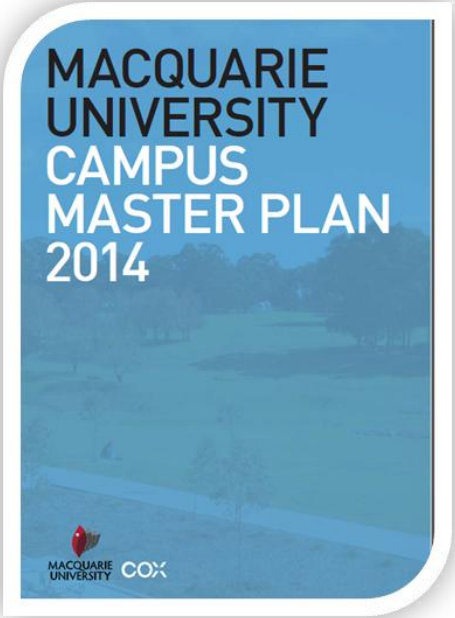
Audits & Reporting

Big Data Analysis



The Brief

- Conduct Level 2 Energy Audits (AS3598) for Approx 50 buildings (~200,000sqm)
- Develop Implementation Plan for Building Upgrades



50%

ENERGY REDUCTION
on 2012 levels by 2030

Greenhouse Gases: 50% total reduction on 2012 levels (fossil fuel powered energy)

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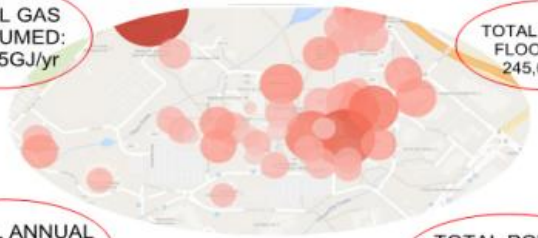
EXISTING EMISSIONS

TOTAL GHG EMISSIONS: 45,707,239 kgCO2/yr

TOTAL GAS CONSUMED: 75,285GJ/yr

TOTAL BUILDING FLOOR AREA: 245,000 sqm

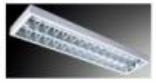


TOTAL ANNUAL ENERGY COSTS: $6,856,000

TOTAL POWER CONSUMED: 41.4GWh/yr

POTENTIAL REDUCTIONS

HVAC



LIGHTING

EQUIPMENT

OTHERS

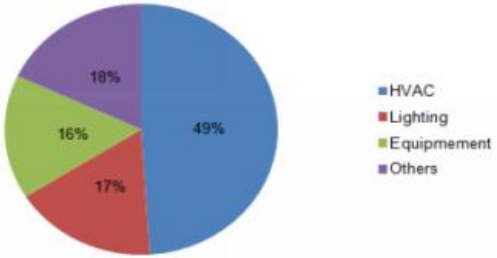
19% REDUCTION $12.8M COST

28% REDUCTION $4.7M COST

10% REDUCTION $0.64M COST

21% REDUCTION $1.2M COST

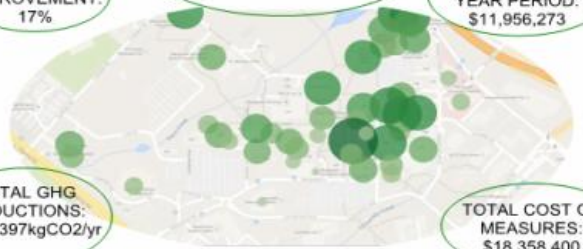
Main Energy Users



EFFICIENCY IMPROVEMENT: 17%

ROOFTOP SOLAR: FURTHER 1,704,522kgCO2/yr AVOIDED 9 YEAR PAYBACK

SAVINGS OVER 10 YEAR PERIOD: $11,956,273



TOTAL GHG REDUCTIONS: 7,731,397kgCO2/yr

TOTAL COST OF MEASURES: $18,358,400

ENERGY SAVINGS INITIATIVES NOMINATED IN AUDIT PROJECT

The Sell

- Detailed analysis of buildings metered data
- Site visits to all buildings
- Energy Audit report for all buildings
- Big Data analysis of results with overall site wide presentation

The Team

Hugh Wilson
Senior
Associate

Richard Stokes
Sustainability
Consultant

Afroz Awan
Mechanical
Engineer

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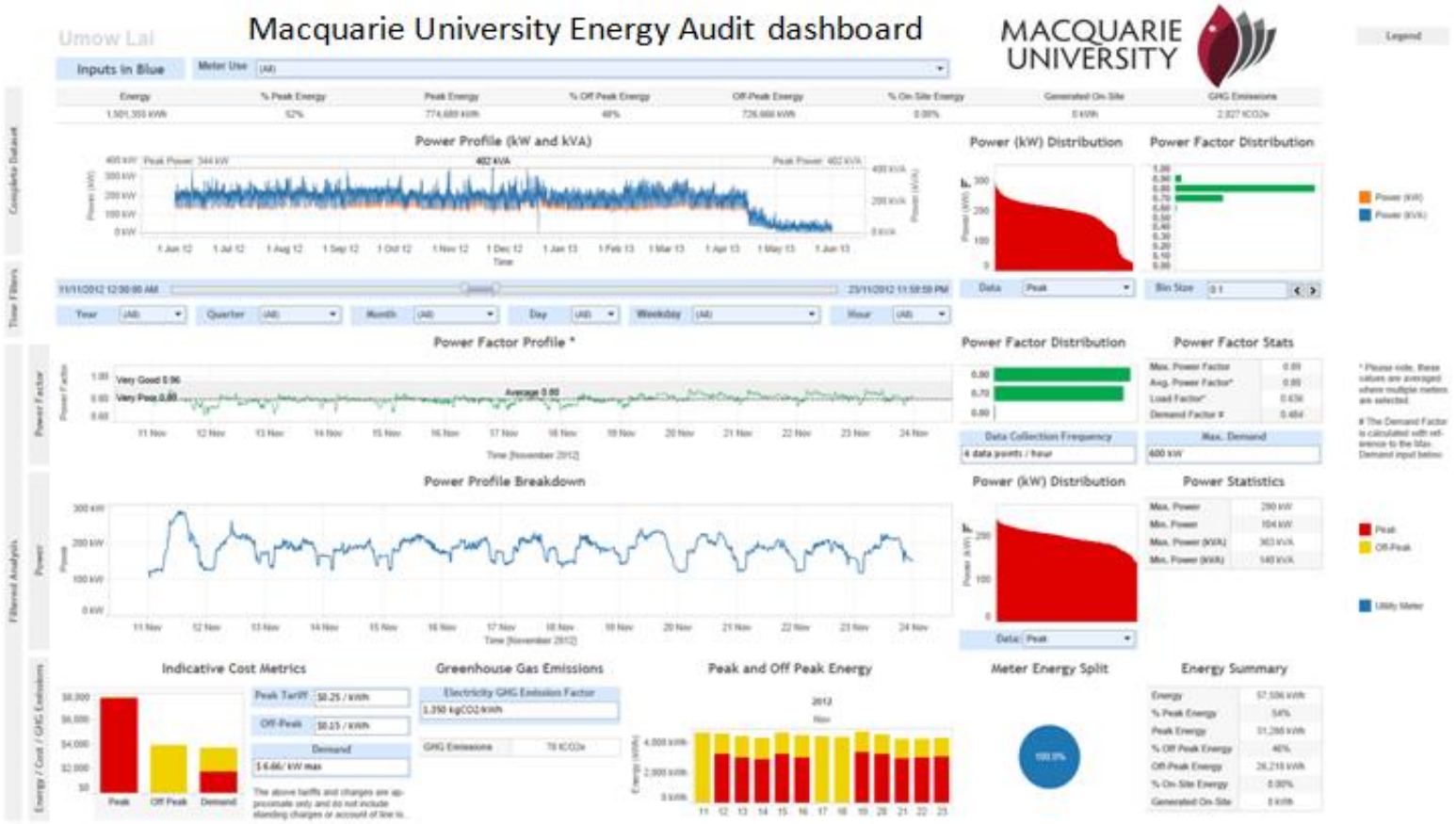
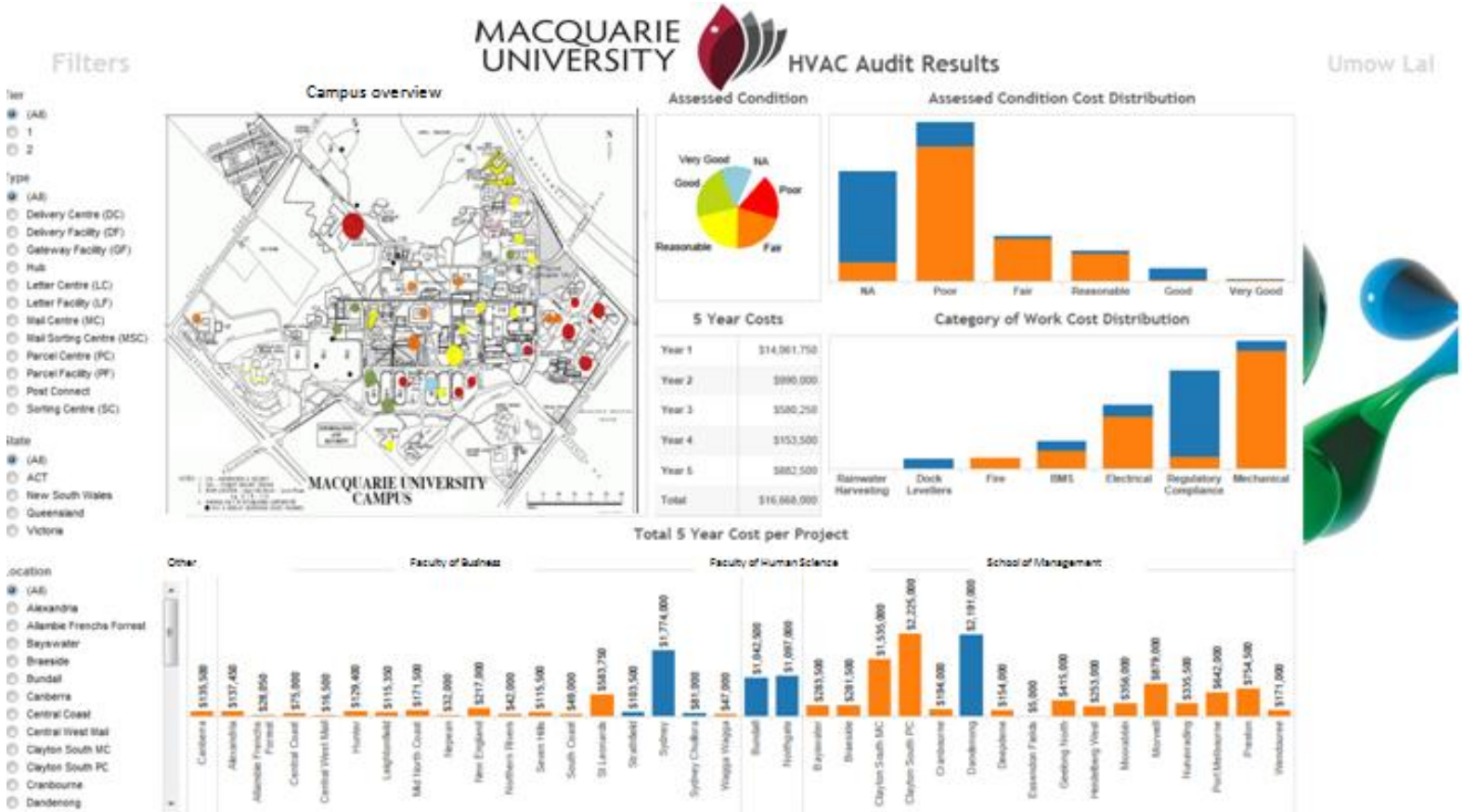
Mock Up



Mock Up


MACQUARIE UNIVERSITY
HVAC Audit Results
Filters
Umow Lai
Campus overview
MACQUARIE UNIVERSITY CAMPUS
Assessed Condition
Very Good
NA
Good
Poor
Reasonable
Fair
Assessed Condition Cost Distribution
NA
Poor
Fair
Reasonable
Good
Very Good
5 Year Costs
Year 1 $14,061,750
Year 2 $990,000
Year 3 $580,250
Year 4 $153,500
Year 5 $882,500
Total $16,668,000
Category of Work Cost Distribution
Rainwater Harvesting
Dock Levellers
Fire
BMS
Electrical
Regulatory Compliance
Mechanical
Total 5 Year Cost per Project
Other
Faculty of Business
Faculty of Human Science
School of Management
Canberra
Alexandria
Allambie Frenchs Forest
Central Coast
Central West Mail
Hunter
Leeuwinhoek
Mid North Coast
Nepean
New England
Northern Rivers
Seven Hills
South Coast
St Leonards
Strathfield
Sydney
Sydney Chullora
Wagga Wagga
Bundall
Nerang
Bayswater
Braeside
Clayton South MC
Clayton South PC
Cranbourne
Dandenong
Deepdene
Essendon Fields
Geelong North
Heidelberg West
Moorabbin
Morwell
Nunawading
Port Melbourne
Preston
Werribee

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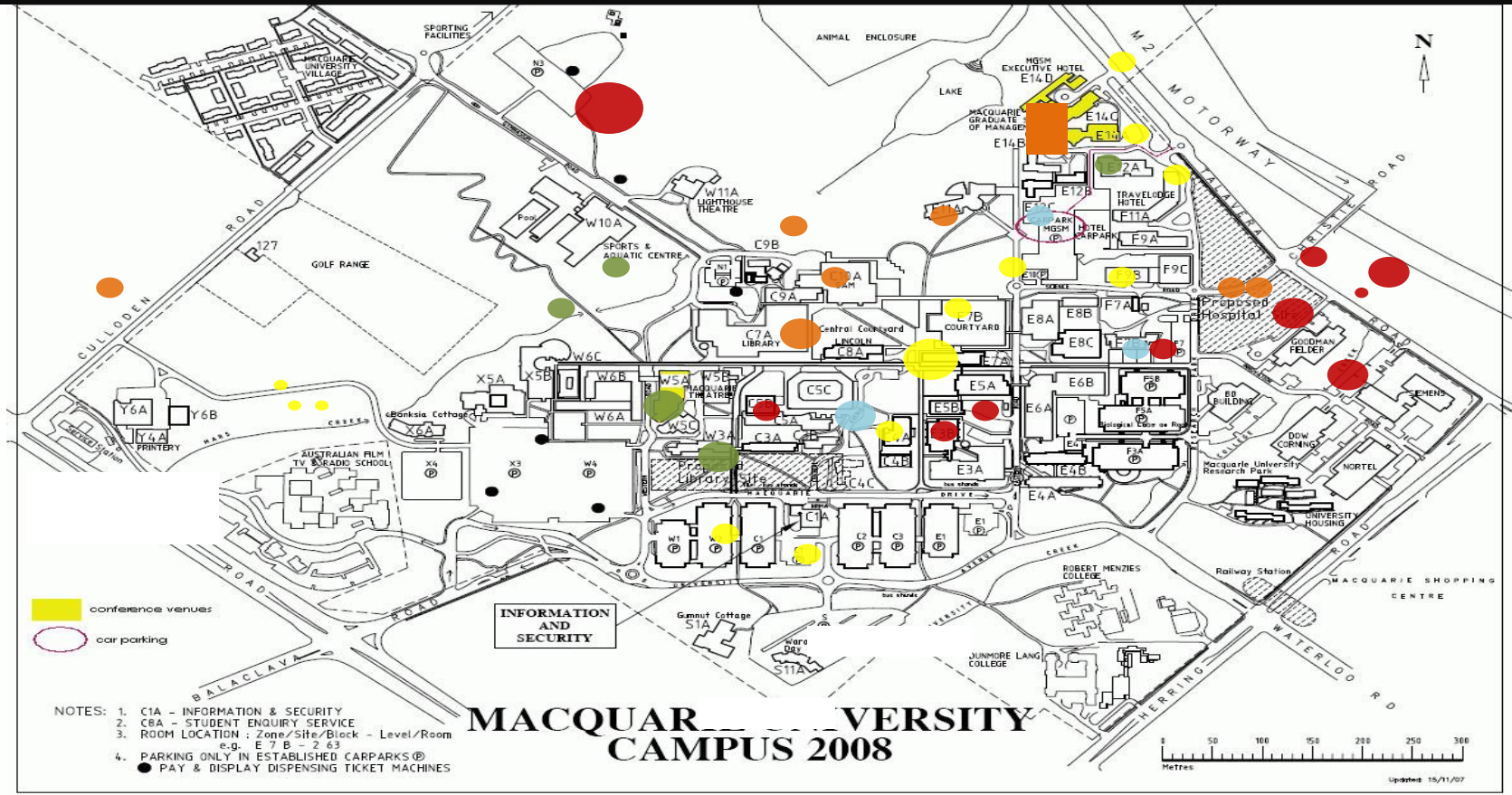
Legend

kWh/m2 pa

- <100
- 100-200
- 200-300
- 300-400
- >400



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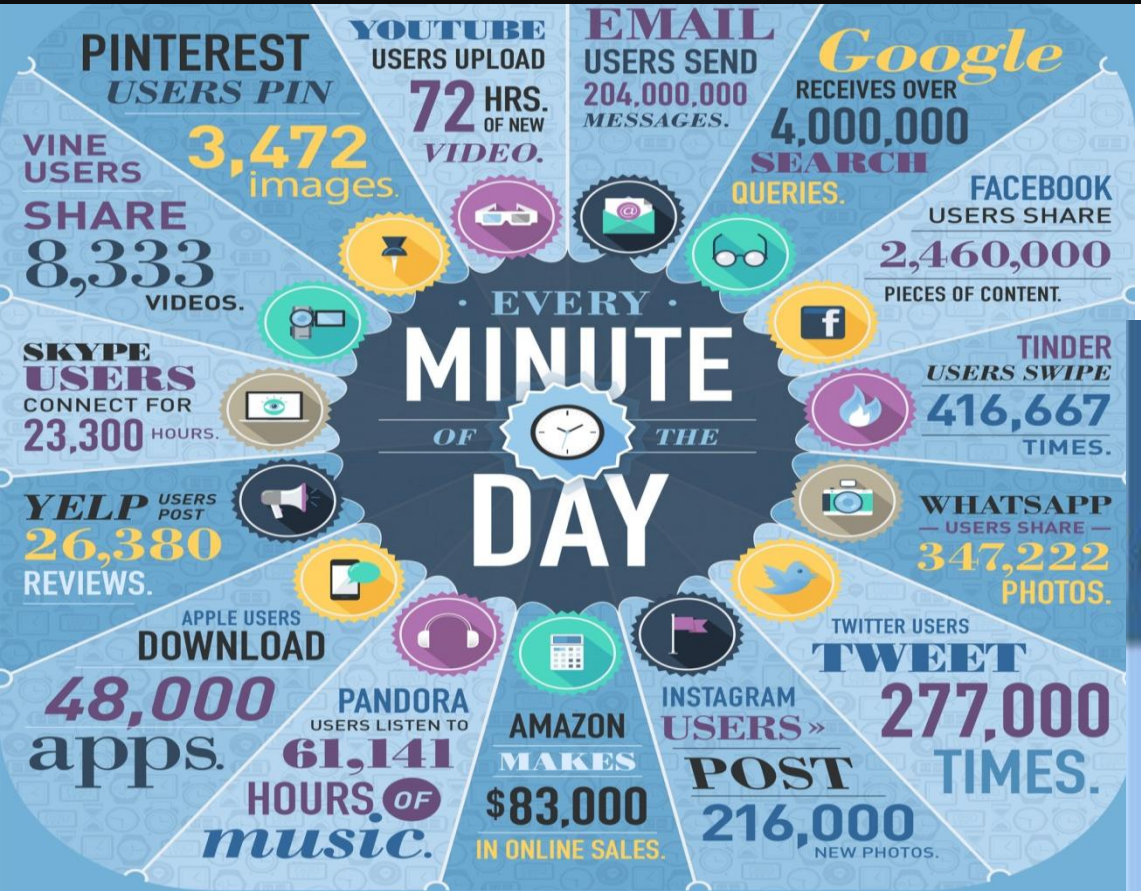


Between the birth of the world and 2003, there were five Exabyte of information created. We now create five Exabyte every two days

Eric Schmidt

ogle Over **24 Petabytes**
Data processed by
Google* every day in 2011

1 EXABYTE

which is...

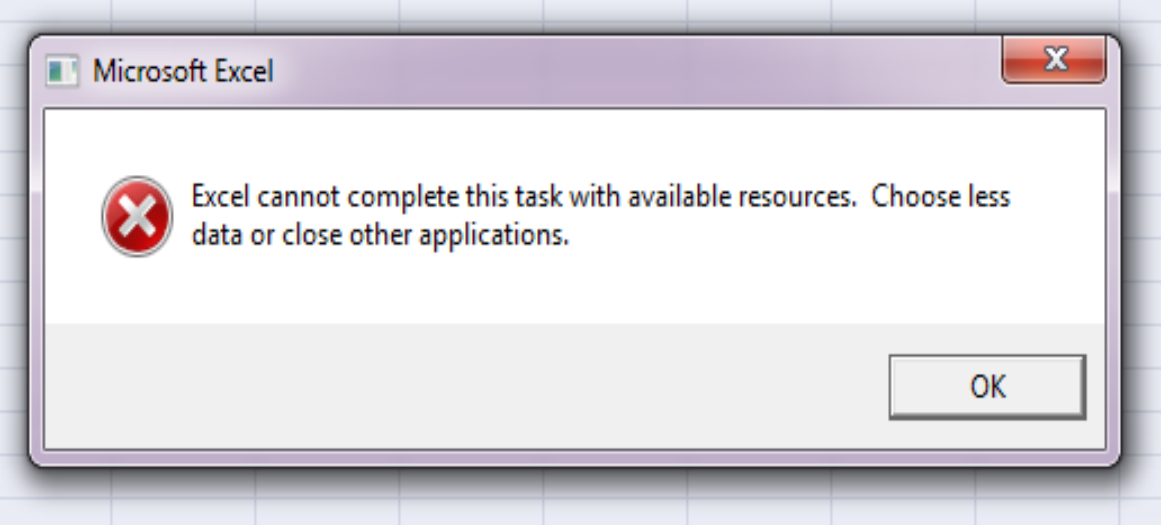
1024 PETABYTES
1,048,576 TERABYTES
1,073,741,824 GIGABYTES
1,099,511,627,776 MEGABYTES

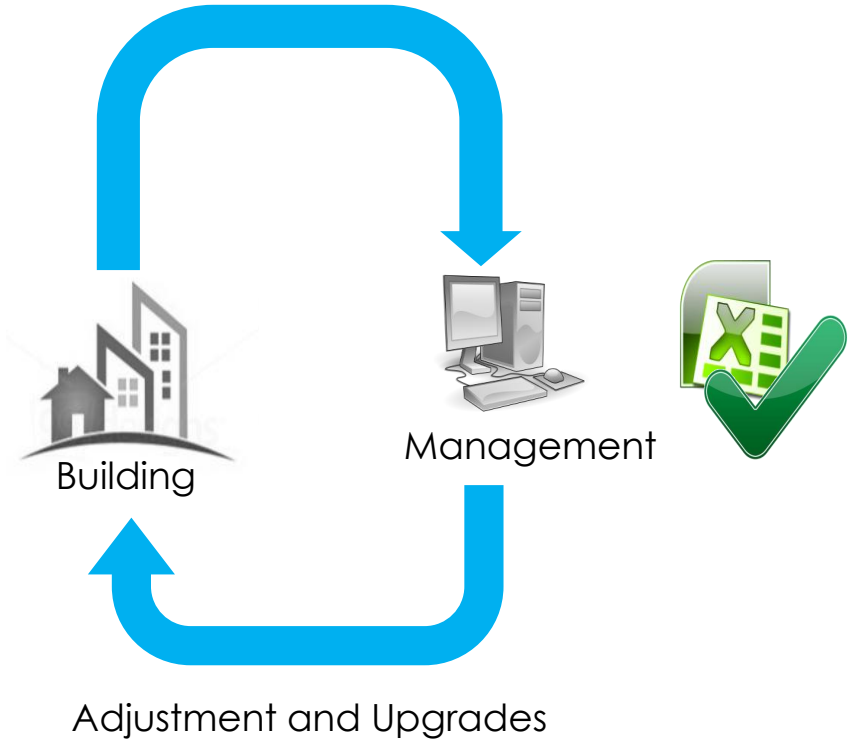
Data

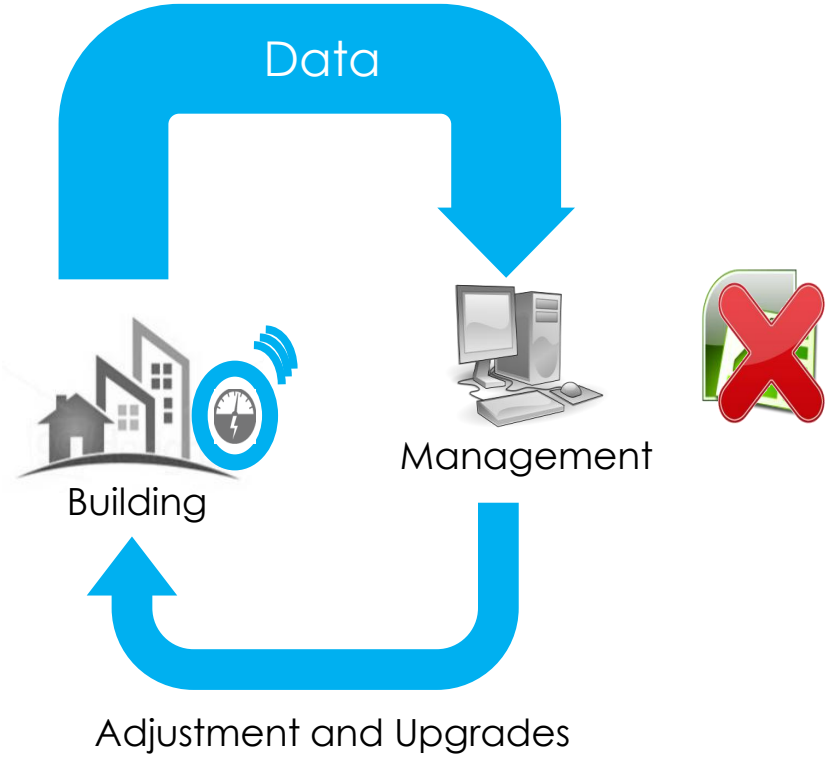
Data

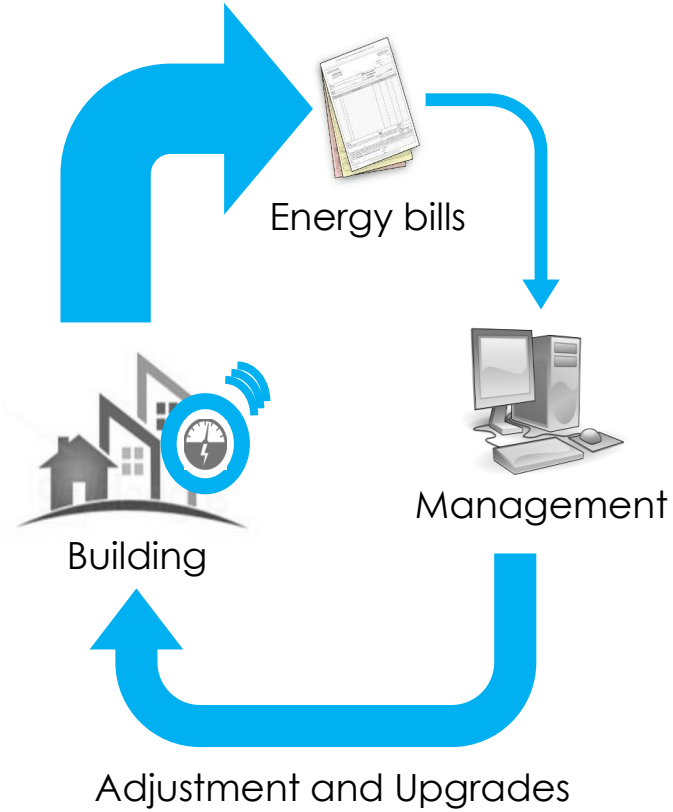
Data

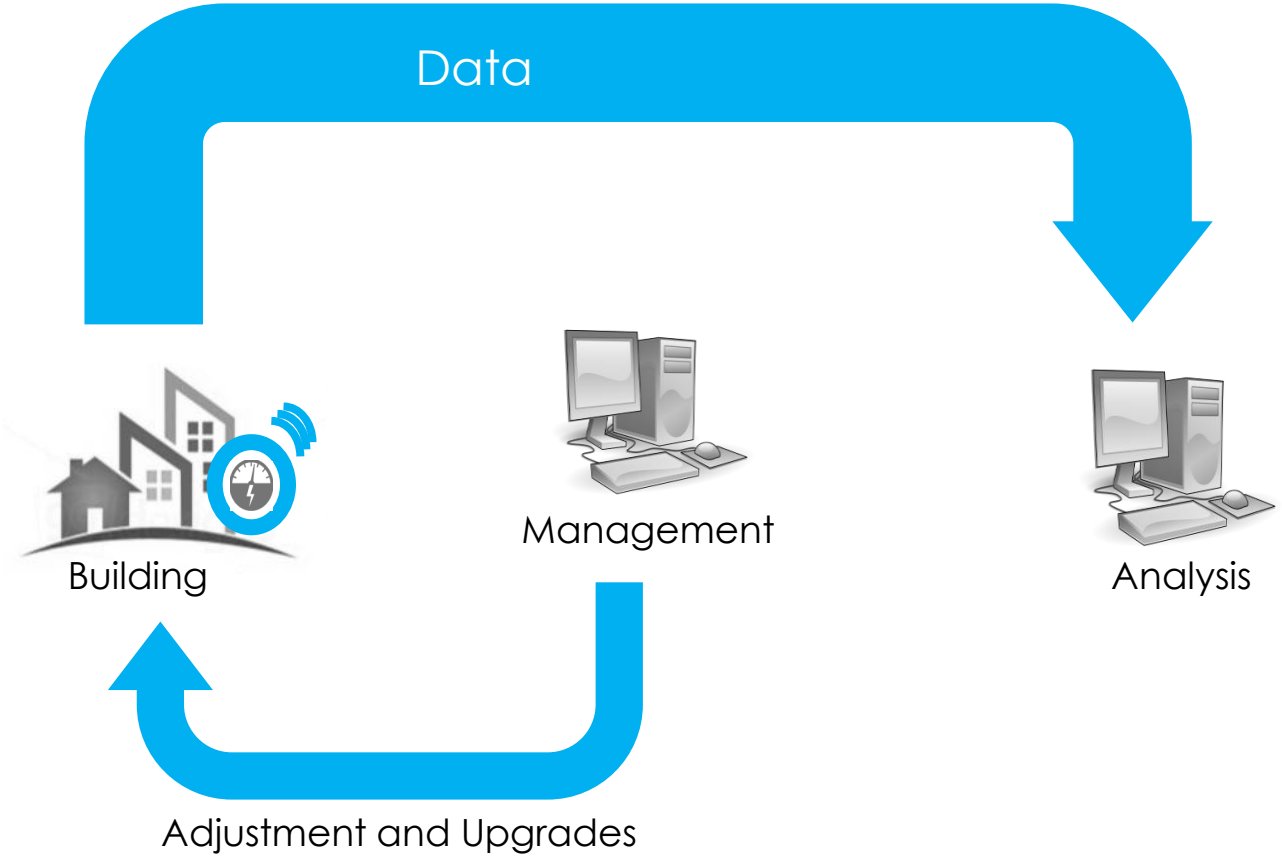
Data

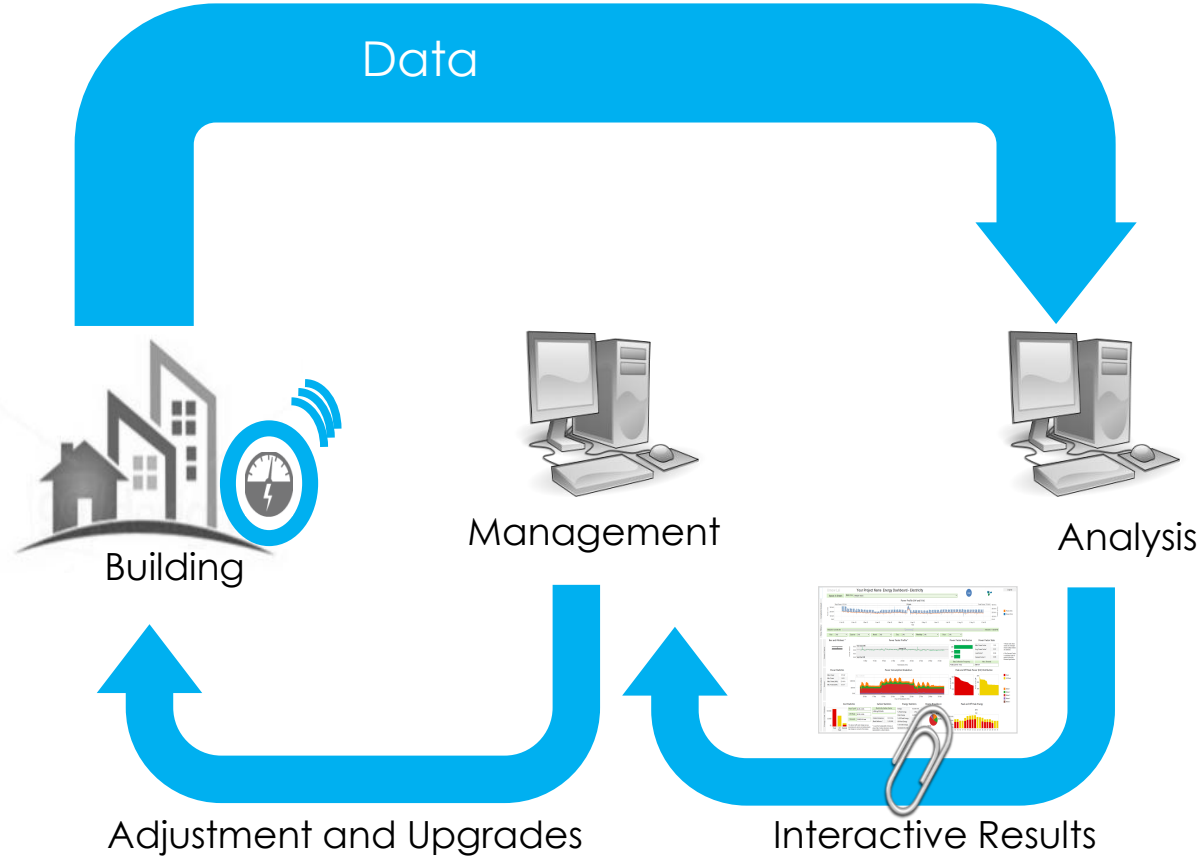

Microsoft Excel
Excel cannot complete this task with available resources. Choose less data or close other applications.
OK


Building
Management
Adjustment and Upgrades


Data
Management
Building
Adjustment and Upgrades


Energy bills
Management
Building
Adjustment and Upgrades


Data
Building
Management
Analysis
Adjustment and Upgrades


Data
Building
Management
Analysis
Adjustment and Upgrades
Interactive Results

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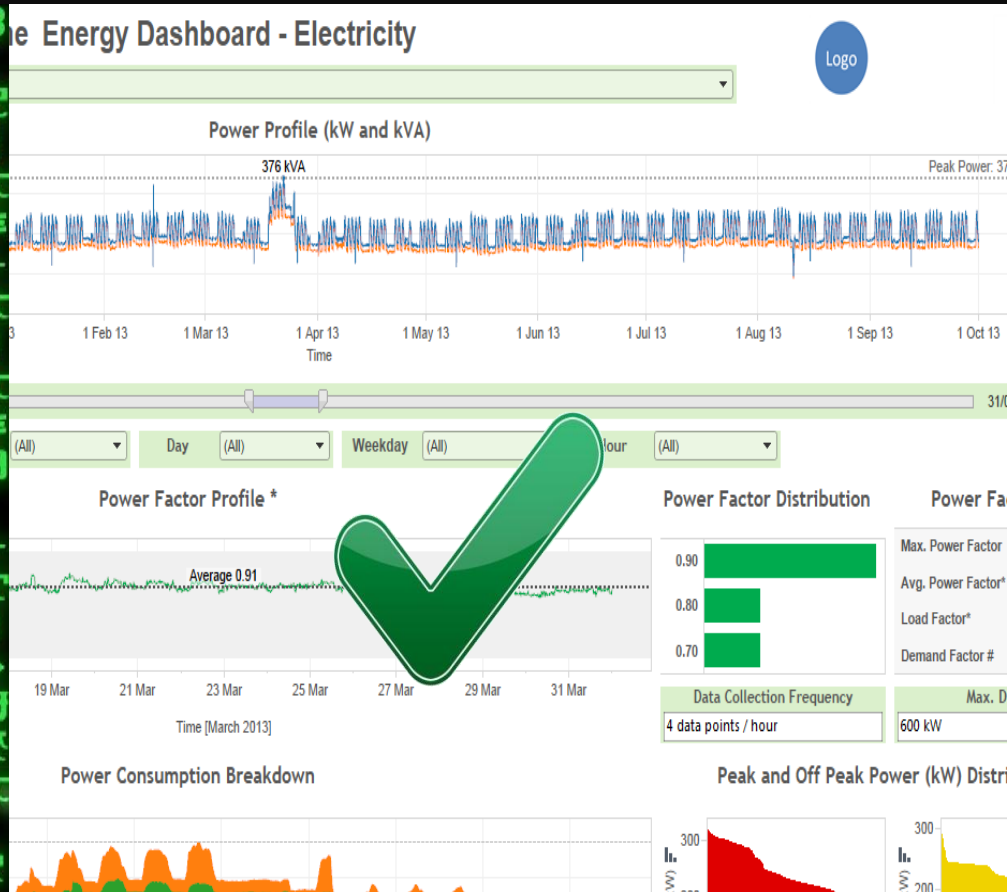


MACQUARIE UNIVERSITY
SYDNEY ~ AUSTRALIA

Umow Lai

Umow Lai

Your Project Name Energy Dashboard - Electricity

Logo

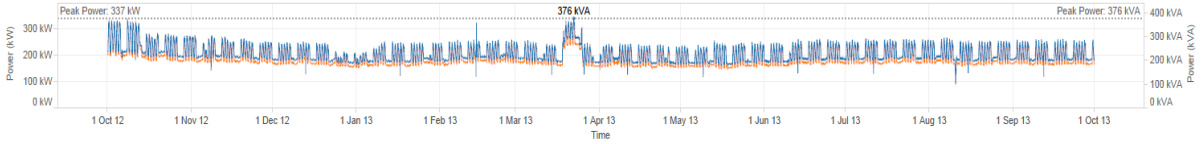
Inputs in Green

Meter Use (Multiple values)

Legend

Complete Dataset

Power Profile (kW and kVA)



Power (kW)
Power (kVA)

Time Filters

14/03/2013 12:00:00 AM — 31/03/2013 11:59:59 PM

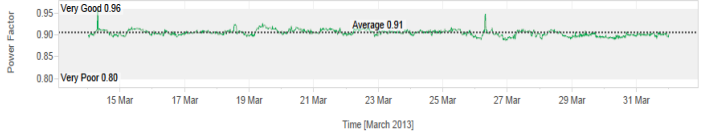
Year (All) | Quarter (All) | Month (All) | Day (All) | Weekday (All) | Hour (All)

Filtered Analysis

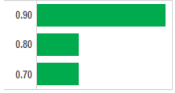
Power Factor

Box and Whiskers *

Power Factor Profile *



Power Factor Distribution



Power Factor Stats

Max. Power Factor	1.00
Avg. Power Factor*	0.90
Load Factor*	0.244
Demand Factor #	0.286

Data Collection Frequency: 4 data points / hour

Max. Demand: 600 kW

* Please note, these values are averaged where multiple meters are selected.

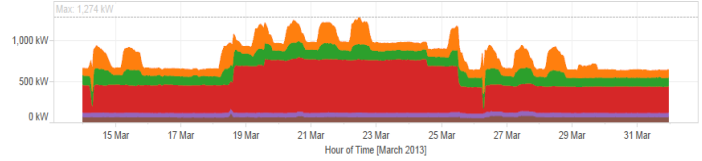
The Demand Factor is calculated with reference to the Max. Demand input below.

Power

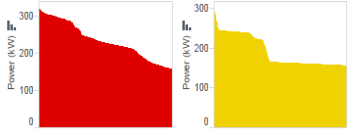
Power Statistics

Max. Power	172 kW
Min. Power	6 kW
Max. Power (kVA)	224 kVA
Min. Power (kVA)	8 kVA

Power Consumption Breakdown



Peak and Off Peak Power (kW) Distribution

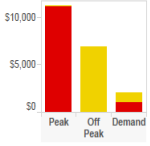


Peak
Off-Peak

Meter 1
Meter 2
Meter 3
Meter 4
Meter 5

Energy / Cost / Carbon

Cost Statistics



Peak Tariff	$0.25 / kWh
Off-Peak	$0.15 / kWh
Demand	$ 6.00/ kW max

The above tariffs and charges are approximate only and do not include standing charges or account of line losses.

Carbon Statistics

Electricity Carbon Factor: 1.350 kgCO2/kWh

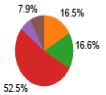
Carbon Emissions	122 tCO2e
Black Balloons ^	2,439,698

^ As per the Sustainability Victoria ad where 50g of carbon dioxide is visually represented by a black balloon.

Energy Statistics

Energy	90,359 kWh
% Peak Energy	49%
Peak Energy	44,594 kWh
% Off Peak Energy	51%
Off-Peak Energy	45,765 kWh
% On-Site Energy	0.00%
Generated On-Site	0 kWh

Energy Breakdown



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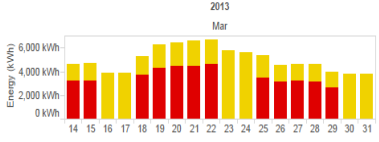

Umow Lai

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Logo

Legend

Complete Dataset

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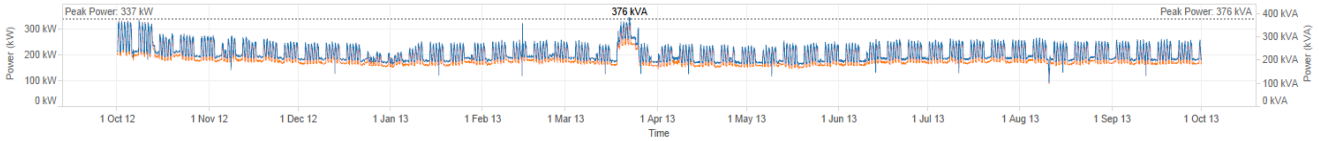

Power (kW)
Power (kVA)

Time Filters

14/03/2013 12:00:00 AM — 31/03/2013 11:59:59 PM

Year	Quarter	Month	Day	Weekday	Hour
(All)	(All)	(All)	(All)	(All)	(All)

Filtered Analysis

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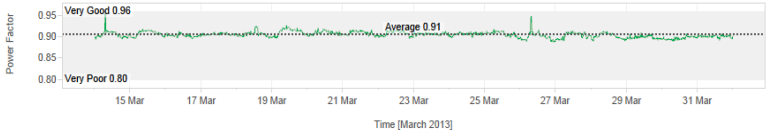
Box and Whiskers *

Power Factor Profile *



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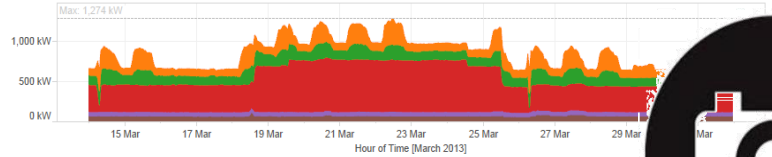
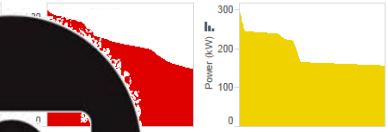


Peak and Off Peak Power (kW) Distribution

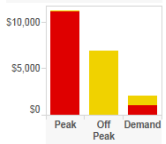


Peak
Off-Peak

Meter 1
Meter 2
Meter 3
Meter 4
Meter 5

Energy / Cost / Carbon

Cost Statistics



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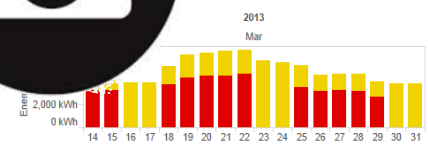
% On-Site Energy	0.00%
Generated On-Site	0 kWh

Energy B… …wn

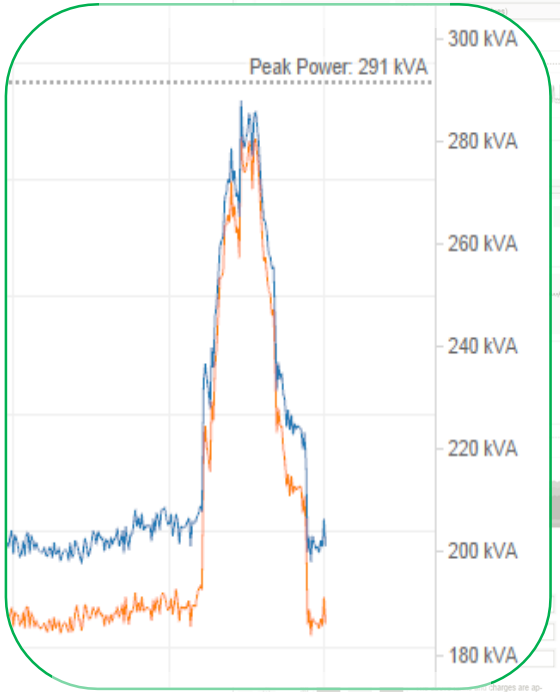
…nd Off Peak Energy



* Please note, these values are averaged where multiple meters are selected.

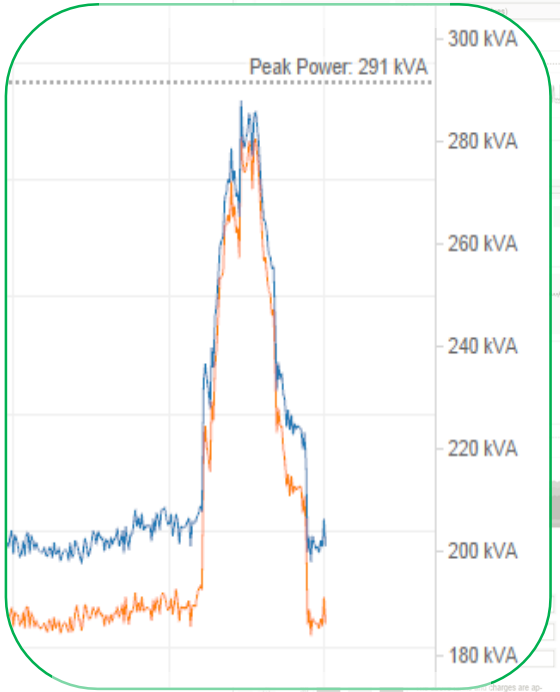
The Demand Factor is calculated with reference to the Max. Demand input below.

Detailed Analysis



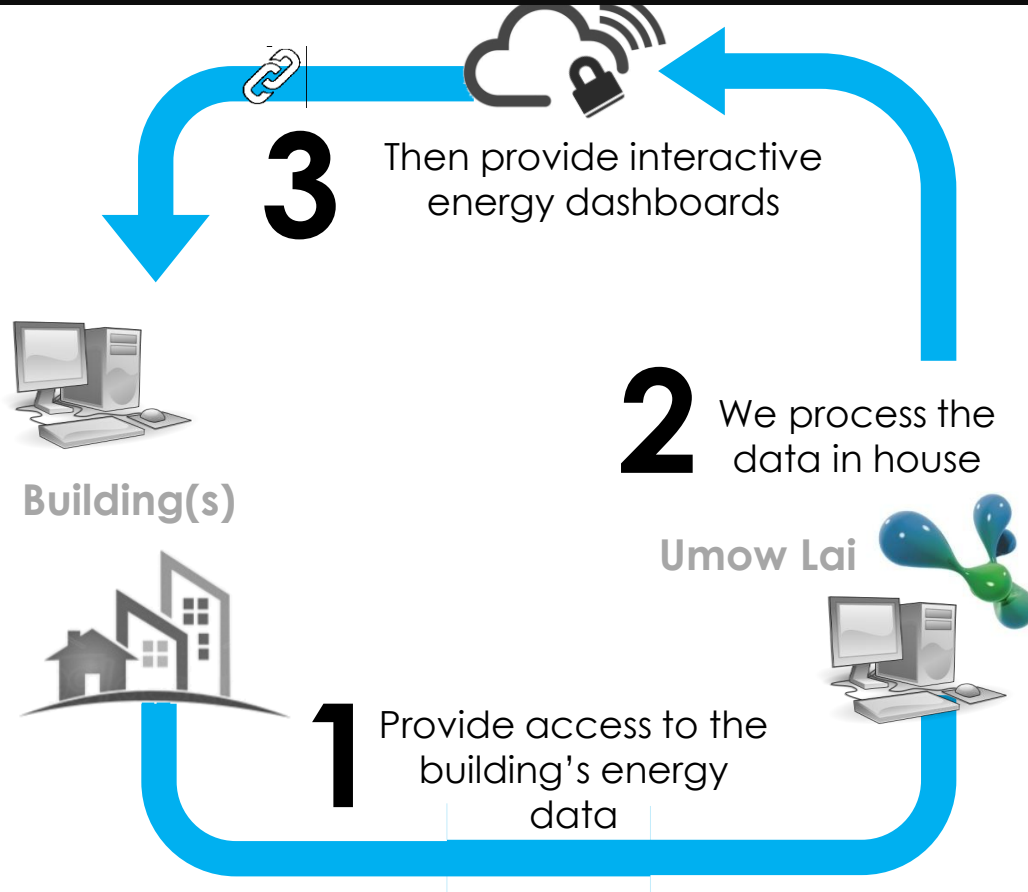
Identify Opportunities

Detailed Analysis



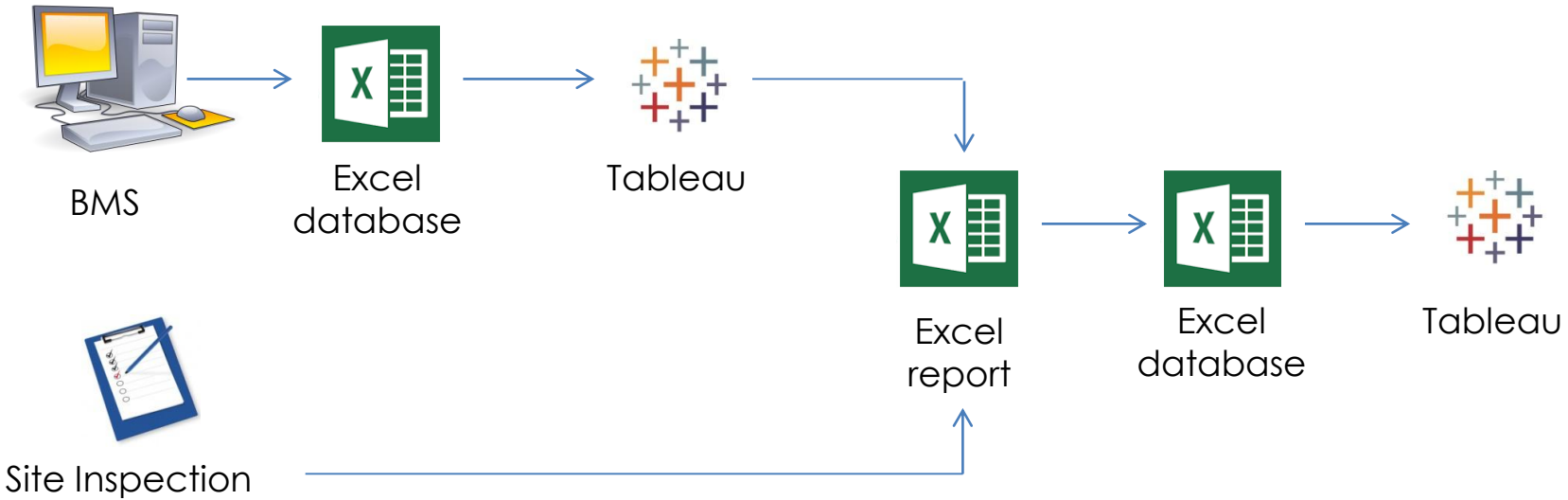
Identify Opportunities

Sharing the Data



Audits, Reporting & Big Data Analysis

- Data from all reports forms results database
- Tableau used to analyse 'Big Data' and present conclusions



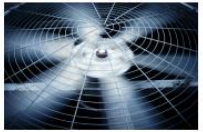
Audit Process

The audit is being conducted through a number of phases outlined below.

- Phase 1 – Project Initiation (Kickoff & Planning)
  - Attend workshop & provide Reverse brief in form of a project plan;
- Phase 2 – Energy Audits (Implementation)
  - Review available existing building information for all sites;
  - Determine total consumption over the past 24 months;
  - Conduct Level 2 & Level 3 site audits for nominated buildings
  - Prepare preliminary report for PCG review and comment
  - Attend workshop and finalise report and submit to PCG
- Phase 3 – Implementation Plan (Discuss Recommendations)
  - Prepare preliminary Implementation plan to assist with the execution of the works

Upgrade Options

BUILDING/ENERGY MANAGEMENT SYSTEM:
- CONTROL STRATEGIES
- SENSING/MONITORING
- PLANT OPERATION
- LEARNING/OPTIMISATION
- SUB-METERING



HVAC SYSTEM:
- RENEWAL/UPGRADE
- EFFICIENT PLANT & SYSTEMS
- THERMAL ZONING
- SETPOINT ADJUSTMENT
- INTELLIGENT CONTROLS

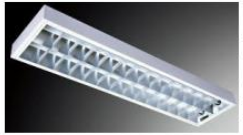
OTHER ENERGY USES:
- LIFTS: SMART CONTROLS
- HOT WATER: EFFICIENT GENERATION & FIXTURES
- SPECIALTY EQUIPMENT: HOURS OF OPERATION & CONTROL

OCCUPANT BEHAVIOUR:
- EDUCATION
- SIGNAGE
- INCENTIVE PROGRAMS
- INTUITIVE CONTROLS

ELECTRICAL EQUIPMENT:
- EFFICIENT PRODUCTS
- OPERATING TIMES
- OCCUPANT BEHAVIOUR
- AUTOMATED CONTROL
- STANDBY POWER REDUCTION

BUILDING ENVELOPE:
- HIGH PERFORMANCE FACADE
- SHADING DEVICES
- INSULATION
- BUILDING ORIENTATION

DISTRICT/SHARED SYSTEMS:
- THERMAL STORAGE
- CO-GENERATION
- DISTRICT COOLING/HEATING
- POWER SHARING
- LOAD BALANCING

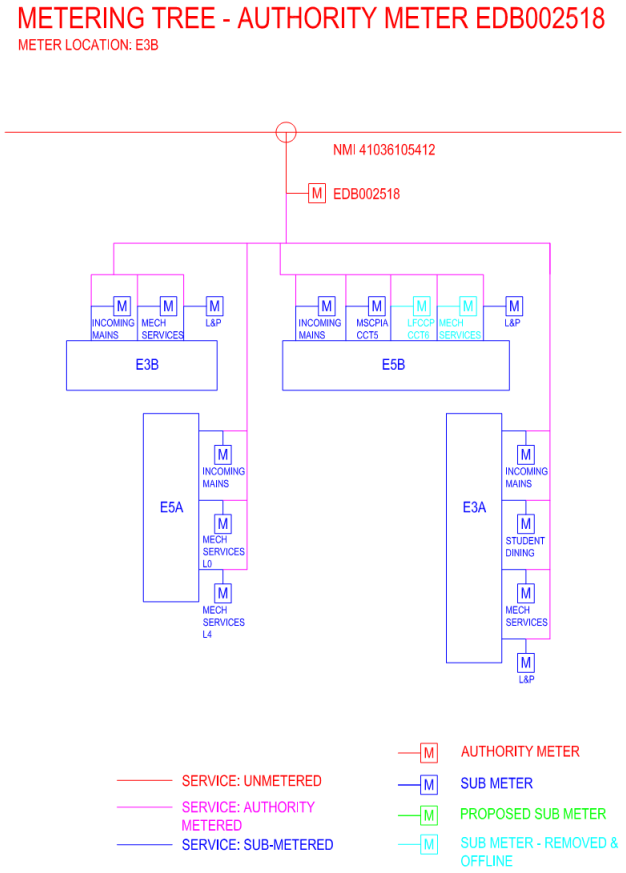


LIGHTING:
- EFFICIENT FITTINGS - LED
- LUX LEVELS & TASK BASED LIGHTING
- LIGHTING ZONING
- MOTION DETECTION
- DAYLIGHT SENSING

ON-SITE GENERATION:
- PV SOLAR
- WIND
- DIRECT USE THERMAL

Metering Challenges

- Metering Coverage and Intensity Varied
- Newer Buildings Have Extensive Sub-Metering
- Older Buildings Typically Authority Meter Only
- Four Central CHW Plants Serving Multiple buildings
- Trigeneration Plant Serving Multiple buildings
- No Metering Trees in Place



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Data Analysis

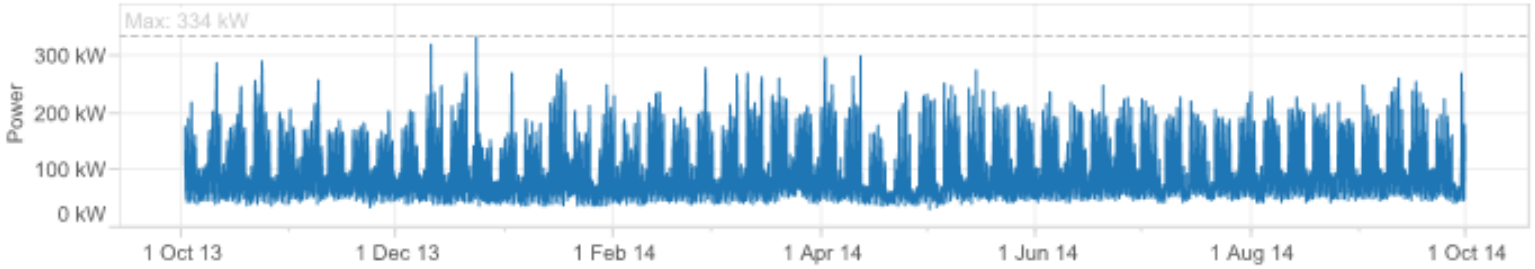
Meter Use E4A Calc

Appendix A - Smart Meter Analysis

The following charts provide insights into the University of Macquarie's metered data for the above referenced building. The building report includes scores and specific commentary on these items which are included for reference only.

Energy	% Peak	Peak Energy	% Off Peak	Off-Peak Energy	% Occupied	In Occupied Hours	GHG Emissions	Approx. Electricity Cost
857,326 kWh	64%	552,567 kWh	36%	304,759 kWh	48%	412,828 kWh	849 tCO2e	$ 120,521

Overall Power Profile - Full Year



The power profile for the building is shown here on the basis of the building's metered data. Through analysis of this power profile, various insights into the building's performance can be gained.

HVAC Startup - Summer - Typical Week

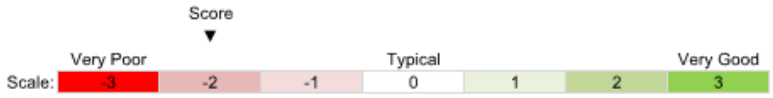
The heating, ventilation and air-conditioning systems can consume a large portion of a

Scoring

Parameter	Analysis		
	Commentary	Value	Score
HVAC Startup:	Many systems operate 24/7	Ok	
Base Load Changes:	Base power load typically approx. 50KW - no change by season or in holidays/weekends (around 40W/m2)	Poor	
Overnight Load Spikes:	No significant load spiking overnight	Good	
Holidays:	Notable reduction in consumption over christmas and public holida	Poor	
Summer Energy Consumption:	Consumption appears fairly consistent regardless of season	Ok	
Winter Energy Consumption:	Consumption appears fairly consistent regardless of season	Ok	
Shoulder Energy Consumption:	Consumption appears fairly consistent regardless of season	Ok	
General Energy Profile:	Consistent daily profile, though only down a quite a high base level	Ok	
Building Layout and Function:	This building generally appears to be utilised as per its originally intended function	Good	
		None	
		None	

2.3 Summary of Metered Energy Data Analysis

Overall, on the basis of the metered data analysis the building is scored as -2 on the scale shown below.



This score forms a portion of the building's overall score.

Scoring

5.2 Lighting

Lighting Power Density							
Actual Condition:	Generally 2x36W T8 utilised. Some areas highly lit.						
Actual Score:	○	◉	○	○	○	○	○
	-3	-2	-1	0	1	2	3
Potential Score:	○	○	○	○	○	○	◉
Recommended Upgrade:	Replace with efficient (T5 or LED) throughout						
Order of Capital Cost:	$90,000		Estimated % Reduction to Peak Elec:		5%		

Lighting Controls							
Actual Condition:	Manual controls. Many areas left on while unoccupied						
Actual Score:	○	◉	○	○	○	○	○
	-3	-2	-1	0	1	2	3
Potential Score:	○	○	○	○	○	○	◉
Recommended Upgrade:	Include occupancy sensors and controls						
Order of Capital Cost:	$12,000		Estimated % Reduction to Peak Elec:		0%		

Reporting

- Excel based
- Automated calculations
- Printed to PDF reports
- Quantified all information
- Generated a database
- Fast and consistent

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Building E5B

Macquarie University
Sydney Campus Building Energy Audit

Report Number: 2
Report Date: 13/7/2015

Engineering Sustainable Environments

Executive Summary

Introduction

Umow Lai have undertaken an energy audit and building survey of Building E5B. The work included a building inspection which was undertaken on the 11/12/2014 and a detailed review of the available energy data for the building for the period 01/10/2013 to 1/10/2014 in general accordance with the Australian Standard AS/NZS:3598:2000.

This report provides a detailed overview of the results for Building E5B and should be read in conjuction with the site wide analysis report and building survey methodology reports.

Overview

Building E5B was constructed in 1976 39 years ago and was last refurbished in 2004. The 1185sqm of useable floor areas is predominantly Wet Labs spaces across 2 floors. The building uses electricity for space heating and electricity for domestic hot water. The building includes lifts. These details were used to form the benchmark for Building E5B and estimate the building's energy breakdown as shown in the pie charts below.

Figure 1 - Electricity Consumption Breakdown

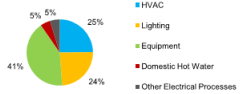


Figure 2 - Gas Consumption Breakdown

Overall Assessed Building Performance

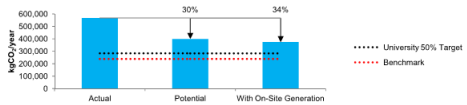
Overall, Building E5B has been assessed on Umow Lai's 7 point scale as -2 (where -3 is very poor and +3 is very good). With regards to total energy consumption the building used 540 MWh between 1/10/2013 and 1/10/2014, making it the 29th largest energy consumer on campus. In terms of specific energy consumption, the building is ranked 8th worst on campus with an energy intensity of 456 kWh/sqm/year.

Several measures were identified to improve the building's performance and it is anticipated that the building could improve to a 3 rating on the same 7 point scale. The measures have been ordered to allow those which are the most effective to be prioritised in future upgrade works on the following page.

Greenhouse Gas Emissions

The greenhouse gas emissions associated with the operation of Building E5B have been calculated. It is estimated that if all the measures identified are implemented a 30% reduction could be achieved through building upgrades. This could be increased to 34% if on-site generation was considered. However this would still fall short of the University 50% target.

Figure 3 - GHG Emission Savings



Ranked Building Upgrade Measures

The following table lists the building upgrade measures that have been identified for Building E5B ranked in order of their payback from shortest to longest. The measures with payback of less than 10 years have been highlighted and a separate total has been provided.

	Building Category	Upgrade	Upgrade Category	Estimated Cost	Energy Savings	Annual Savings	Simple Payback *	
1	Equipment Controls	An audit of the building and each piece of equipment may yield	Building Use	$ 5,000	11,200	$ 1,700	3 yrs	✓
2	Domestic Hot Water	New gas fired, possibly including solar boost hot water system, depending	Capital Works	$ 8,000	7,800	$ 1,700	5 yrs	✓
3	Lighting Controls	Include occupancy sensors and controls	Controls	$ 12,000	16,200	$ 2,400	5 yrs	✓
4	Ventilation System	Include CO2 sensing and outside air modulation	Controls	$ 13,000	10,700	$ 1,600	9 yrs	✓
5	On-site generation	20kWp PV array across available roof area	Capital Works	$ 44,000	24,000	$ 4,900	9 yrs	✓
6	Lighting Power Density	Replace with efficient (T5 or LED) throughout	Capital Works	$ 90,000	48,600	$ 8,300	11 yrs	
7	Other Elec. Use	Sources of heat (servers, chillers) could be isolated either outside (best) or in	Capital Works	$ 20,000	10,400	$ 1,600	13 yrs	
8	Building Fabric	Ensure operable windows are fastened closed and seal windows to reduce	FM Upgrades	$ 5,000	1,800	$ 300	19 yrs	
9	Heating Controls	Full controls upgrade as part of HVAC refurbishment	Capital Works	$ 50,000	13,400	$ 2,000	25 yrs	
10	Cooling Controls	Full controls upgrade as part of HVAC refurbishment	Capital Works	$ 100,000	13,400	$ 2,000	No payback	
11	Heating Efficiency	Full A/C refurbishment should be considered. Costs split across cooling	Capital Works	$ 160,000	13,400	$ 2,000	No payback	
12	Cooling Efficiency	Full A/C refurbishment should be considered. Costs split across cooling	Capital Works	$ 350,000	13,400	$ 3,900	No payback	
13	-	-	-	-	-	-	-	
14	-	-	-	-	-	-	-	
			Total (All Measures)	**$ 857,000**	**184,300**	**$ 32,400**	**27 yrs**	
			Total (Only Measures with Payback <10 Years)	**$ 82,000**	**69,900**	**$ 12,300**	**7 yrs**	

Note: Energy consumption figures are kWh/year. Gas consumption has been converted from GJ to kWh in order to compare energy on a common metric.

1.0 Building Overview

The following section provides an overview of Building E5B including details sourced from the RLB condition surveys and a photo obtained from the University's 'lost on campus' webpages.

Building survey completed by:	Umow Lai
Date of survey:	11/12/2014
Faculty:	Science
Total Usable Floor Area (UFA):	1,185 sqm
Available Roof Area:	400 sqm
Number of Floors:	2
Building Completion Date:	1976
Most Recent Refurbishment:	2004
Standalone or District System:	E6 CHW Network
Primary Space Type:	Wet Labs
% of UFA for Primary:	70%
Secondary Space Type:	Office, Admin
Space Heating:	Elec
Domestic Hot Water:	Elec
Includes Lifts:	Yes
Includes HVAC:	Yes
Other items of note:	Extensive Lab equipment, Fume Cupboards, District Cooling

Benchmarks	Electric
Extended Hours:	Yes
Intensive Equipment:	Yes
Intensity:	191.7 kWh/sqm/yr
Total:	227,195 kWh/yr
Peak Elec:	137 kW

Gas	
Intensity:	0 MJ/sqm/yr
Total:	0 MJ/year

Energy Costs	Electric	Gas
Energy:	$0.15/kWh	$13.0/GJ
Demand:	$10.5/kW	-

Figure 4 - Location of Building E5B on Macquarie University's Sydney Campus

Figure 5 - Photo of Building E5B

2.0 Energy Meter Analysis

The energy meter data that was available for Building E5B has been analysed in detail using Umow Lai's energy dashboards. The following observations provide a valuable insight into the building's performance.

2.1 Numerical Data Observations

The following observations represent the building's key performance metrics and can be compared to good practice.

Parameter	Overall		Intensity		Analysis		
	Value	Units	Value	Units	Value	Unit	Score
Total Elec. Consumption:	540,376	kWh/year	456	kWh/m^2/yr	-138%	vs target	
Gas Consumption[#]:	-	GJ/year	-	MJ/m^2/yr	0%	vs target	
Overall Peak Power:	152	kW	128	W/m^2	6%	over avg.	
Typical Peak Power:	92	kW	61%	of peak	100%	over avg.	
Overnight Elec. Consumption:	208,922	kWh	176	kWh/m^2/yr	39%	of total	
Peak Power Overnight:	80	kW	68	W/m^2	87%	of typical	
Weekday Elec. Consumption:	397,309	kWh/yr	79,462	kWh/yr	74%	of total	
Saturday Elec. Consumption:	71,949	kWh/yr	61	kWh/m^2/yr	91%	of weekday	
Unoccupied Elec. Consumption:	356,258	kWh/yr	301	kWh/m^2/yr	66%	of total	
Average Power Factor:	0.98		n/a		Good		
Minimum Power Factor:	0.96		n/a		Good		
R^2 Value for Temp. vs Energy:	1		n/a		Good		

* Overnight hours between 8pm and 5am

[#] Gas consumption based on area weighted portion of total gas consumption for metered buildings adjusted for performance.

2.2 Descriptive Data Observations

The following table includes the general observations made from analysing the building's electricity data. Examples of charts depicting the flagged observations have been included in Appendix A.

Parameter	Analysis		
	Commentary	Value	Score
HVAC Startup:	Many systems operate 24/7	Ok	
Base Load Changes:	Base power load typically approx. 50KW - no change by season or in holidays/weekends (around 40W/m2)	Poor	
Overnight Load Spikes:	No significant load spiking overnight	Good	
Holidays:	Notable reduction in consumption over christmas and public holida	Poor	
Summer Energy Consumption:	Consumption appears fairly consistent regardless of season	Ok	
Winter Energy Consumption:	Consumption appears fairly consistent regardless of season	Ok	
Shoulder Energy Consumption:	Consumption appears fairly consistent regardless of season	Ok	
General Energy Profile:	Consistent daily profile, though only down a quite a high base level	Ok	
Building Layout and Function:	This building generally appears to be utilised as per its originally intended function	Good	
		None	
		None	

2.3 Summary of Metered Energy Data Analysis

Overall, on the basis of the metered data analysis the building is scored as -2 on the scale shown below.

Score ▼

	Very Poor			Typical			Very Good
Scale:	-3	-2	-1	0	1	2	3

This score forms a portion of the building's overall score.

3.0 Metering Review

The following tables summarise the building's electricity, gas and thermal (if applicable) metering capabilities.

3.1 Electricity Meters

Observation	Analysis		
	Commentary	Value	Score
Sub-metering:	Electricity is sub-metered within the building with multiple sub-meters	Good	
Integrity:	Metering data of good quality meter so should be of an appropriate standard.	Good	
Labelling:	The labelling on the electricity meter was adequate.	Ok	
Linked to BMS:	The meter is linked to the BMCS.	Ok	

3.3 Thermal Meters

Observation	Analysis		
	Commentary	Value	Score
Sub-metering:	Connection to District chilled water , but no thermal metering	Poor	
Integrity:	None	Poor	
Labelling:	None	Poor	
Linked to BMS:	None	Poor	

3.3 Summary of Metering Review

Overall, on the basis of the building's metering the building is scored as 0 on the scale shown below.

Score ▼

	Very Poor			Typical			Very Good
Scale:	-3	-2	-1	0	1	2	3

This score forms a portion of the building's overall score.

3.4 Additional Comments on Occupant Behaviour

No particular concerns about the way this building is being used by the occupants

4.0 Observations From Site Inspection

Overview of key energy consuming systems:

Mechanical Services:

E5B includes an array of different split type A/C systems throughout the facility
Many rooms included significant levels of laboratory equipment including process chillers and other heat producing items
Sensitive equipment is included in many areas that require 24/7 conditioning
Some room set points were advised by users to be 18oC
Users advised that A/C zones extended across multiple offices, and that over-cooling was common
A/C Control is generally manual

Electrical Services:

Generally lighting is achieved through the use of 2x36W T8 fluorescent fittings.
Some areas appeared significantly over-lit – room 135 for example included 11 off 2x36W lights – totalling 792W for a 30m2 room (26.4W/m2)
Lighting control is generally manually switched – with users noting that they switch off lights when they leave and back on when they return the next day

Notable Items from Site Inspection:
Computer servers are located within an office which is included in a cluster of 4 offices on a single A/C zone – this means the conditioning runs 24/7 and often overcools the other areas to maintain these computers in an acceptable environment
One area includes 2 off wall mounted split systems, however, these units are not used as they drip condensate when they are turned on
The facade of E5B is similar to E5A – including some shading built into the facade structure and a fairly significant extent of low quality glazing

5.0 Building Survey Assessment

The various components of Building E5B were surveyed and have been allocated scores as follows.

5.1 Heating Ventilation and Air Conditioning (HVAC)

Building Fabric			
Actual Condition:	Brick Construction & concrete construction , reasonable percentage of glazing or mediocre quality. Shading built into facade		
Actual Score:	○ -3	◉ -2	○ -1	○ 0	○ 1	○ 2	○ 3
Potential Score:	○ -3	○ -2	○ -1	◉ 0	○ 1	○ 2	○ 3
Recommended Upgrade:	Ensure operable windows are fastened closed and seal windows to reduce leakage		
Order of Capital Cost:	$5,000	Estimated % Reduction to Peak Elec:	0%

Ventilation System			
Actual Condition:	Fixed outside air where relevant. Mechanical toilet exhaust		
Actual Score:	○ -3	○ -2	◉ -1	○ 0	○ 1	○ 2	○ 3
Potential Score:	○ -3	○ -2	○ -1	○ 0	○ 1	◉ 2	○ 3
Recommended Upgrade:	Include CO2 sensing and outside air modulation		
Order of Capital Cost:	$13,000	Estimated % Reduction to Peak Elec:	0%

Cooling Efficiency			
Actual Condition:	Mix-match of A/C Systems - splits etc.		
Actual Score:	◉ -3	○ -2	○ -1	○ 0	○ 1	○ 2	○ 3
Potential Score:	○ -3	○ -2	○ -1	○ 0	○ 1	○ 2	◉ 3
Recommended Upgrade:	Full A/C refurbishment should be considered. Costs split across cooling & Heating		
Order of Capital Cost:	$350,000	Estimated % Reduction to Peak Elec:	10%

Cooling Controls			
Actual Condition:	All manual controls. Many systems 24/7		
Actual Score:	◉ -3	○ -2	○ -1	○ 0	○ 1	○ 2	○ 3
Potential Score:	○ -3	○ -2	○ -1	○ 0	○ 1	○ 2	◉ 3
Recommended Upgrade:	Full controls upgrade as part of HVAC refurbishment		
Order of Capital Cost:	$100,000	Estimated % Reduction to Peak Elec:	0%

Heating Efficiency			
Actual Condition:	Mix-match of A/C Systems - splits etc.		
Actual Score:	◉ -3	○ -2	○ -1	○ 0	○ 1	○ 2	○ 3
Potential Score:	○ -3	○ -2	○ -1	○ 0	○ 1	○ 2	◉ 3
Recommended Upgrade:	Full A/C refurbishment should be considered. Costs split across cooling & Heating		
Order of Capital Cost:	$160,000	Estimated % Reduction to Peak Elec:	0%

Heating Controls			
Actual Condition:	All manual.		
Actual Score:	◉ -3	○ -2	○ -1	○ 0	○ 1	○ 2	○ 3
Potential Score:	○ -3	○ -2	○ -1	○ 0	○ 1	○ 2	◉ 3
Recommended Upgrade:	Full controls upgrade as part of HVAC refurbishment		
Order of Capital Cost:	$50,000	Estimated % Reduction to Peak Elec:	0%

5.2 Lighting

Lighting Power Density			
Actual Condition:	Generally 2x36W T8 utilised. Some areas highly lit.		
Actual Score:	○ -3	◉ -2	○ -1	○ 0	○ 1	○ 2	○ 3
Potential Score:	○ -3	○ -2	○ -1	○ 0	○ 1	○ 2	◉ 3
Recommended Upgrade:	Replace with efficient (T5 or LED) throughout		
Order of Capital Cost:	$90,000	Estimated % Reduction to Peak Elec:	5%

Lighting Controls			
Actual Condition:	Manual controls. Many areas left on while unoccupied		
Actual Score:	○ -3	◉ -2	○ -1	○ 0	○ 1	○ 2	○ 3
Potential Score:	○ -3	○ -2	○ -1	○ 0	○ 1	○ 2	◉ 3
Recommended Upgrade:	Include occupancy sensors and controls		
Order of Capital Cost:	$12,000	Estimated % Reduction to Peak Elec:	0%

5.3 Equipment

Equipment Power Density			
Actual Condition:	High level of equipment installation in building - lab equipment		
Actual Score:	◉ -3	○ -2	○ -1	○ 0	○ 1	○ 2	○ 3
Potential Score:	◉ -3	○ -2	○ -1	○ 0	○ 1	○ 2	○ 3
Recommended Upgrade:	Specialist equipment required for use of the building. No improvement considered worthwhile		
Order of Capital Cost:	$0	Estimated % Reduction to Peak Elec:	0%

Equipment Controls			
Actual Condition:	Many items running full time.		
Actual Score:	◉ -3	○ -2	○ -1	○ 0	○ 1	○ 2	○ 3
Potential Score:	○ -3	○ -2	◉ -1	○ 0	○ 1	○ 2	○ 3
Recommended Upgrade:	An audit of the building and each piece of equipment may yield potential for reducing consumption		
Order of Capital Cost:	$5,000	Estimated % Reduction to Peak Elec:	0%

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5.0 Building Survey Assessment

The various components of Building E4A were surveyed and have been allocated scores as follows.

5.1 Heating Ventilation and Air Conditioning (HVAC)

Building Fabric							
Actual Condition:	Brick Construction,minimal glazing on eastern and western facade. Glazing on North and South facade shaded by vegetation or shading devices. Single glazes panels. Louvres						
Actual Score:	○	○	○	○	◉	○	○
	-3	-2	-1	0	1	2	3
Potential Score:	○	○	○	○	○	◉	○
Recommended Upgrade:	Louvres along the facade installed in conditioned rooms to be closed and sealed to prevent leakage						
Order of Capital Cost:	$8,000	Estimated % Reduction to Peak Elec:		0%			

Ventilation System							
Actual Condition:	The building facade is fitted with louvres to allow building to be switched to Natural Ventilation Mode however system has been deactivated due to compliants.						
Actual Score:	○	◉	○	○	○	○	○
	-3	-2	-1	0	1	2	3
Potential Score:	○	○	○	○	○	◉	○
Recommended Upgrade:	Ventilation mode is recommended to be utilised in shoulder seasons. The BMCS to be programmed to allow for night purge mode every night to reduce load during the day. Include motion detectors in toilets to trigger exhaust fan operation. Include run on timer						
Order of Capital Cost:	$9,000	Estimated % Reduction to Peak Elec:		0%			

Cooling Efficiency							
Actual Condition:	Chilled water plant and chilled water fan coil units.						
Actual Score:	○	○	○	○	◉	○	○
	-3	-2	-1	0	1	2	3
Potential Score:	○	○	○	○	○	◉	○
Recommended Upgrade:	Lower supply air temperature to reduce fan consumption. Includes recommissioning of building, and review of diffusers for suitability						
Order of Capital Cost:	$16,800	Estimated % Reduction to Peak Elec:		0%			

Cooling Controls							
Actual Condition:	Extensive scheduling within BMCS. All units scheduled to remain on during weekdays regardless of occupancy.						
Actual Score:	○	○	◉	○	○	○	○
	-3	-2	-1	0	1	2	3
Potential Score:	○	○	○	○	○	◉	○
Recommended Upgrade:	Reinstate Ventilation Mode within building to allow mode activation during shoulder seasons. Education of occupants to encourage use of this mode during this time.						
Order of Capital Cost:	$4,800	Estimated % Reduction to Peak Elec:		0%			

Heating Efficiency							
Actual Condition:	Heat recovery type chiller used to provide heating so chiller is required to run to provide heating. Reverse Cycle Chiller also installed						
Actual Score:	○	○	○	◉	○	○	○
	-3	-2	-1	0	1	2	3
Potential Score:	○	○	○	◉	○	○	○
Recommended Upgrade:	No energy savings initiatives considered worthwhile. For recommendation on improving heating performance, refer to Recommendations section below.						

5.4 Other

Domestic Hot Water							
Actual Condition:	Hot water unit is expected to be of significant age (no access available during inspection)						
Actual Score:	○	◉	○	○	○	○	○
	-3	-2	-1	0	1	2	3
Potential Score:	○	○	○	○	◉	○	○
Recommended Upgrade:	New gas fired, possibly including solar boost hot water system, depending on demand						
Order of Capital Cost:	$8,000	Estimated % Reduction to Peak Elec:		3%			

Other Elec. Use							
Actual Condition:	Some areas running 24/7 to support small array of PC's. Process chiller installed within rooms.						
Actual Score:	○	◉	○	○	○	○	○
	-3	-2	-1	0	1	2	3
Potential Score:	○	○	○	○	○	◉	○
Recommended Upgrade:	Sources of heat (servers, chillers) could be isolated either outside (best) or in small internal areas, and provided with local cooling						
Order of Capital Cost:	$20,000	Estimated % Reduction to Peak Elec:		0%			

Other Gas Use							
Actual Condition:	N/A						
Actual Score:	○	○	○	◉	○	○	○
	-3	-2	-1	0	1	2	3
Potential Score:	○	○	○	◉	○	○	○
Recommended Upgrade:	N/A						
Order of Capital Cost:	$0	Estimated % Reduction to Peak Elec:		-			

5.5 Summary of Building Survey Review

For the building survey, the building has achieved a score of -3 as shown on the scale shown below.

	Score ▼						
	Very Poor			Typical			Very Good
Scale:	-3	-2	-1	0	1	2	3

This score forms a portion of the building's overall score.

7.3 Total Energy Consumption and Cost Breakdown

The total energy consumption, electrical power demand and total running cost has been observed for Building E4A and the maximum potential performance has been estimated on the basis of all of the opportunities identified.

	Actual			Maximum Potential			
Energy Use	kWh/year *	kW peak	Cost	kWh/year	kW peak	Cost	Savings
Electricity	853,000	334	$170,000	666,000	324	$141,000	$29,000
Natural Gas		-	$0		-	$0	$0
Total	**853,000**	**-**	**$170,000**	**666,000**	**-**	**$141,000**	**$29,000**

* Gas consumption has been converted from GJ to kWh in order to compare energy on a common metric.

Figure 10 - Energy Consumption Breakdown

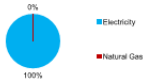
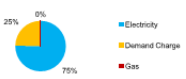


Figure 11 - Approximate Cost Breakdown



7.4 Total Greenhouse Gas Emissions

The total Greenhouse Gas Emissions (GHG) that can be attributed to the operation of Building E4A have been calculated in order to establish a baseline. It is understand that the University is targeting a 50% improvement upon a 2012 baseline by 2030. The potential GHG emissions from Building E4A shown has been estimated on the basis of all the identified measures being implemented except on-site generation which has been seperated for clarity.

	Actual		Maximum Potential		Savings	
Greenhouse Gas Emissions	kgCO2/yr	kgCO2/sqm	kgCO2/yr	kgCO2/sqm	kgCO2/yr	%
Electricity	895,175	133	699,308	104	195,867	22%
Natural Gas	0		0		0	0%
Total	**895,175**	**133**	**699,308**	**104**	195,867	22%

Figure 12 - GHG Emission Breakdown

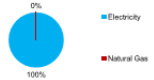


Figure 13 - Potential GHG Emission Savings

7.5 Overall Building Score

Overall, on the basis of the metered data analysis, the building metering and the building survey, the building is scored as 0.6 as shown on the scale below. The building has been assessed as having the maximum potential to achieve a score of 2 through the upgrade measures identified.

						Overall ▼		
	Very Poor			Typical				Very Good
Scale:	-3	-2	-1	0	1	2	3	
						▲ Potential		

The following section provides analysis of the estimated energy savings by the upgrade measures identified to achieve this potential score.

6.0 Energy Savings Identified

The table below summarises the previously identified building upgrade measures including estimated capital installed costs, estimated operational energy savings and the simple payback for these measures. Following discussions with the University, all measures with a payback of less than 10 years have been recommended as indicated by the ticks and crosses.

Building Category	Upgrade	Upgrade Category	Estimated Cost	Energy Savings	Annual Savings	Simple Payback *	
Building Fabric	Ensure operable windows are fastened closed and seal windows to reduce	FM Upgrades	$5,000	1,800	$300	~ 19 yrs	✗
Ventilation System	Include CO2 sensing and outside air modulation	Controls	$13,000	10,700	$1,600	~ 9 yrs	✓
Cooling Efficiency	Full A/C refurbishment should be considered. Costs split across cooling	Capital Works	$350,000	13,400	$3,900	No payback	✗
Cooling Controls	Full controls upgrade as part of HVAC refurbishment	Capital Works	$100,000	13,400	$2,000	No payback	✗
Heating Efficiency	Full A/C refurbishment should be considered. Costs split across cooling	Capital Works	$160,000	13,400	$2,000	No payback	✗
Heating Controls	Full controls upgrade as part of HVAC refurbishment	Capital Works	$50,000	13,400	$2,000	~ 25 yrs	✗
Lighting Power Density	Replace with efficient (T5 or LED) throughout	Capital Works	$90,000	48,600	$8,300	~ 11 yrs	✗
Lighting Controls	Include occupancy sensors and controls	Controls	$12,000	16,200	$2,400	~ 5 yrs	✓
Equipment Power Density	Specialist equipment required for use of the building. No improvement	None	$0	0	$0	-	
Equipment Controls	An audit of the building and each piece of equipment may yield	Building Use	$5,000	11,200	$1,700	~ 3 yrs	✓
Domestic Hot Water	New gas fired, possibly including solar boost hot water system, depending	Capital Works	$8,000	7,800	$1,700	~ 5 yrs	✓
Other Elec. Use	Sources of heat (servers, chillers) could be isolated either outside (best) or in	Capital Works	$20,000	10,400	$1,600	~ 13 yrs	✗
Other Gas Use	N/A	None	$0	0	$0	-	
On-site generation	20kWp PV array across available roof area	Capital Works	$44,000	24,000	$4,900	~ 9 yrs	✓
Building Layout and Functionality			$0		$0	-	
					$0	-	
					$0	-	
					$0	-	
Total			**$857,000**	**184,300**	**$32,400**	**~ 27 yrs**	

* Payback is calcuated by dividing the estimated cost by the annual savings to determine the approximate number of years that it would take for the cost to be paid off. This does not include consideration of inflation, discount rates, fuel price escalation, maintenance, renewal etc and further detailed study is recommended for measures to be considered.

7.0 Results

On the basis of the building's usage type and assessed performance the breakdown of electricity and gas consumption has been estimated as summarised by the following tabes and charts. Additionally the potential energy consumption has been estimated on the basis of all of the measures being implemented as well as Greenhouse Gas Emissions.

7.1 Electrical Breakdown

		Actual			Maximum Potential		
Category	Typical *	Score	%	kWh/year	Score	%	kWh/year
HVAC	25%	-2.4	25%	134,000	2.5	18%	68,000
Lighting	25%	-2.0	24%	130,000	3.0	17%	65,000
Equipment	40%	-3.0	42%	225,000	3.0	56%	214,000
Domestic Hot Water	5%	-2.0	5%	26,000	1.0	5%	18,000
Other Electrical Processes	5%	-2.0	5%	26,000	2.0	4%	16,000
Total Electrical	**100%**	**-2.5**	**100%**	**540,000**	**2.8**	**100%**	**380,000**

* Typical breakdown from Council of Australian Governments (COAG) National Strategy on Energy Efficiency - Baseline Energy Consumption and Greenhouse Gas Emissions In Commercial Buildings in Australia. Part 1 - Report. November 2012

Figure 6 - Electricity Consumption Breakdown

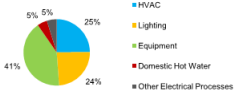
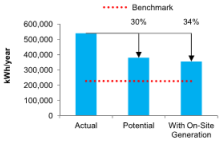


Figure 7 - Potential Electricity Savings



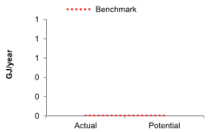
7.2 Natural Gas Energy Breakdown

		Actual			Maximum Potential		
Category	Typical *	Score	%	GJ/year	Score	%	GJ/year
Space Heating	0%	0.0	0%	0	0.0	0%	0
Domestic Hot Water	0%	0.0	0%	0	1.0	0%	0
Kitchen	0%	0.0	0%	0	0.0	0%	0
Other Natural Gas Use	0%	0.0	0%	0	0.0	0%	0
Total Natural Gas	**0%**	**0.0**	**0%**	**0**	**0.0**	**0%**	**0**

* Typical breakdown from Council of Australian Governments (COAG) National Strategy on Energy Efficiency - Baseline Energy Consumption and Greenhouse Gas Emissions In Commercial Buildings in Australia. Part 1 - Report. November 2012

Figure 8 - Gas Consumption Breakdown

Figure 9 - Potential Gas Savings



7.3 Total Energy Consumption and Cost Breakdown

The total energy consumption, electrical power demand and total running cost has been observed for Building E5B and the maximum potential performance has been estimated on the basis of all of the opportunities identified.

	Actual			Maximum Potential			
Energy Use	kWh/year *	kW peak	Cost	kWh/year	kW peak	Cost	Savings
Electricity	540,000	152	$100,000	380,000	125	$73,000	$27,000
Natural Gas		-	$0		-	$0	$0
Total	**540,000**	**-**	**$100,000**	**380,000**	**-**	**$73,000**	**$27,000**

* Gas consumption has been converted from GJ to kWh in order to compare energy on a common metric.

Figure 10 - Energy Consumption Breakdown

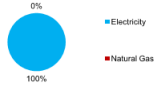
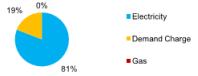


Figure 11 - Approximate Cost Breakdown



7.4 Total Greenhouse Gas Emissions

The total Greenhouse Gas Emissions (GHG) that can be attributed to the operation of Building E5B have been calculated in order to establish a baseline. It is understand that the University is targeting a 50% improvement upon a 2012 baseline by 2030. The potential GHG emissions from Building E5B shown has been estimated on the basis of all the identified measures being implemented except on-site generation which has been seperated for clarity.

	Actual		Maximum Potential		Savings		
Greenhouse Gas Emissions	kgCO2/yr	kgCO2/sqm	kgCO2/yr	kgCO2/sqm	kgCO2/yr	kgCO2/sqm	%
Electricity	567,395	479	399,022	337	168,373	142	30%
Natural Gas		0		0	0	0	0%
Total	**567,395**	**479**	**399,022**	**337**	**168,373**	**142**	**30%**

Figure 12 - GHG Emission Breakdown

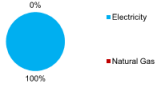
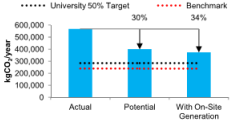


Figure 13 - Potential GHG Emission Savings



7.5 Overall Building Score

Overall, on the basis of the metered data analysis, the building metering and the building survey, the building is scored as -2.1 as shown on the scale below. The building has been assessed as having the maximum potential to achieve a score of 3 through the upgrade measures identified.

The following section provides analysis of the estimated energy savings by the upgrade measures identified to achieve this potential score.

8.0 Further Analysis

The following sections explore the building survey and energy audit results further, comparing the cost effectiveness of the building upgrade works identified, the range of savings and payback from implementing some or all of these measures and how the building compares to the rest of the University of Macquarie Campus.

8.1 Cost Benefit Analysis

The cost benefit analysis for the identified upgrade measures for Building E5B demonstrates that some measures are more effective than others. The top 3 (best payback) and the bottom 3 (worst payback) measures have been listed.

Figure 14 - Cost Benefit Analysis for Potential Upgrade Measures

Top 3

1. Equipment Controls
2. Domestic Hot Water
3. Lighting Controls

Bottom 3

10. Cooling Controls
11. Heating Efficiency
12. Cooling Efficiency

8.2 Total Estimated Energy Savings

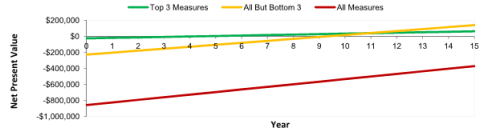
Following on from the previous chart, this analysis looks at the total energy savings that are estimated from the top 3 measures collectively (green), all measures except the bottom 3 (orange) and all measures (red).

Figure 15 - Total Estimated Available Energy Savings from Building E5B

8.3 Estimated Payback

On the basis of the same categories from the previous chart, the payback has been estimated. It is evident that the top 3 measures have the shortest payback.

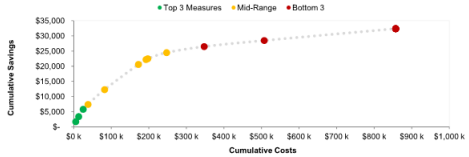
Figure 16 - Net Present Value Showing Simple Payback



8.4 Cumulative Impact Analysis

Considering the cumulative cost and savings enabled by implementing the measures in their ranked order we can show the diminishing returns from the least effective measures. The most cost effective measures should be prioritised.

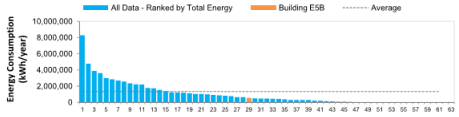
Figure 17 - Cumulative Costs vs Cumulative Savings



8.5 Total Energy Consumption Compared to Rest of Campus

The total energy consumption of the building can be compared to others on campus in order to identify the major users of energy for prioritising upgrade works. Further detail will be provided in the site wide analysis report.

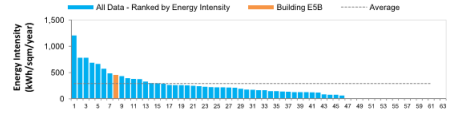
Figure 18 - Total Energy Consumption (540 MWh/year) Compared to Campus (Rank 29)



8.6 Energy Intensity Compared to Rest of Campus

The energy intensity considers the efficiency of the building and allows the least efficient spaces to be identified.

Figure 19 - Energy Intensity (456 kWh/sqm/year) Compared to Campus (Rank 8)



8.7 Limitations

The figures presented in this analysis are based on the building survey and metered data analysis completed by Umow Lai for the purpose of identifiying the most cost effective energy saving measures that could be applied to this building. The energy breakdown is

9.0 Conclusions

E5B is showing as the highest energy intensity building on campus of those audited to date.
This is reflective of the high density of laboratory and specialist equipment, the ad-hoc nature of much of the air conditioning system, and the fact that the building is essentially running as a 24/7 operation.
Although there is metering information for the building, there is no other BMS data to analyse, or to provide the ability to review and control operations.

Several measures have been identified to improve the performance of the building, some of which have a payback of less than 10 years as per the University preference.

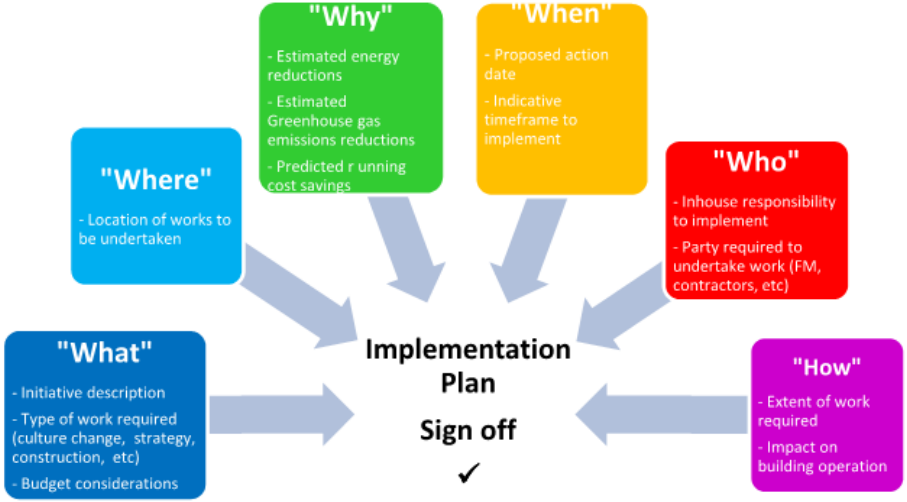
Inlcuded in these is a full HVAC refurbishment, which is a high cost exercise, but would offer the chance to reconcile all the mechanical systems, pressure, air delivery etc. to vatly improve both the efficiency and comfort in the building. We anticipate that this would occurr at the next major refurbishment, though if none is planned, it might be worthy of consideration regardless.

The anticipated savings from all of the measures identified are not sufficient for the building to achieve the Universities 50% reduction in Greenhouse Gas Emission baseline. Therefore it is recommended that:

- All measures with a payback of less than 10 years are considered in detail.
- Measures with a payback of 10 years or more are considered at the next major refurbishment for the building.
- The remaining Greenhouse Gas emission reductions required to achieve the University 50% reduction target are considered on a site-wide basis.

Please refer to the site wide report for further information on overall strategy.

Implementation Plan



Mapped Data Analysis

This dashboard plots the data gathered across the campus map to provide an overview of various results. The presented data can be changed using the highlighted inputs and filters in order to find information of interest.

Scores

-3.0 3.0

Chart Variable

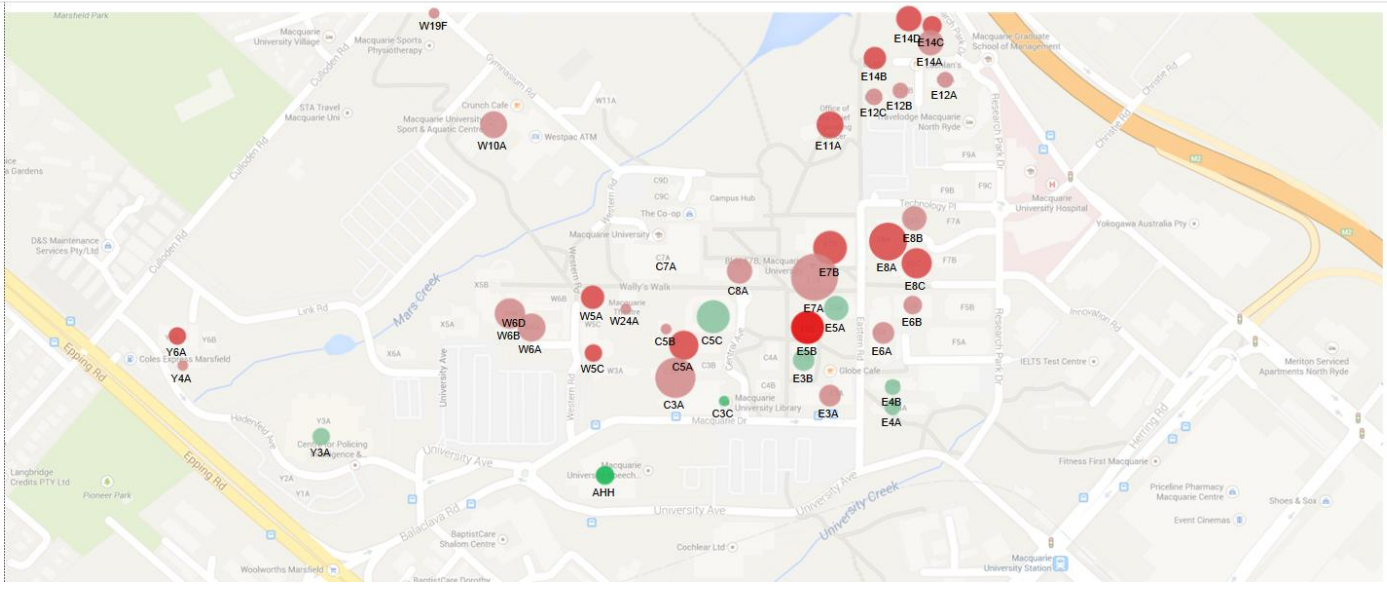
Upgrade Cost

Absolute (Total) or Intensity (per sqm)

Absolute

Selected Data

0
500,000
1,000,000
1,734,000



Overall Categories

- (All)
- HVAC
- Lighting
- Equipment
- Other
- On-site generation
- Custom

Upgrade Categories

- (All)
- Building Fabric
- Ventilation System
- Cooling Efficiency
- Cooling Controls
- Heating Controls
- Heating Efficiency
- Lighting Power Density
- Lighting Controls
- Equipment Power Density
- Equipment Controls
- Domestic Hot Water
- On-site generation
- Other Elec. Use
- Other Gas Use
- 0
- Building Layout and Functionality

Overall GHG Intensity

Scores

-3.0 3.0

Chart Data

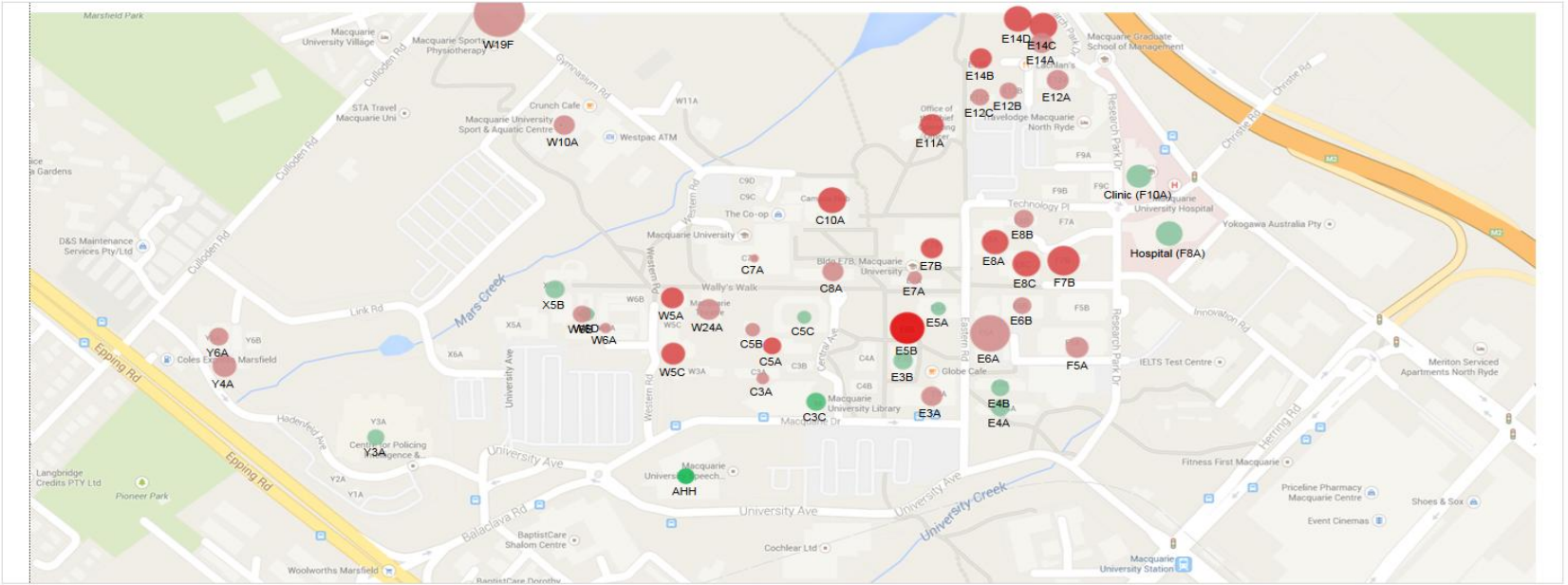
GHG Emissions

Absolute (Total) or Intensity (per sqm)

Intensity

Selected Data

33
200
400
600
800
1,051



Overall Categories

- (All)
- Custom
- Equipment
- HVAC
- Lighting
- On-site generation
- Other

Upgrade Categories

- (All)
- 0
- Building Fabric
- Building Layout and Functionality
- Cooling Controls
- Cooling Efficiency
- Domestic Hot Water
- Equipment Controls
- Equipment Power Density
- Heating Controls
- Heating Efficiency
- Lighting Controls
- Lighting Power Density
- On-site generation
- Other Elec. Use
- Other Gas Use
- Ventilation System

HVAC Emissions Intensity

Scores

-3.0 3.0

Chart Data

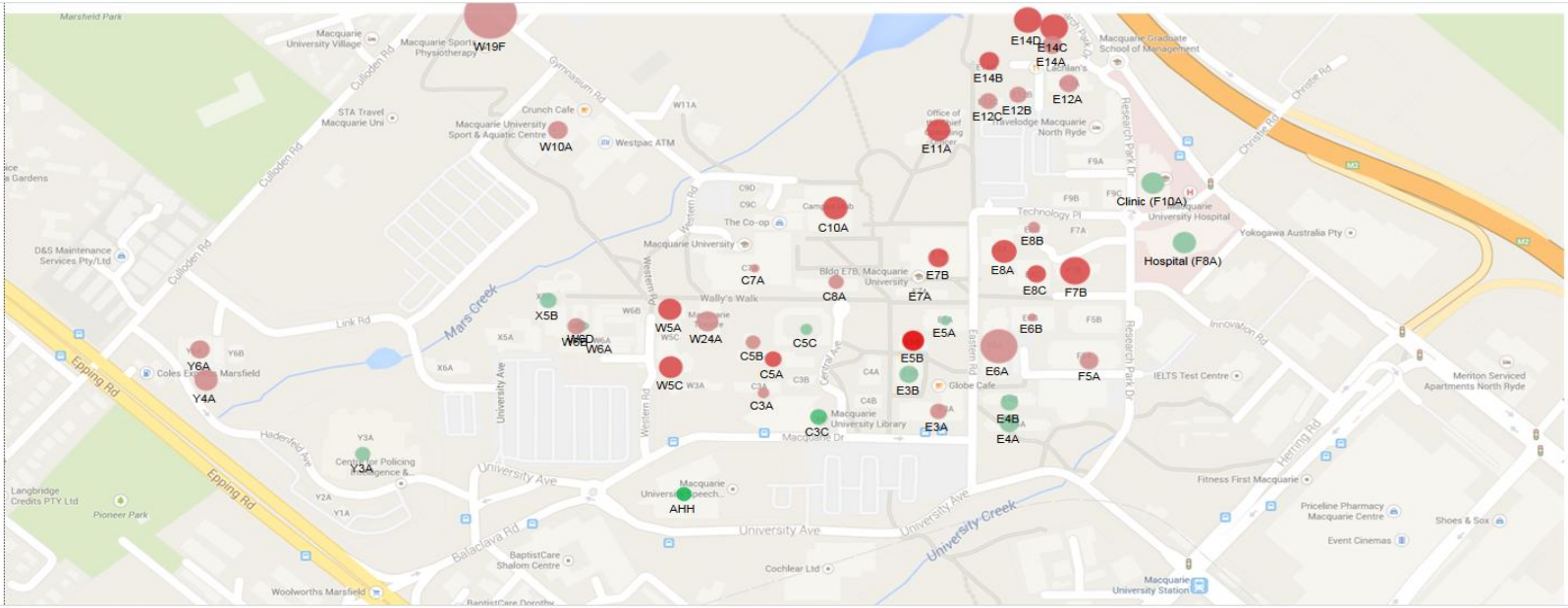
GHG Emissions

Absolute (Total) or Intensity (per sqm)

Intensity

Selected Data

17.2
200.0
400.0
683.7



Overall Categories

- (All)
- Custom
- Equipment
- HVAC
- Lighting
- On-site generation
- Other

Upgrade Categories

- (All)
- Building Fabric
- Cooling Controls
- Cooling Efficiency
- Heating Controls
- Heating Efficiency
- Ventilation System

Lighting GHG Emissions Intensity

Scores

-3.0 3.0

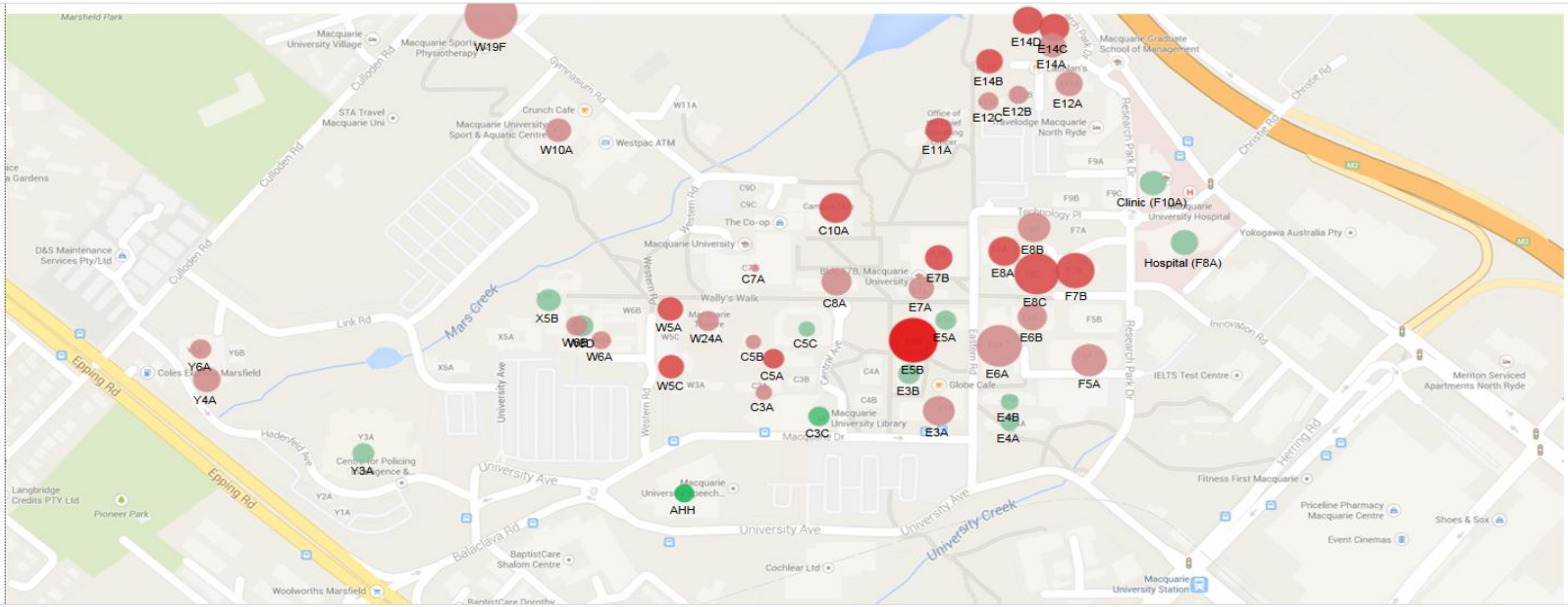
Chart Data

GHG Emissions

Absolute (Total) or Intensity (per sqm)

Intensity

3.6
50.0
100.0
136.1



Overall Categories

- (All)
- Custom
- Equipment
- HVAC
- Lighting
- On-site generation
- Other

Upgrade Categories

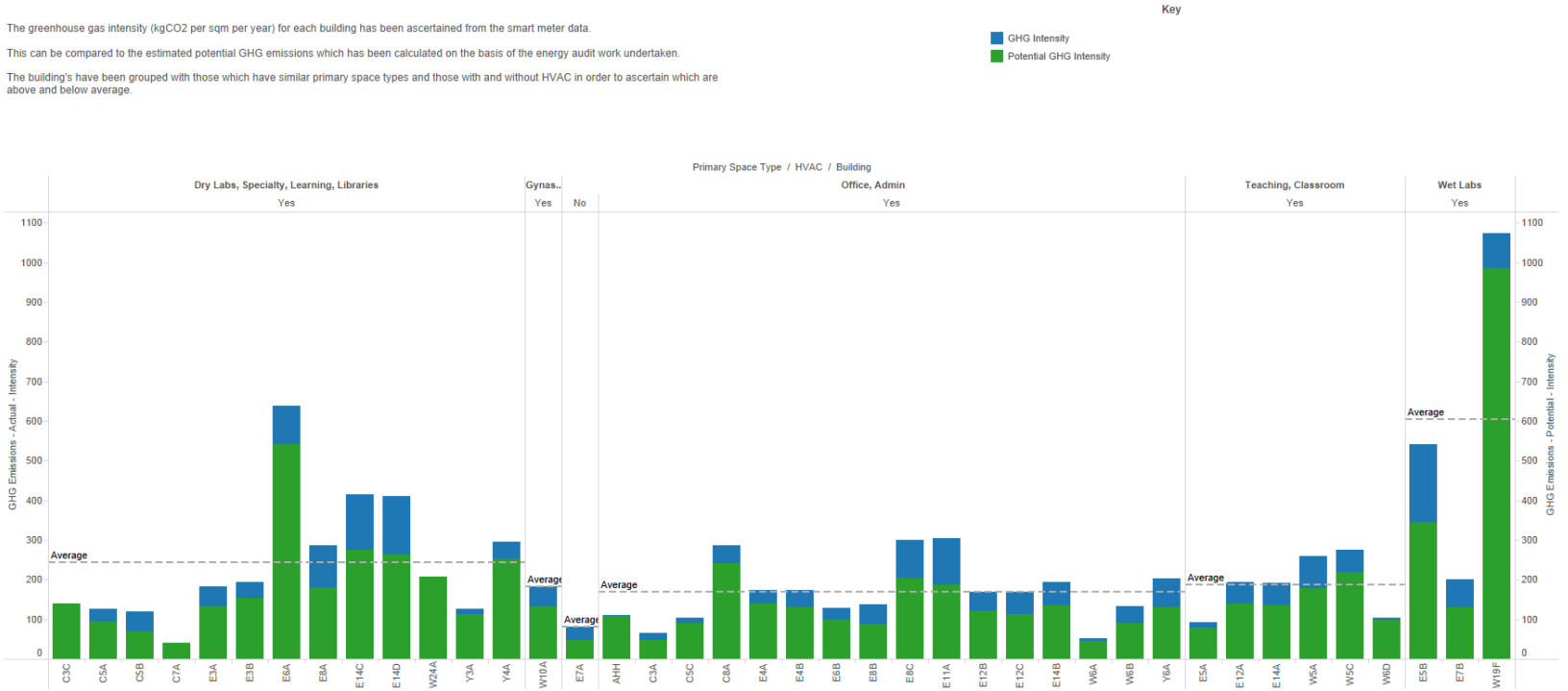
- (All)
- Lighting Controls
- Lighting Power Density

Greenhouse Gas Intensity Analysis

The greenhouse gas intensity (kgCO2 per sqm per year) for each building has been ascertained from the smart meter data.

This can be compared to the estimated potential GHG emissions which has been calculated on the basis of the energy audit work undertaken.

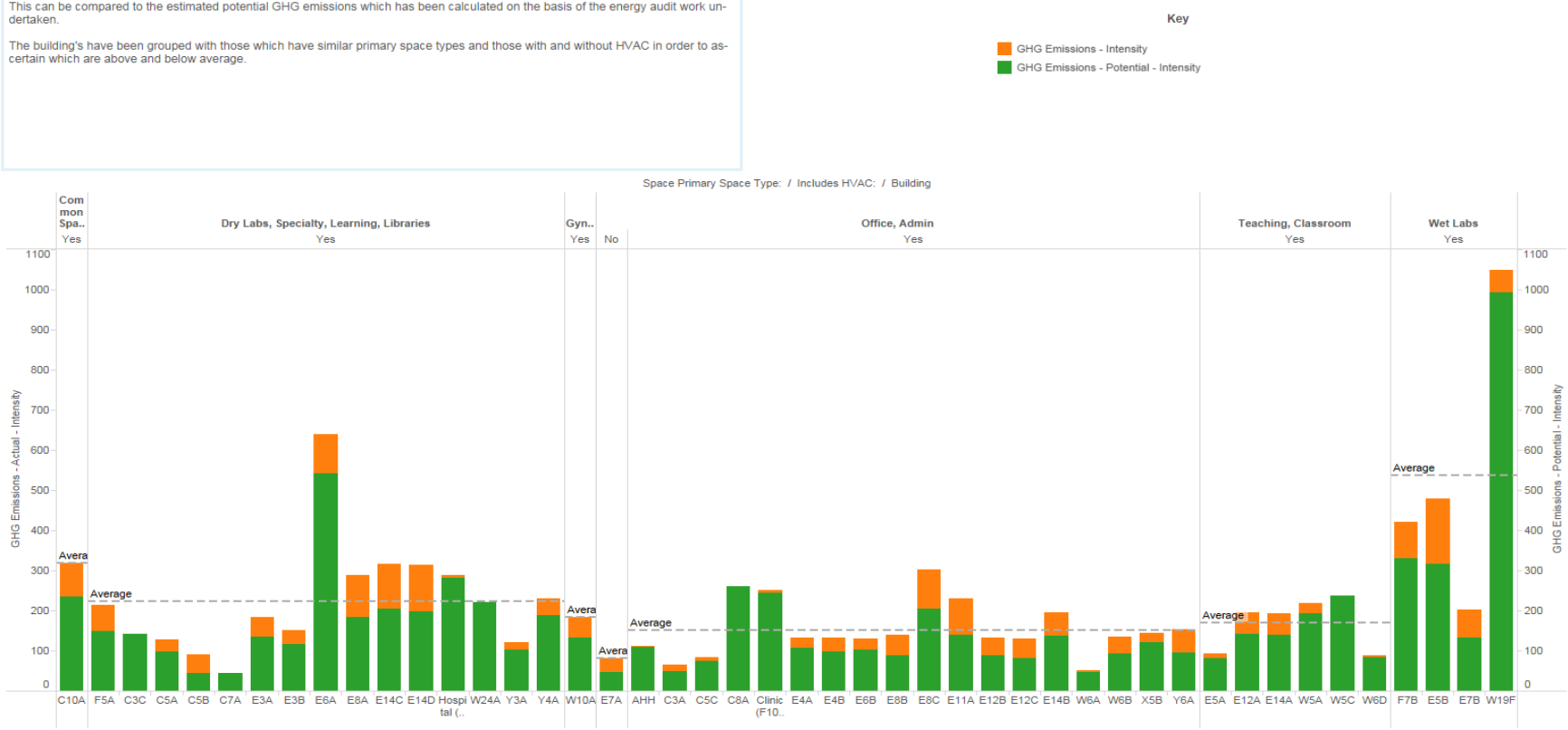
The building's have been grouped with those which have similar primary space types and those with and without HVAC in order to ascertain which are above and below average.



Greenhouse Gas Intensity Analysis

This can be compared to the estimated potential GHG emissions which has been calculated on the basis of the energy audit work undertaken.

The building's have been grouped with those which have similar primary space types and those with and without HVAC in order to ascertain which are above and below average.



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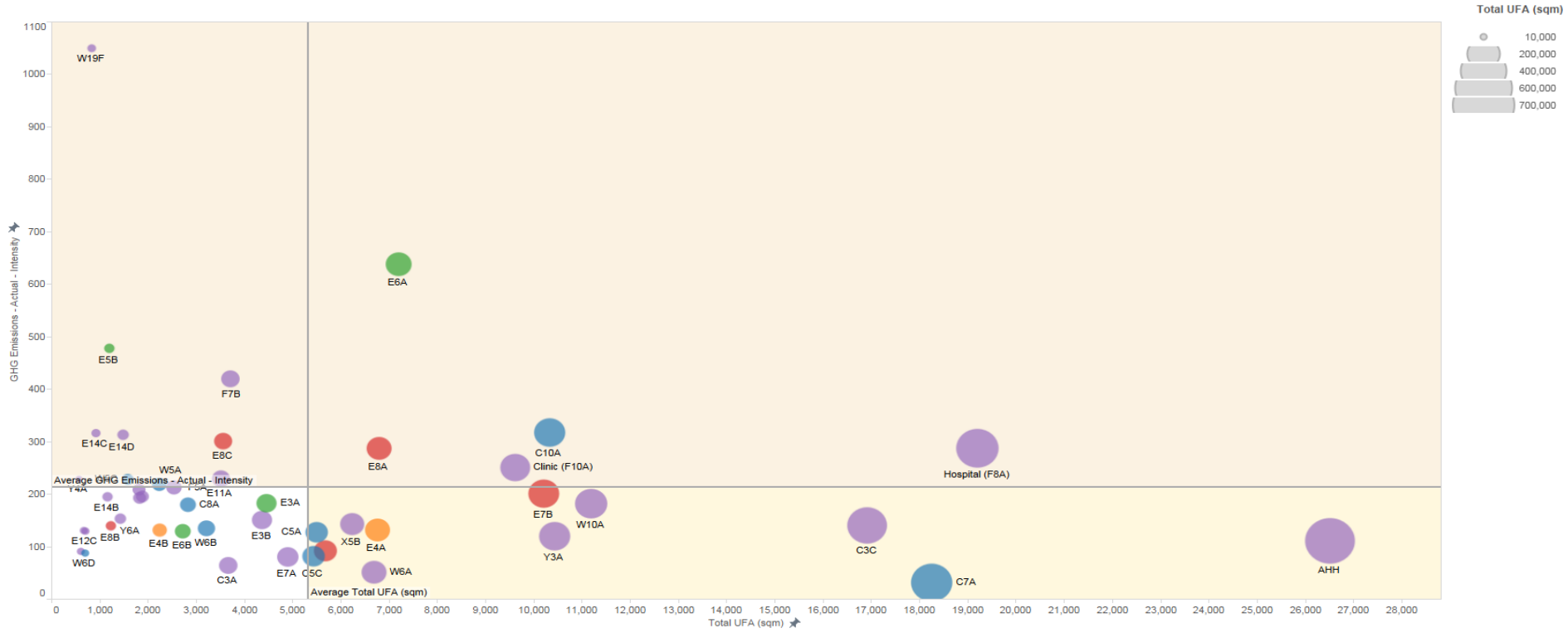
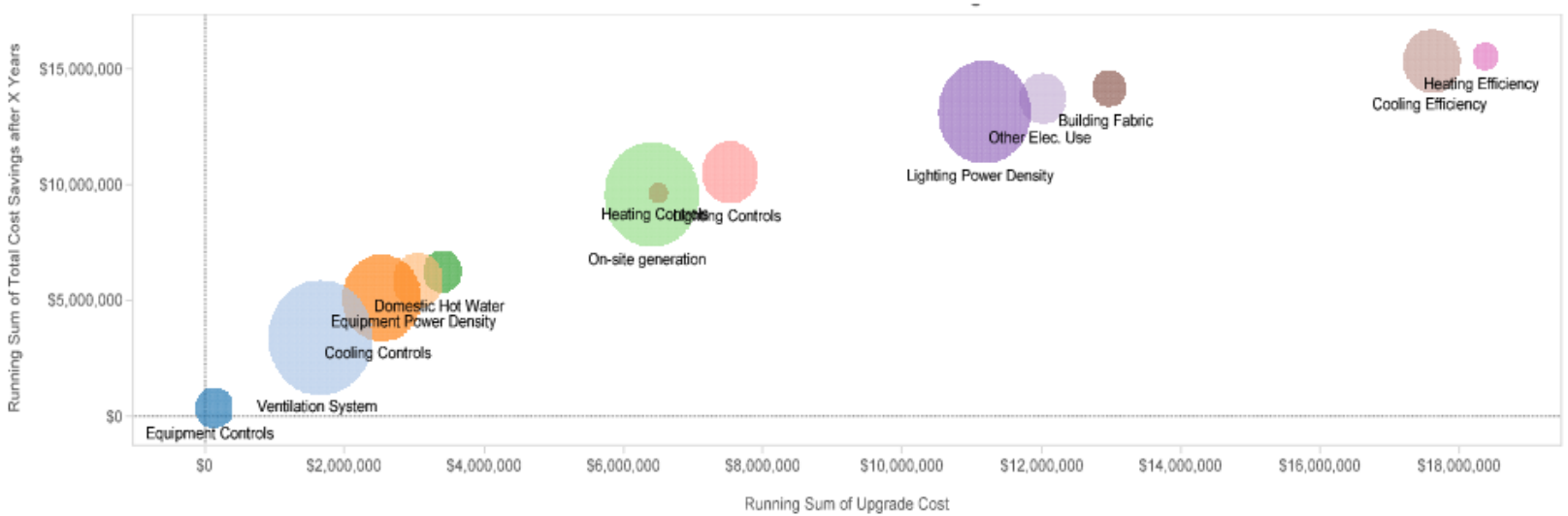
Big Bad Buildings



Cumulative Cost of Initiatives



Running Sum of Upgrade Cost vs. Running Sum of Total Cost Savings after X Years. Color shows details about Building Category. Size shows sum of GHG Savings. The marks are labeled by Building Category. Details are shown for Building Category. The data is filtered on Total Cost Savings, Building and Faculty. The Total Cost Savings filter includes values greater than or equal to $1. The Building filter keeps 46 of 46 members. The Faculty filter keeps 9 of 9 members. The view is filtered on Building Category, which keeps 16 of 16 members.

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Cumulative Cost Savings Analysis

This chart features in the individual building reports, but is also very interesting for considering the campus as a whole. By ordering the building upgrades with those with the shortest payback to the left, we can see how far a certain amount of capital expenditure would go and when the returns become diminished (when the trend is flat).

The total annual cost savings are multiplied by a variable in order to show the total cost savings after so many years.

The size of the circle represents the extent of GHG emission savings available.

NPV Period

10 yrs

GHG Savings

1,082
500,000
1,000,000
1,401,443

(All)
Arts
Chancellery
Library
MGSM
Other
Private
Science
Science & Tech

Building

(All)
AHH
C3A
C3C
C5A
C5B
C5C
C8A
E3A
E3B
E4A
E4B
E5A
E5B
E6A
E6B
E7A
E7B
E8A
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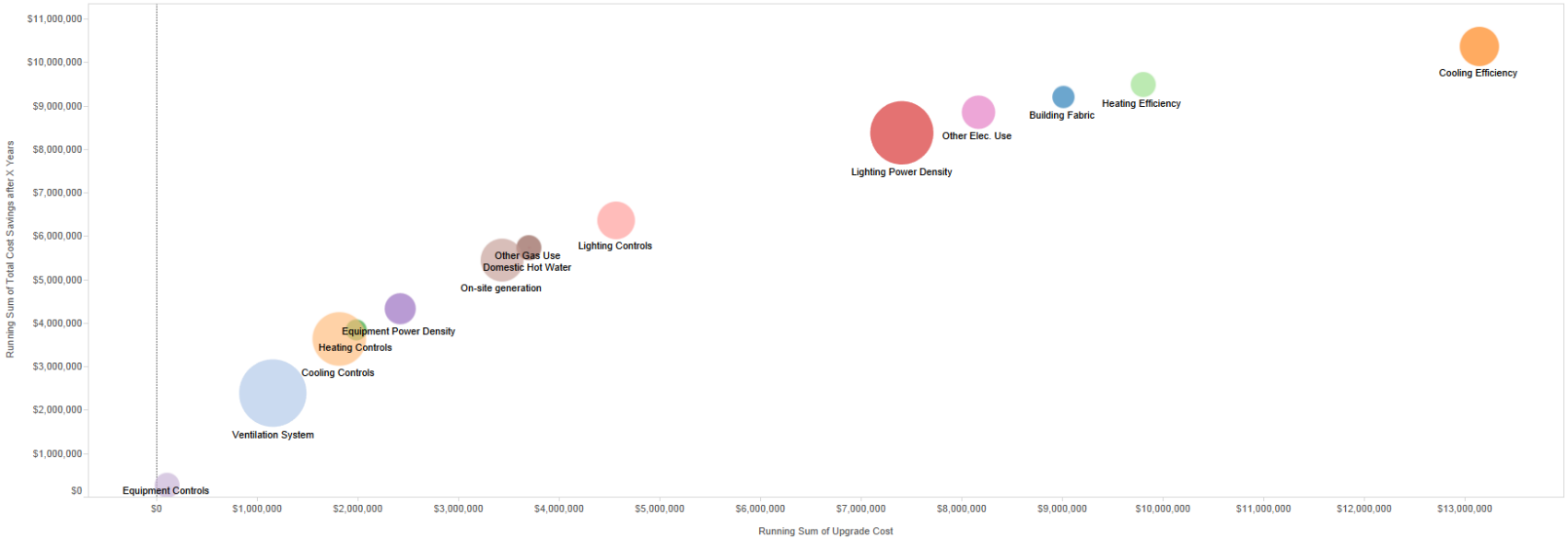
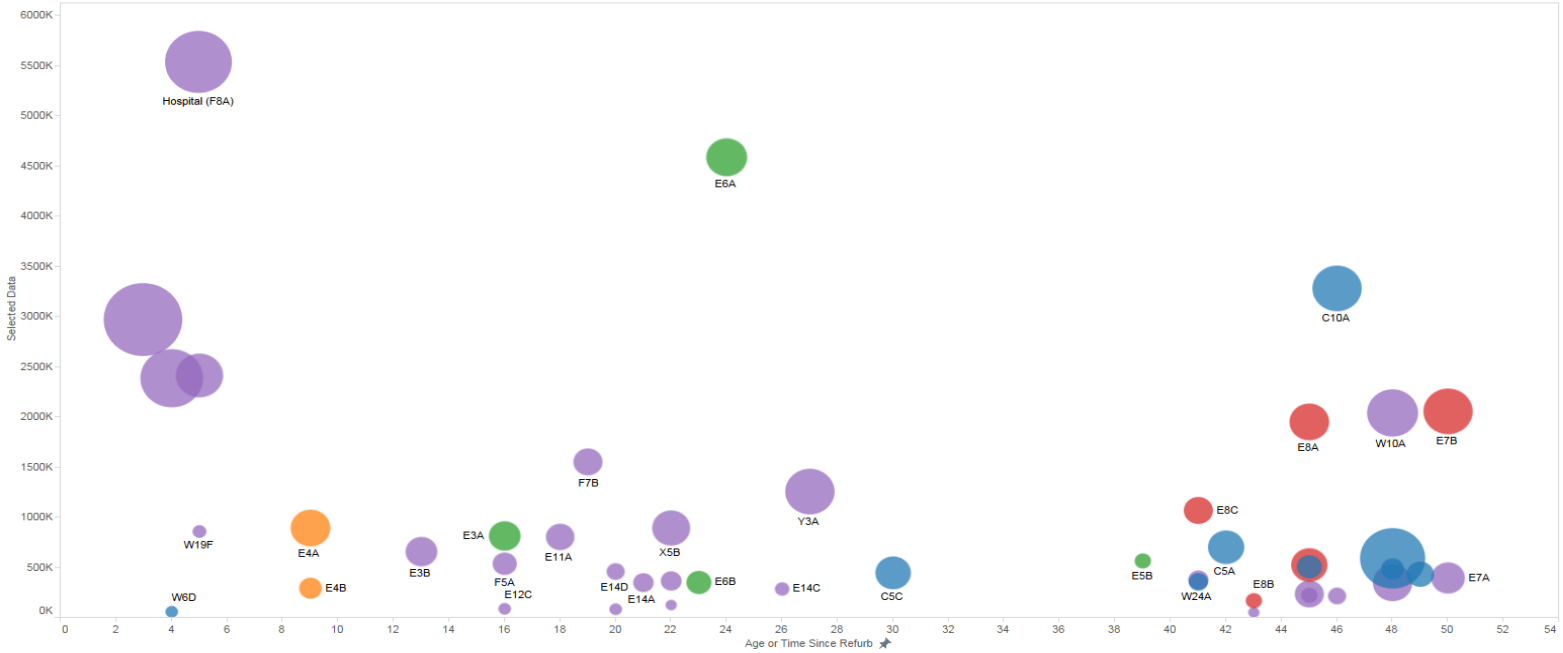
E14A
E14B
E14C
E14D
W5A
W5C



Building Age vs Performance

The circle size represents the area of the building and the red circles indicate those which are entirely without HVAC due to their connection to the district energy system.

The data can be changed between GHG emissions, electricity and gas consumption.



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Payback Analysis

The simple payback is defined as the number of years that it takes for the capital expenditure to be offset by the estimated annual cost savings for each identified measure.

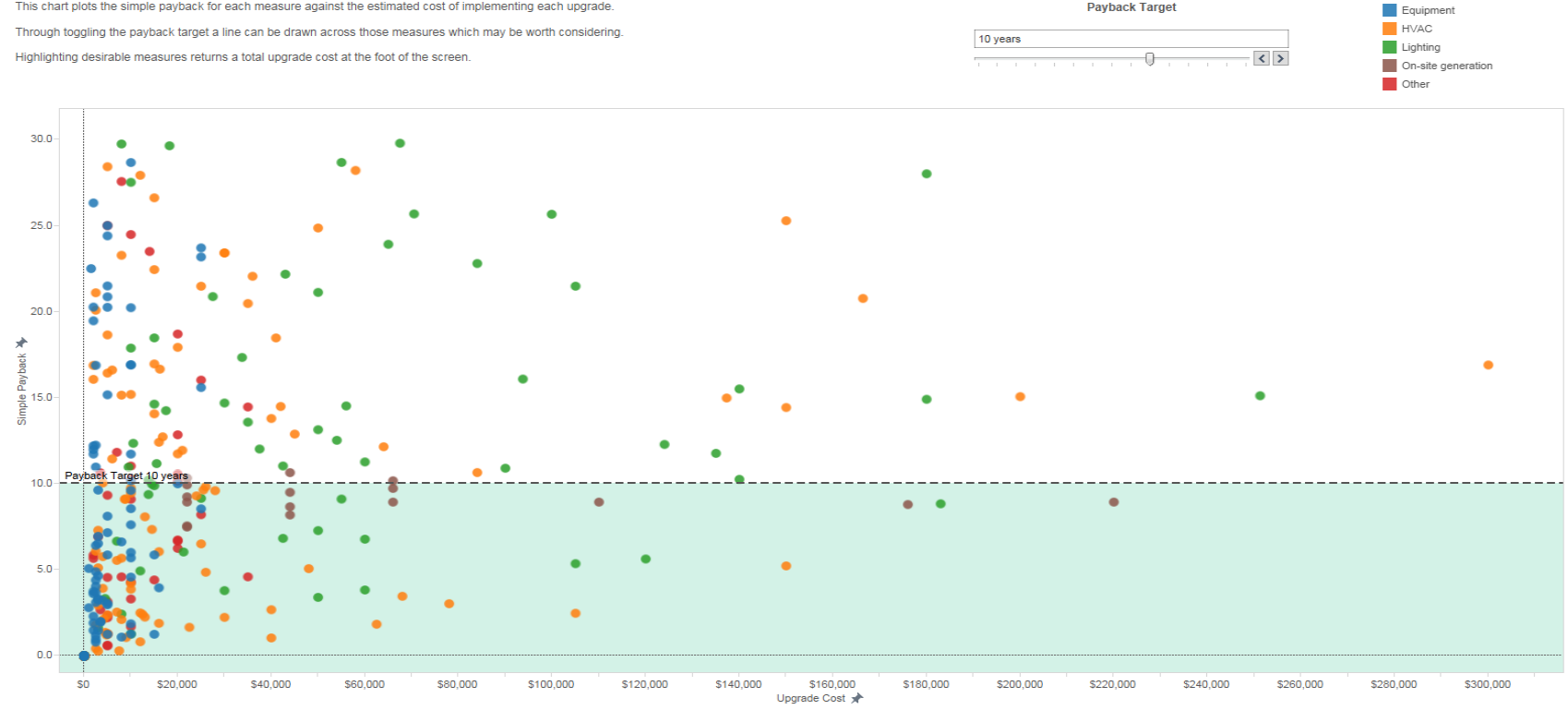
This chart plots the simple payback for each measure against the estimated cost of implementing each upgrade.

Through toggling the payback target a line can be drawn across those measures which may be worth considering.

Highlighting desirable measures returns a total upgrade cost at the foot of the screen.

Payback Target

10 years



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Overall Category

- (All)
- Custom
- Equipment
- HVAC
- Lighting
- On-site generation
- Other

Building Category

- (All)
- Building Fabric
- Cooling Controls
- Cooling Efficiency
- Domestic Hot Water
- Equipment Controls
- Equipment Power Den...
- Heating Controls
- Heating Efficiency
- Lighting Controls
- Lighting Power Density
- On-site generation
- Other Elec. Use
- Ventilation System

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Upgrade Cost vs Payback Analysis

The simple payback is defined as the number of years that it takes for the capital expenditure to be offset by the estimated annual cost savings for each identified measure.

This chart plots the simple payback for each measure against the estimated cost of implementing each upgrade.

Through toggling the payback target a line can be drawn across those measures which may be worth considering.

Highlighting desirable measures returns a total upgrade cost at the foot of the screen.

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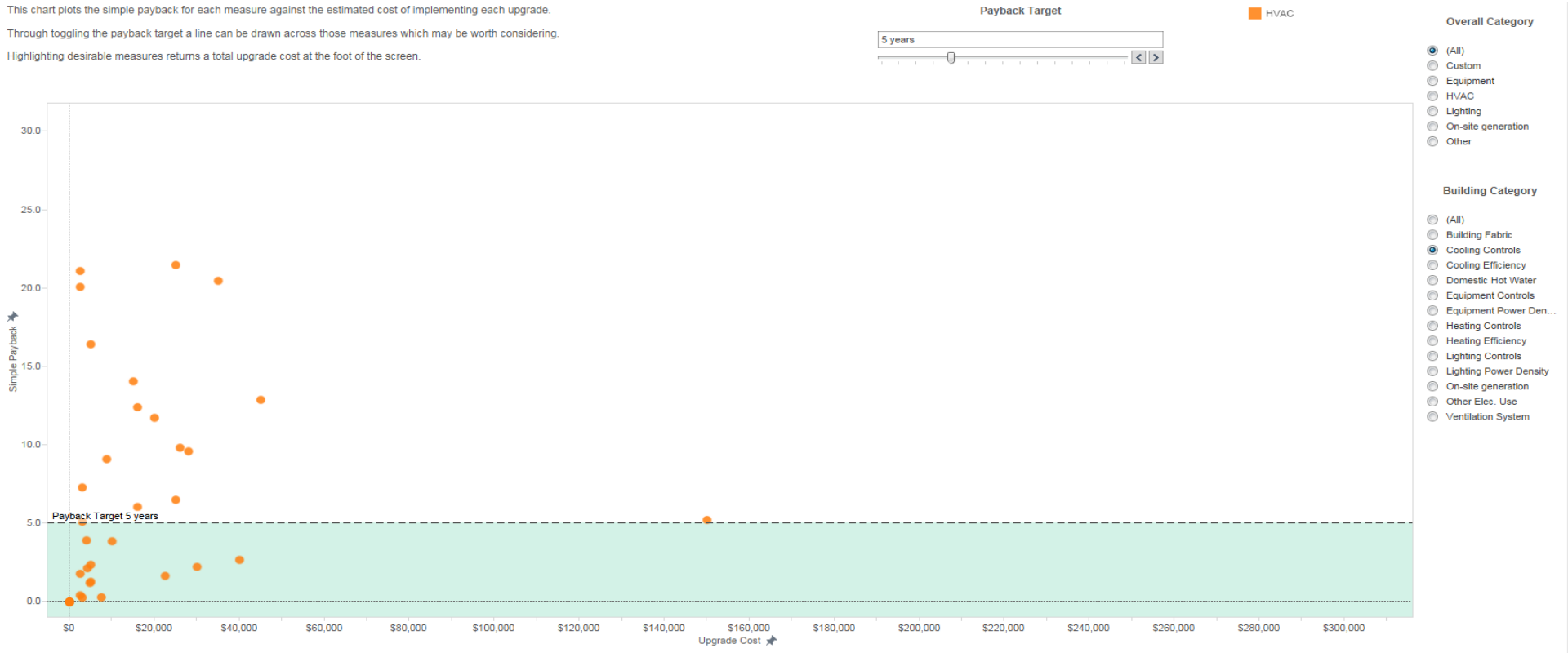
Payback Analysis – HVAC Controls

This chart plots the simple payback for each measure against the estimated cost of implementing each upgrade.

Through toggling the payback target a line can be drawn across those measures which may be worth considering.

Highlighting desirable measures returns a total upgrade cost at the foot of the screen.



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Payback Analysis – HVAC Controls

This chart plots the simple payback for each measure against the estimated cost of implementing each upgrade.

Through toggling the payback target a line can be drawn across those measures which may be worth considering.

Highlighting desirable measures returns a total upgrade cost at the foot of the screen.

Payback Target

5 years

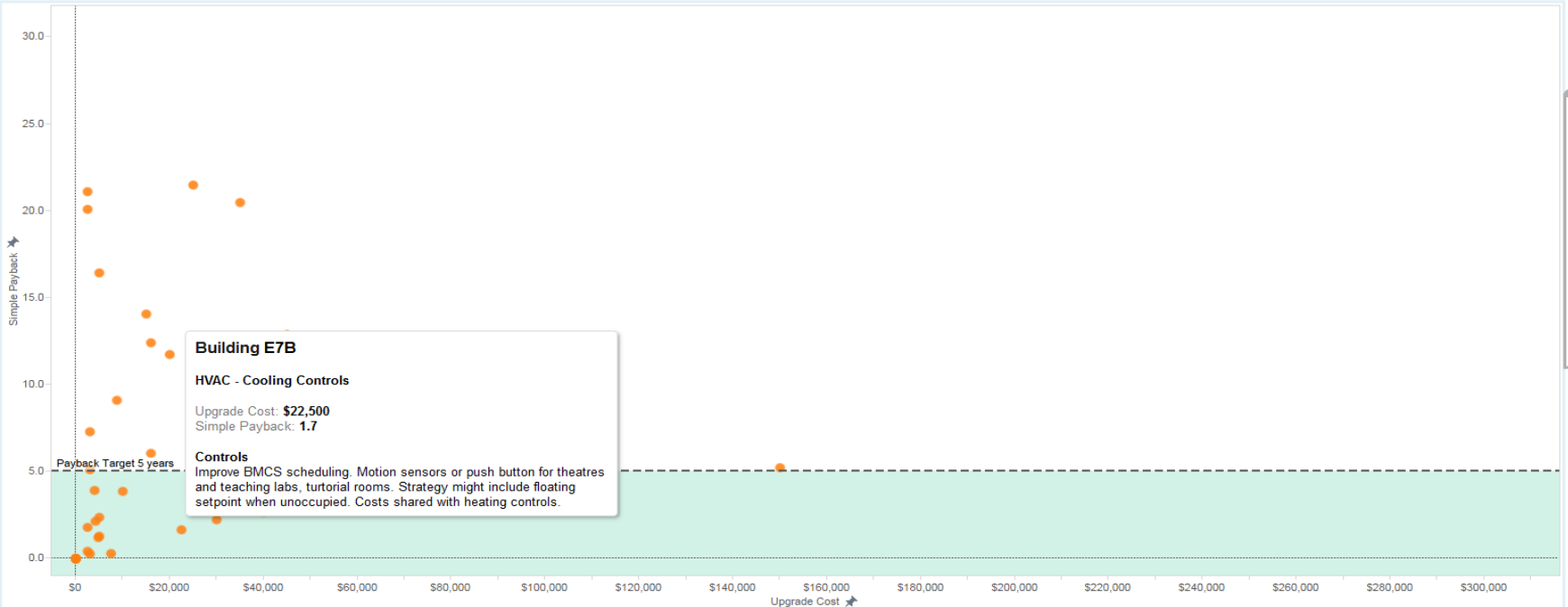
HVAC

Overall Category

- (All)
- Custom
- Equipment
- HVAC
- Lighting
- On-site generation
- Other

Building Category

- (All)
- Building Fabric
- Cooling Controls
- Cooling Efficiency
- Domestic Hot Water
- Equipment Controls
- Equipment Power Den...
- Heating Controls
- Heating Efficiency
- Lighting Controls
- Lighting Power Density
- On-site generation
- Other Elec. Use
- Ventilation System



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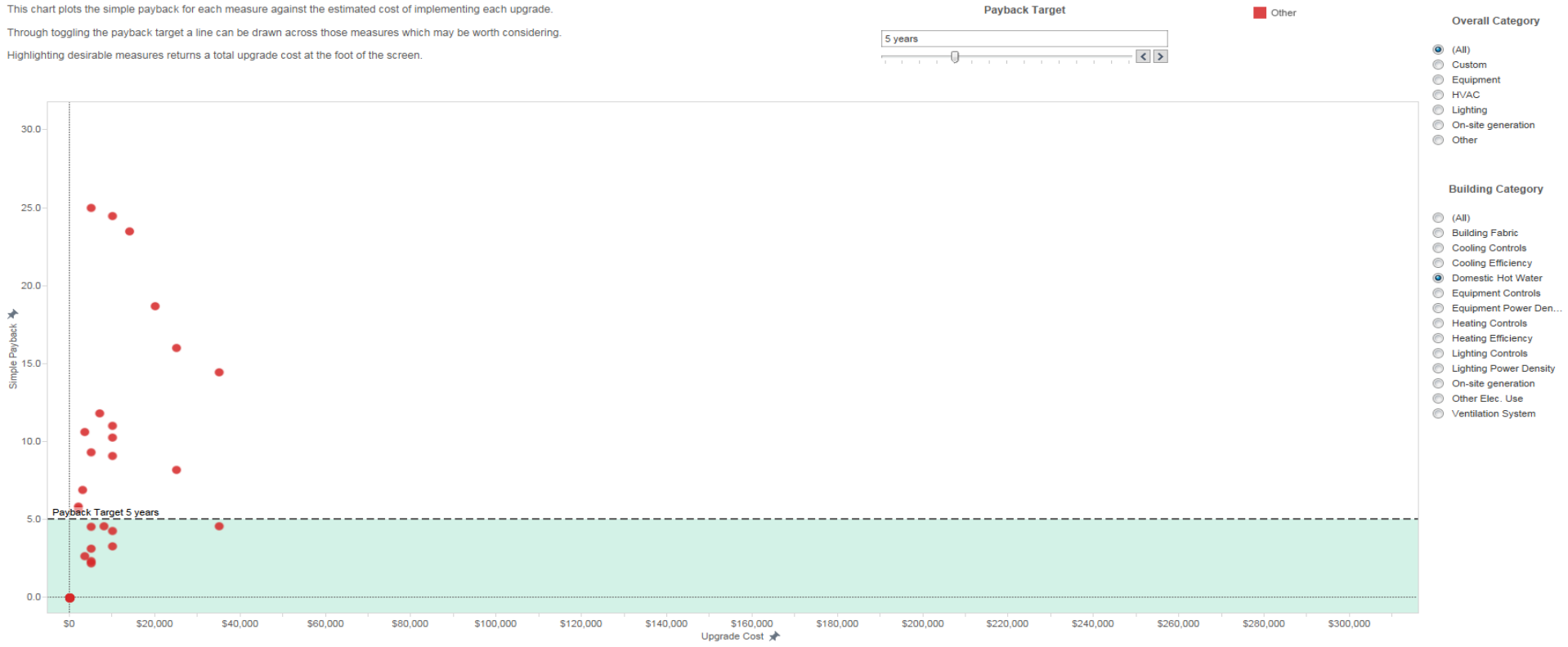
Payback Analysis – DHW

This chart plots the simple payback for each measure against the estimated cost of implementing each upgrade.

Through toggling the payback target a line can be drawn across those measures which may be worth considering.

Highlighting desirable measures returns a total upgrade cost at the foot of the screen.



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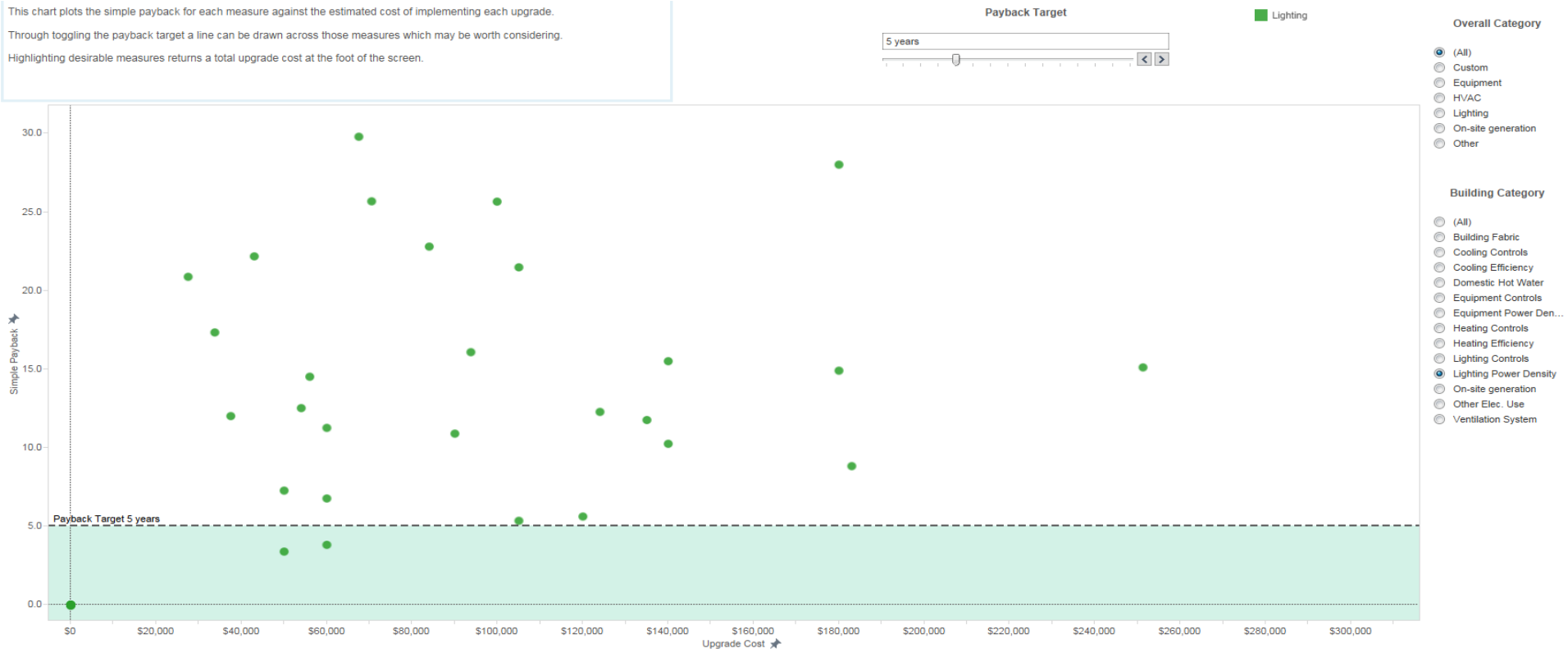
Payback Analysis – Lighting Density

This chart plots the simple payback for each measure against the estimated cost of implementing each upgrade.

Through toggling the payback target a line can be drawn across those measures which may be worth considering.

Highlighting desirable measures returns a total upgrade cost at the foot of the screen.



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Payback Analysis – Lighting Controls

This chart plots the simple payback for each measure against the estimated cost of implementing each upgrade.

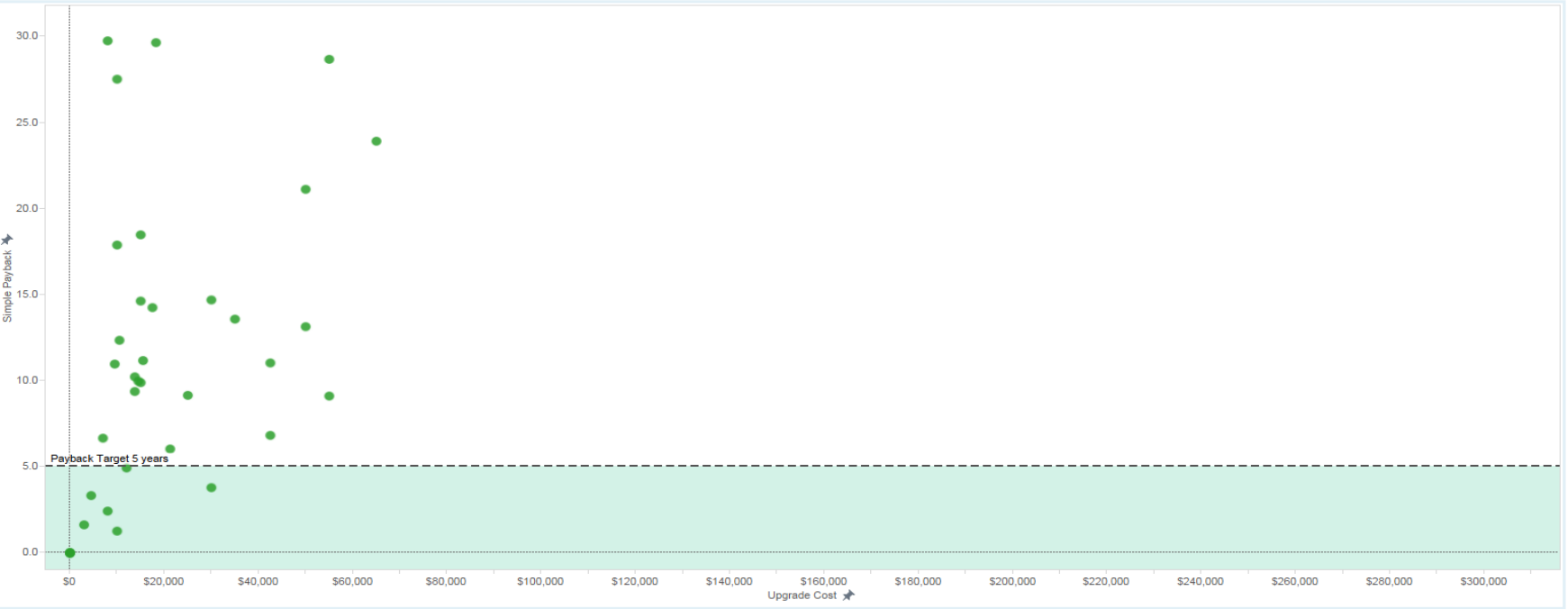
Through toggling the payback target a line can be drawn across those measures which may be worth considering.

Highlighting desirable measures returns a total upgrade cost at the foot of the screen.

Payback Target

5 years

Lighting



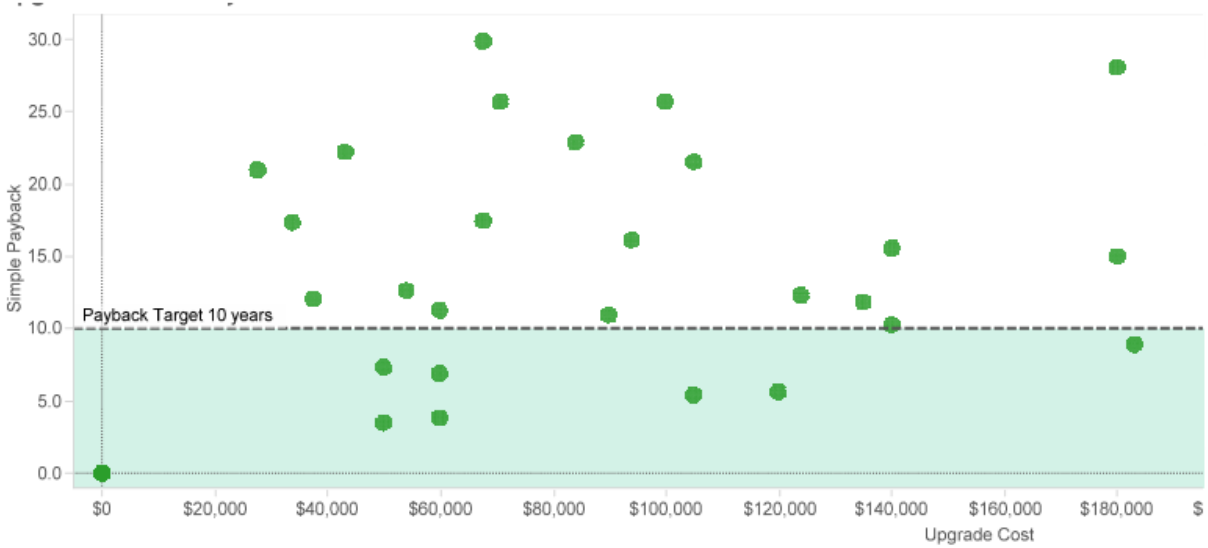
Overall Category

- (All)
- Custom
- Equipment
- HVAC
- Lighting
- On-site generation
- Other

Building Category

- (All)
- Building Fabric
- Cooling Controls
- Cooling Efficiency
- Domestic Hot Water
- Equipment Controls
- Equipment Power Den…
- Heating Controls
- Heating Efficiency
- Lighting Controls
- Lighting Power Density
- On-site generation
- Other Elec. Use
- Ventilation System

5.9 Example Initiative – Lighting Power Density



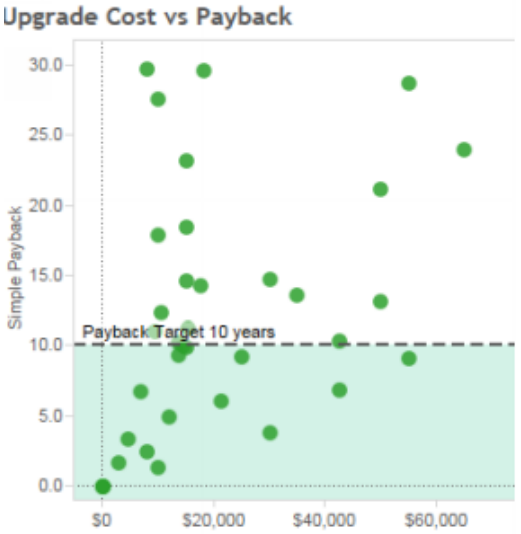


Figure 13 Lighting Controls Cost Vs Payback

Building Score Card

Overview of Building E8B

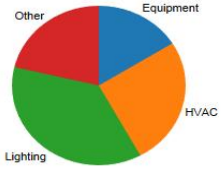
Building	Faculty	Floors	Space Primary Space Type:	Secondary Space Type:	Completed	Most Recent Refurb	Total UFA (sqm)
E8B	Science	3	Office, Admin	Dry Labs, Specialty, Learning, Libraries	1972	1998	1,216

Benchmark Assumptions

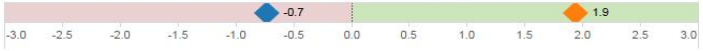
Includes Lifts:	Includes HVAC:	Space Heating:	Domestic Hot Water:	Other items of note:	Electrical Benchmark (kWh/yr)	Gas Benchmark (GJ/yr)	Peak Electrical Demand Benchmark (kW)
No	Yes	Gas	Gas	Partially air conditioned - ad hoc arrangement. Museum on Ground	145,594	222	122

Potential*

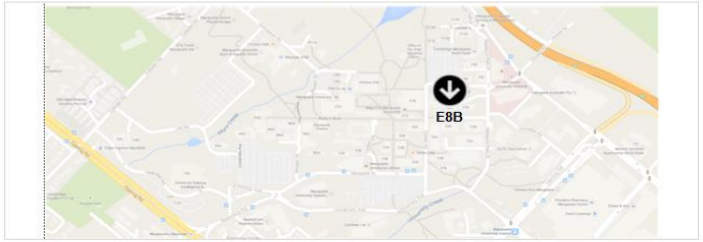
GHG Emissions Split*



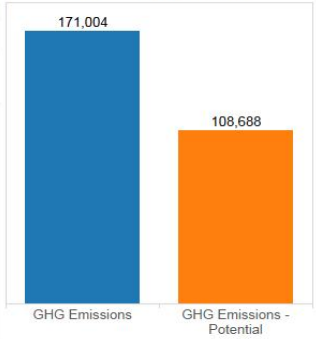
Overall Score Actual and Potential



Building E8B Location



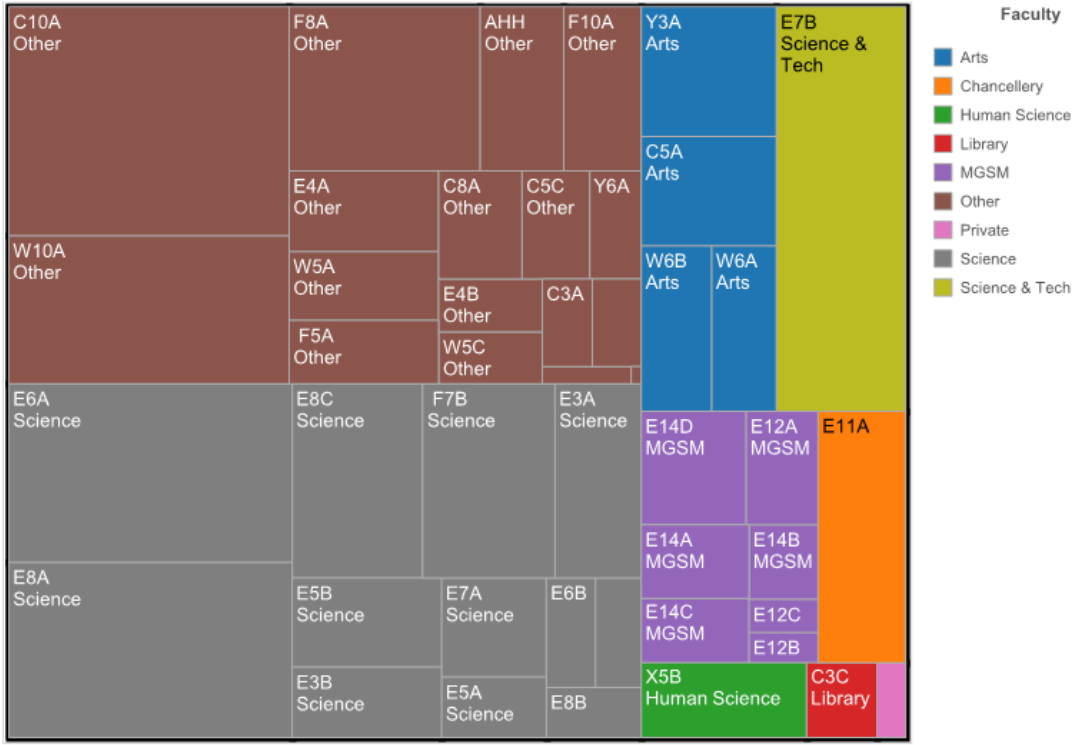
GHG Saving Potential*



Building E8B Upgrade List

Building Category	Upgrade Detail	Elec Savings (kWh/yr)	Gas Savings (GJ/yr)	Total Cost Savings	Upgrade Cost	Simple Payback	GHG Savings (kgCO2/yr)
On-site generation	10kWp PV array across available roof area	15,000	0	$2,912	$22,000	7.6	15,750
Lighting Controls	Full lighting controls upgrade - automated scheduling, motion and light level detection	8,961	0	$1,344	$13,750	10.2	9,409
Lighting Power Density	Upgrade all lighting to high efficient T5 fittings (or LED)	26,881	0	$4,309	$54,000	12.5	28,225
Cooling Controls	Removal of portable A/C, incorporating schedules for chilled beams. Note - assumes A/C full refurb. Costs combined with heating controls	2,028	0	$304	$5,000	16.4	2,130
Ventilation System	Occupancy sensor for Toilet exhaust	1,082	20	$361	$6,000	16.6	2,410

Overall GHG By Faculty



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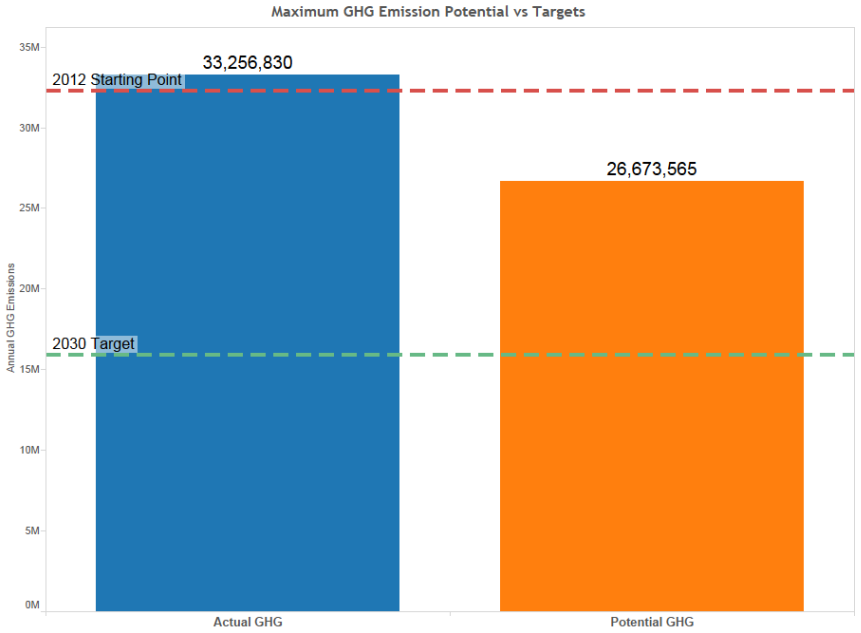
Overall GHG Emissions Review

Looking at the whole campus combined (for the building's included to date) the potential GHG reductions from all of the energy saving measures identified is not sufficient to achieve the University 50% reduction target by 2030.

These figures currently do not include PV and are subject to change.



MACQUARIE University

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Macquarie University Energy Strategy

Audit Results & Implementation Plan - Executive Briefing

Other Big Data Applications

- NABERS Energy Tracking
- PV and cogen feasibility
- Existing building performance analysis
- HVAC Condition Audits
- Analysing and presenting modelling results
- Mapping our projects on the website

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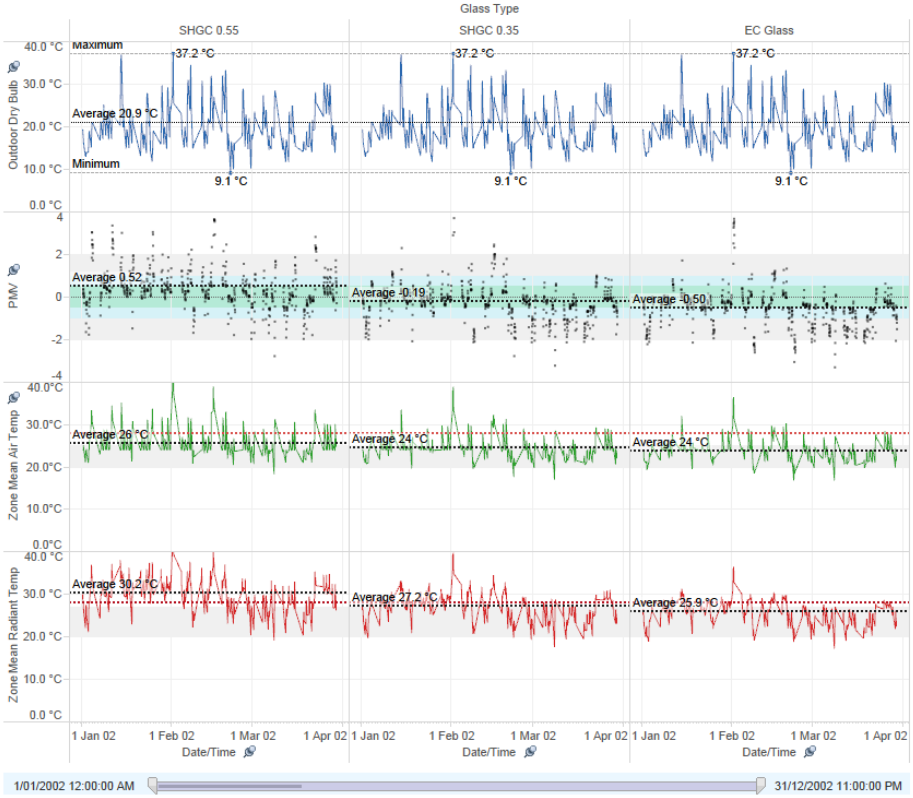
ACU Thermal Comfort Analysis



The thermal comfort modelling results for the proposed stair at the Australian Catholic University (ACU) building on Victoria Parade are shown below.

The results have been filtered for occupied hours (8am to 5pm) in the summer months of January to March only for a typical year (hourly weather data from 2002).

The inputs marked in blue can be toggled to further filter the results.

Predicted Mean Vote (PMV)

	SHGC 0.55	SHGC 0.35	EC Glass
% of PMV in Excellent Range (+/- 0.5)	50%	58%	51%
% of PMV in Good Range (+/- 1)	75%	77%	73%
% of PMV in Ok Range (+/- 2)	91%	96%	94%
Average PMV	0.5	-0.2	-0.5

Air Temperature

	SHGC 0.55	SHGC 0.35	EC Glass
% of Time within 1 °C of Control Band (21-24°C)	70%	79%	81%
Hours above Peak Operative Temp.	119 hrs	56 hrs	31 hrs
% of Time Above Peak Operative Temp.	19%	9%	5%
Average Internal Air Temperature	25.6°C	24.4°C	23.9°C

Radiant Temperature

	SHGC 0.55	SHGC 0.35	EC Glass
% of Time within Target (20-27°C)	17%	42%	62%
Hours Above Temperature Target (27°C)	531 hrs	363 hrs	228 hrs
% of Occupied Time Above Target (27°C)	83%	57%	36%
Average Radiant Temperature	30.2 °C	27.2 °C	25.9 °C

Key

- Outdoor Dry Bulb
- PMV
- Zone Mean Air Temp
- Zone Mean Radiant Temp

Level Assessed

- Ground
- Level 5

Glass Type

- (All)
- EC Glass
- SHGC 0.35
- SHGC 0.55

Peak Operative Temp.

28°C

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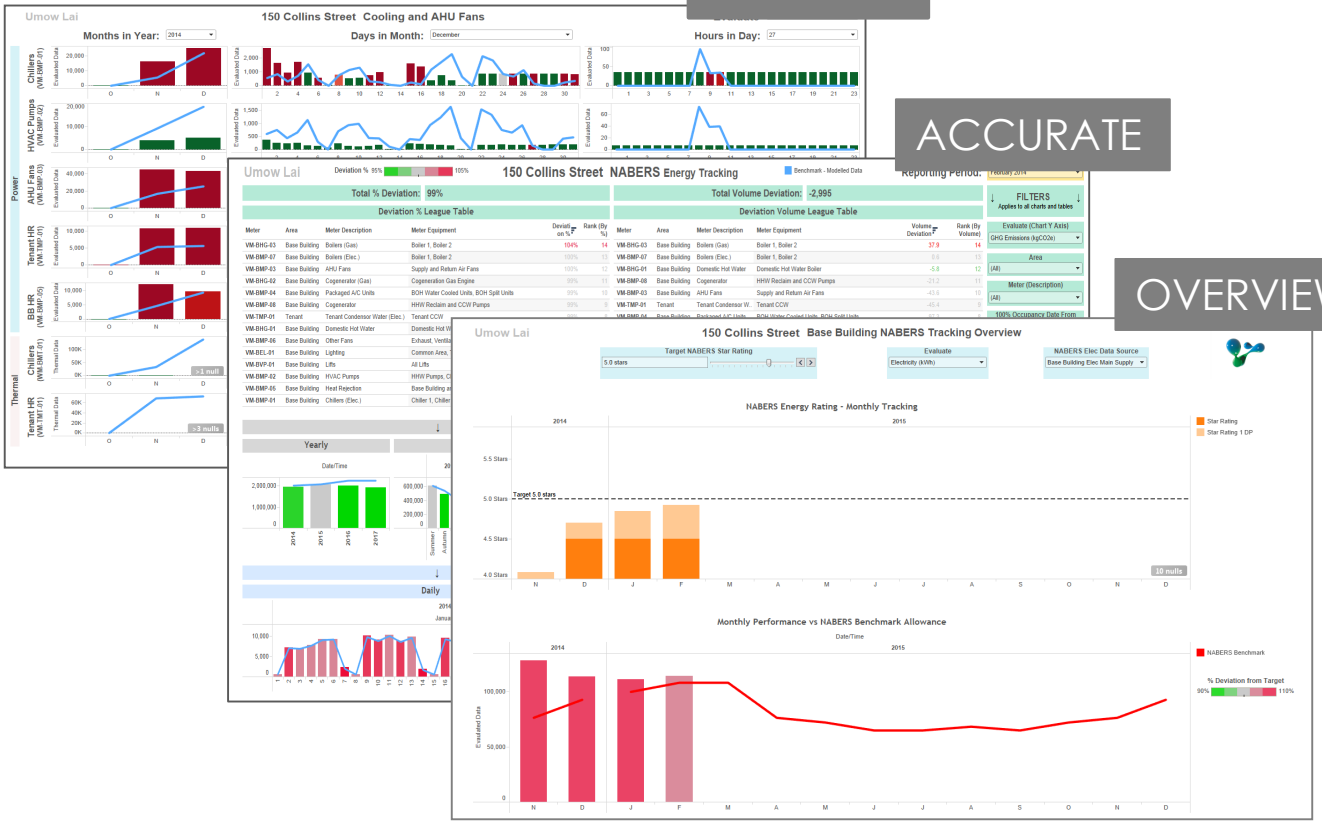
DETAILED

ACCURATE

OVERVIEW



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ACCURATE

Umow Lai Deviation % 95% 105% **150 Collins Street NABERS Energy Tracking** Benchmark - Modelled Data Reporting

Total % Deviation: 99%

Total Volume Deviation: -2,995

Deviation % League Table

Meter	Area	Meter Description	Meter Equipment	Deviation %	Rank (By %)
VM-BHG-03	Base Building	Boilers (Gas)	Boiler 1, Boiler 2	104%	14
VM-BMP-07	Base Building	Boilers (Elec.)	Boiler 1, Boiler 2	100%	13
VM-BMP-03	Base Building	AHU Fans	Supply and Return Air Fans	100%	12
VM-BHG-02	Base Building	Cogenerator (Gas)	Cogeneration Gas Engine	99%	11
VM-BMP-04	Base Building	Packaged A/C Units	BOH Water Cooled Units, BOH Split Units	99%	10
VM-BMP-08	Base Building	Cogenerator	HHW Reclaim and CCW Pumps	99%	9
VM-TMP-01	Tenant	Tenant Condensor Water (Elec.)	Tenant CCW	99%	8
VM-BHG-01	Base Building	Domestic Hot Water	Domestic Hot Water Boiler	99%	7
VM-BMP-06	Base Building	Other Fans	Exhaust, Ventilation, Carpark, Smoke Spill	99%	6
VM-BEL-01	Base Building	Lighting	Common Area, Toilets, Carpark, Back of House and Pla..	98%	5
VM-BVP-01	Base Building	Lifts	All Lifts	98%	4
VM-BMP-02	Base Building	HVAC Pumps	HHW Pumps, CHW Pumps	98%	3
VM-BMP-05	Base Building	Heat Rejection	Base Building and Cogen Cooling Towers, CCW	98%	2
VM-BMP-01	Base Building	Chillers (Elec.)	Chiller 1, Chiller 2, Chiller 3	98%	1

Deviation Volume League Table

Meter	Area	Meter Description	Meter Equipment	Volume Deviation	Rank (By Volume)
VM-BHG-03	Base Building	Boilers (Gas)	Boiler 1, Boiler 2	37.9	14
VM-BMP-07	Base Building	Boilers (Elec.)	Boiler 1, Boiler 2	0.6	13
VM-BHG-01	Base Building	Domestic Hot Water	Domestic Hot Water Boiler	-5.8	12
VM-BMP-08	Base Building	Cogenerator	HHW Reclaim and CCW Pumps	-21.2	11
VM-BMP-03	Base Building	AHU Fans	Supply and Return Air Fans	-43.6	10
VM-TMP-01	Tenant	Tenant Condensor W..	Tenant CCW	-45.4	9
VM-BMP-04	Base Building	Packaged A/C Units	BOH Water Cooled Units, BOH Split Units	-97.3	8
VM-BMP-06	Base Building	Other Fans	Exhaust, Ventilation, Carpark, Smoke Spill	-176.2	7
VM-BVP-01	Base Building	Lifts	All Lifts	-194.6	6
VM-BHG-02	Base Building	Cogenerator (Gas)	Cogeneration Gas Engine	-288.6	5
VM-BMP-05	Base Building	Heat Rejection	Base Building and Cogen Cooling Towers, CCW	-290.2	4
VM-BEL-01	Base Building	Lighting	Common Area, Toilets, Carpark, Back of House and Plan..	-397.9	3
VM-BMP-02	Base Building	HVAC Pumps	HHW Pumps, CHW Pumps	-552.3	2
VM-BMP-01	Base Building	Chillers (Elec.)	Chiller 1, Chiller 2, Chiller 3	-920.1	1

FILTERS
Applies to all charts and tables

Evaluate (Chart Y Axis): GHG Emissions (kgCO2e)

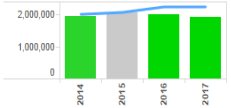
Area: (All)

Meter (Description): (All)

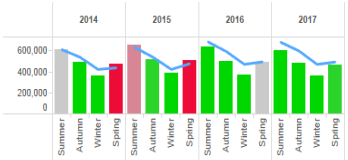
100% Occupancy Date From: 1/10/2015

Periodic Tracking of Actual Data Compared to Modelled Benchmark

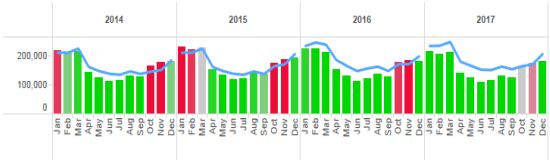
Yearly



Seasons



Monthly

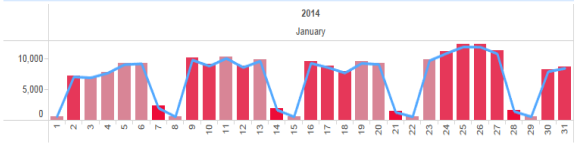


The charts to the left represent the actual data and the as-designed modelled performance for benchmarking purposes. Monthly data is considered broadly suitable for comparisons but it should be noted that actual weather patterns (e.g. a very hot month) may not align with the modelled weather which may skew results.

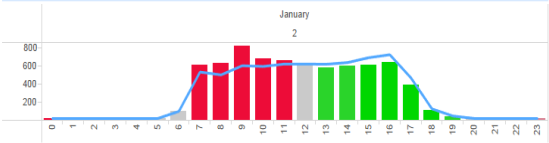
The charts below reflect daily and hourly comparisons in energy use compared to the modelled benchmark. Please note that the modelled data at this level of detail is less likely to be suitable for direct comparisons so is provided for reference only.

Additional Detailed Analysis — Reference Only

Daily



Hourly



FILTERS
For daily and hourly charts only

Select Year: 2014

Select Month: January

Select Day: 2

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OVERVIEW

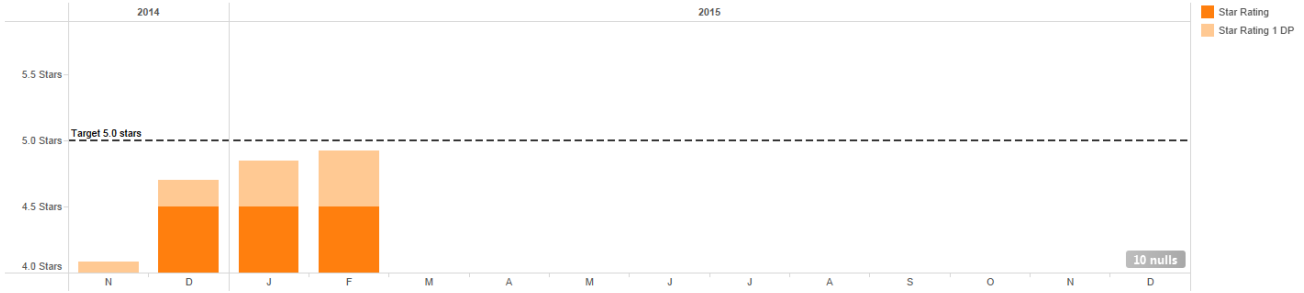
150 Collins Street Base Building NABERS Tracking Overview

Target NABERS Star Rating: 5.0 stars

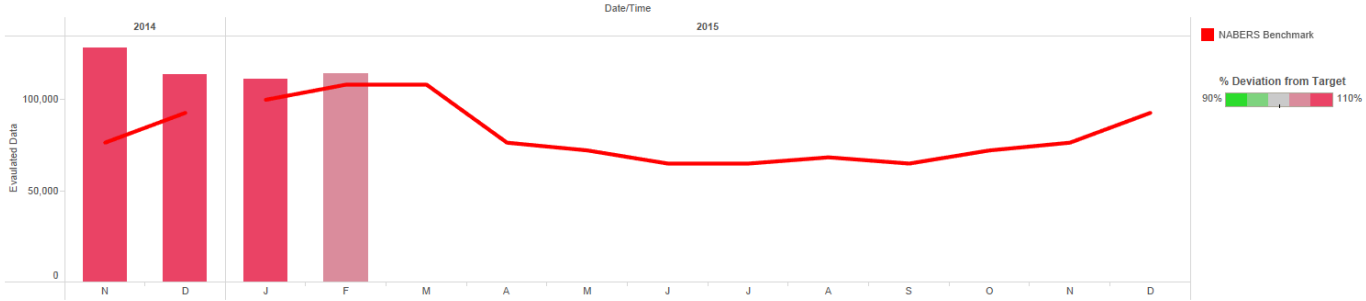
Evaluate: Electricity (kWh)

NABERS Elec Data Source: Base Building Elec Main Supply

NABERS Energy Rating - Monthly Tracking

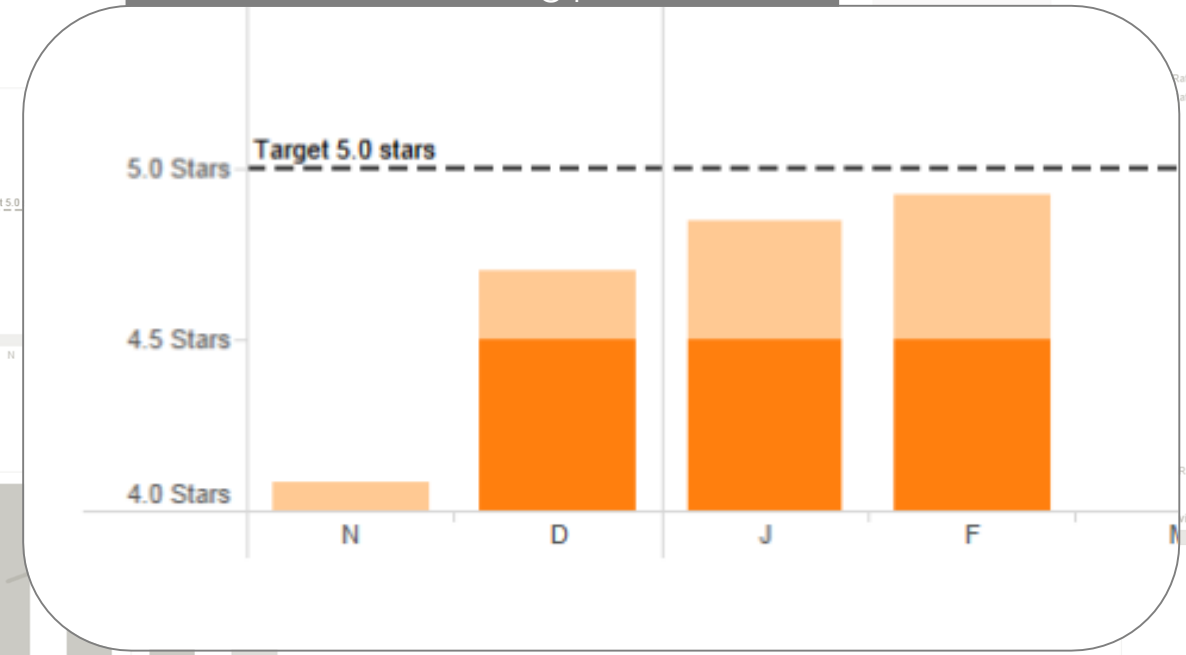


Monthly Performance vs NABERS Benchmark Allowance



OVERVIEW

NABERS Status Tracking per Month



Deviation per Meter

ACCURATE

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Deviation % 95% 105%

150 Collins Street NAB

Total % Deviation: 99%

Deviation % League Table

Meter	Area	Meter Description	Meter Equipment	Deviation %	Rank (By %)
VM-BHG-03	Base Building	Boilers (Gas)	Boiler 1, Boiler 2	104%	14
VM-BMP-07	Base Building	Boilers (Elec.)	Boiler 1, Boiler 2	100%	13
VM-BMP-03	Base Building	AHU Fans	Supply and Return Air Fans	100%	12
VM-BHG-02	Base Building	Cogenerator (Gas)	Cogeneration Gas Engine	99%	11
VM-BMP-04	Base Building	Packaged A/C Units	BOH Water Cooled Units, BOH Split Units	99%	10

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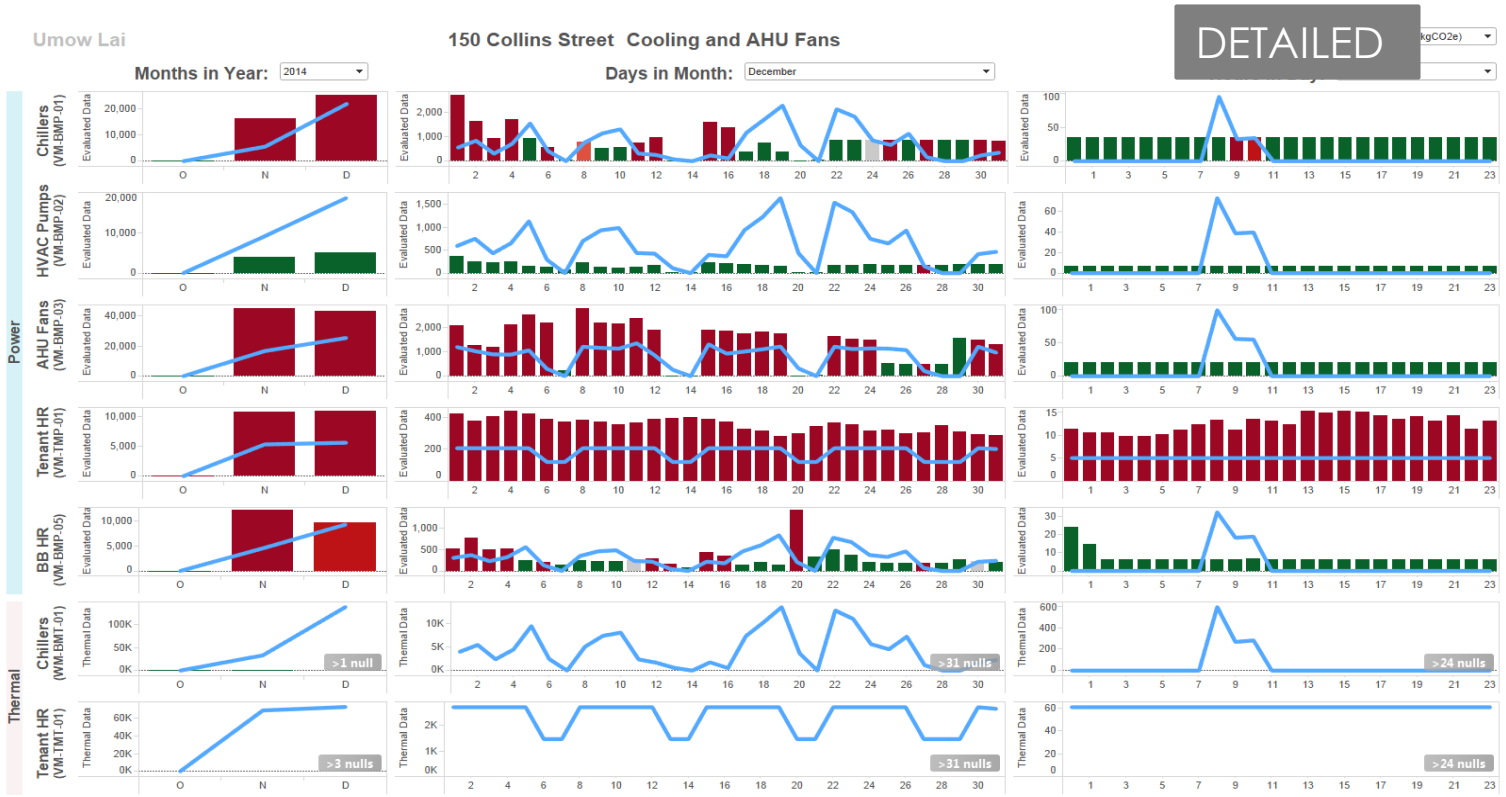

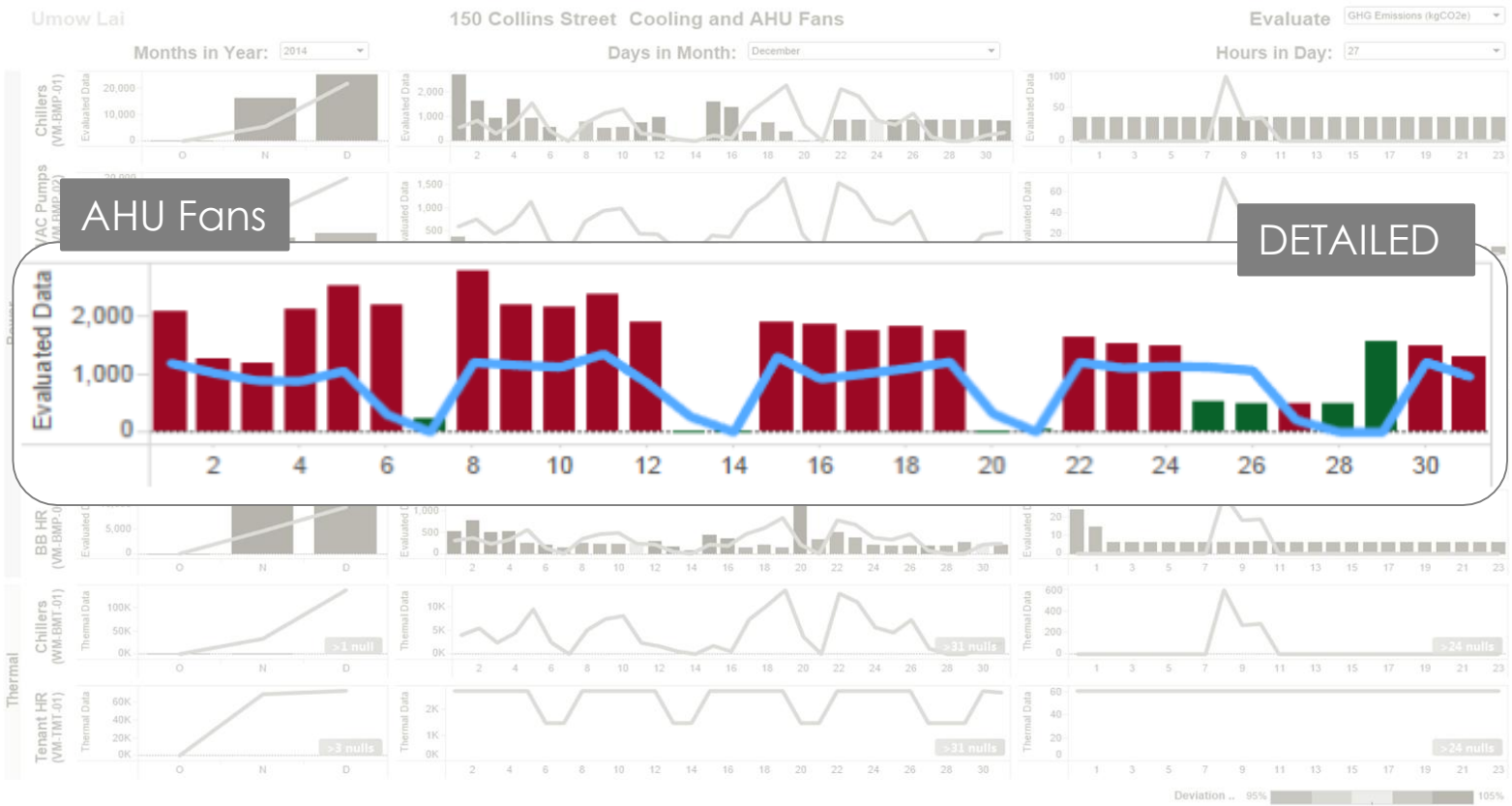
Umow Lai
150 Collins Street Cooling and AHU Fans
Evaluate
GHG Emissions (kgCO2e)
Months in Year:
2014
Days in Month:
December
Hours in Day:
27
AHU Fans
DETAILED
Evaluated Data
2,000
1,000
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
Chillers (VM-BMP-01)
BB HR (VM-BMP-0
Thermal
Chillers (VM-BMT-01)
Tenant HR (VM-TMT-01)
Thermal Data
>1 null
>31 nulls
>24 nulls
>3 nulls
Deviation ..
95%
105%

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Project Name Energy Dashboard - Electricity

Logo

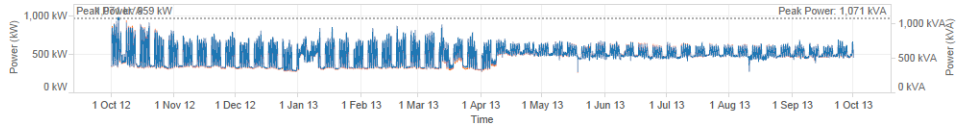
Inputs in Blue

Meter Use (All)

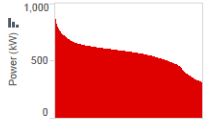
Complete Dataset

Energy	% Peak Energy	Peak Energy	% Off Peak Energy	Off-Peak Energy	% On-Site Energy	Generated On-Site	GHG Emissions
4,247,566 kWh	55%	2,337,430 kWh	45%	1,910,136 kWh	0.00%	0 kWh	5,734 tCO2e

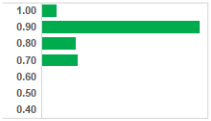
Power Profile (kW and kVA)



Power (kW) Distribution



Power Factor Distribution



Data Peak

Bin Size 0.1

Time Filters

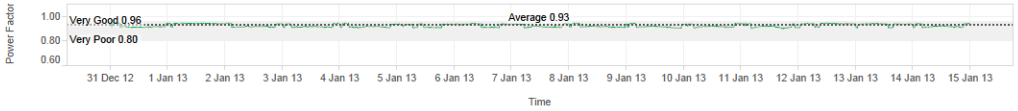
31/12/2012 12:00:00 AM — 14/01/2013 11:59:59 PM

Year (All) | Quarter (All) | Month (All) | Day (All) | Weekday (All) | Hour (All)

Filtered Analysis

Power Factor

Power Factor Profile *



Power Factor Distribution

Data Collection Frequency: 4 data points / hour

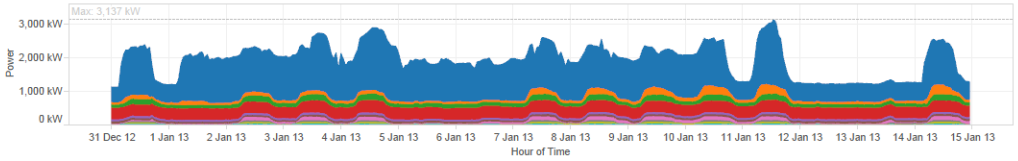
Power Factor Stats

Max. Power Factor	1.00
Avg. Power Factor*	0.93
Load Factor*	0.094
Demand Factor #	0.863

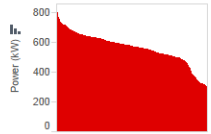
Max. Demand: 600 kW

Power

Power Profile Breakdown



Power (kW) Distribution



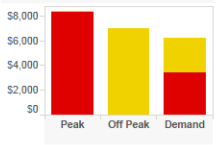
Data: Peak

Power Statistics

Max. Power	518 kW
Min. Power	1 kW
Max. Power (kVA)	601 kVA
Min. Power (kVA)	1 kVA

Energy / Cost / GHG Emissions

Indicative Cost Metrics



Peak Tariff $0.08 / kWh

Off-Peak $0.09 / kWh

Demand $ 6.66/ kW max

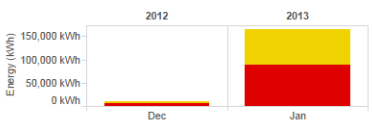
The above tariffs and charges are approximate only and do not include standing charges or account of line lo..

Greenhouse Gas Emissions

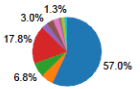
Electricity GHG Emission Factor: 1.350 kgCO2/kWh

GHG Emissions	237 tCO2e

Peak and Off Peak Energy



Meter Energy Split



Energy Summary

Energy	175,706 kWh
% Peak Energy	56%
Peak Energy	98,573 kWh
% Off Peak Energy	44%
Off-Peak Energy	77,133 kWh
% On-Site Energy	0.00%
Generated On-Site	0 kWh

Legend

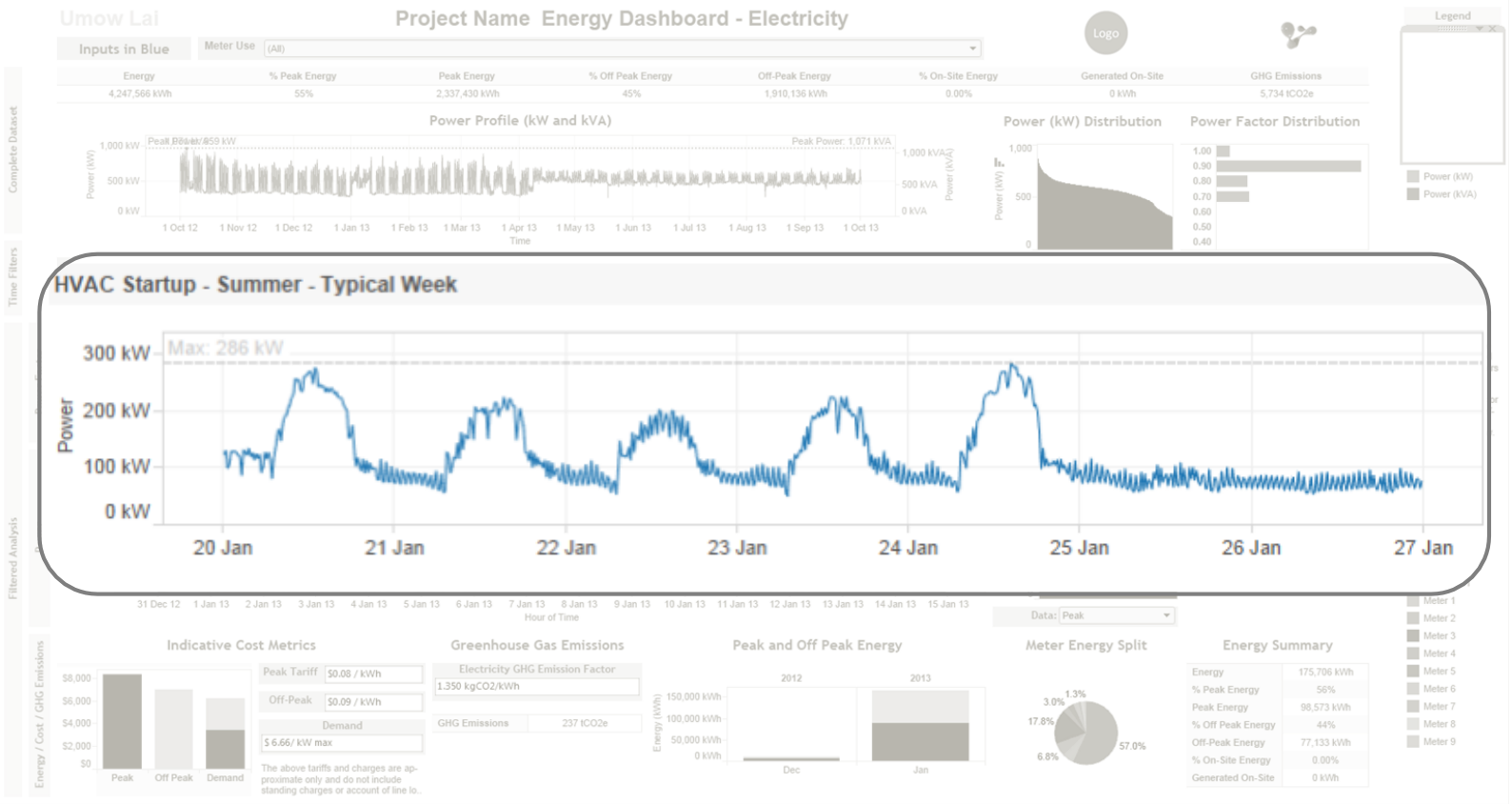
Power (kW)
Power (kVA)

Peak
Off-Peak

BB Meter 1
Meter 1
Meter 2
Meter 3
Meter 4
Meter 5
Meter 6
Meter 7
Meter 8
Meter 9

* Please note, these values are averaged where multiple meters are selected.

The Demand Factor is calculated with reference to the Max. Demand input below.


Umow Lai
Project Name Energy Dashboard - Electricity
Inputs in Blue
Meter Use
(All)
Logo
Legend
Energy
% Peak Energy
Peak Energy
% Off Peak Energy
Off-Peak Energy
% On-Site Energy
Generated On-Site
GHG Emissions
4,247,566 kWh
55%
2,337,430 kWh
45%
1,910,136 kWh
0.00%
0 kWh
5,734 tCO2e
Power Profile (kW and kVA)
Power (kW) Distribution
Power Factor Distribution
Power (kW)
Power (kVA)
Complete Dataset
Time Filters
Filtered Analysis
HVAC Startup - Summer - Typical Week
Max: 286 kW
300 kW
200 kW
100 kW
0 kW
Power
20 Jan
21 Jan
22 Jan
23 Jan
24 Jan
25 Jan
26 Jan
27 Jan
Hour of Time
Data: Peak
Meter 1
Meter 2
Meter 3
Meter 4
Meter 5
Meter 6
Meter 7
Meter 8
Meter 9
Indicative Cost Metrics
Peak Tariff
$0.08 / kWh
Off-Peak
$0.09 / kWh
Demand
$ 6.66/ kW max
Peak
Off Peak
Demand
Greenhouse Gas Emissions
Electricity GHG Emission Factor
1.350 kgCO2/kWh
GHG Emissions
237 tCO2e
Peak and Off Peak Energy
2012
2013
Dec
Jan
Meter Energy Split
Energy Summary
Energy
175,706 kWh
% Peak Energy
56%
Peak Energy
98,573 kWh
% Off Peak Energy
44%
Off-Peak Energy
77,133 kWh
% On-Site Energy
0.00%
Generated On-Site
0 kWh

Australia Post - Nationwide HVAC Audit Results

Filters

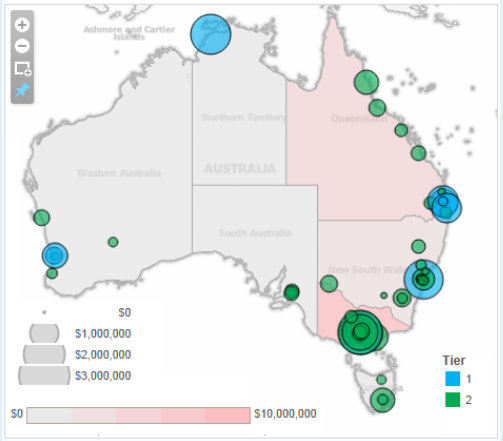
Tier
- (All)
- 1
- 2

Type
- (All)
- Airport Distribution Centr…
- Business Centre (BC)
- Call Centre (CC)
- Delivery Centre (DC)
- Delivery Facility (DF)
- Gateway Facility (GF)
- General Post Office (GPO)
- Hub
- Letter Centre (LC)
- Letter Facility (LF)
- Mail Centre (MC)
- Mail Sorting Centre (MSC)
- Parcel Centre (PC)
- Parcel Facility (PF)

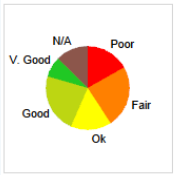
State
- (All)
- ACT
- NSW
- NT
- QLD
- SA

Location
- (All)
- Alexandria
- Allambie Frenchs Forest
- Bayswater
- Belmont
- Bendigo
- Braeside
- Brisbane
- Bunbury
- Bundall

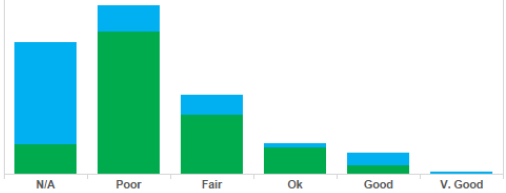
National Overview



Assessed Condition



Assessed Condition Cost Distribution



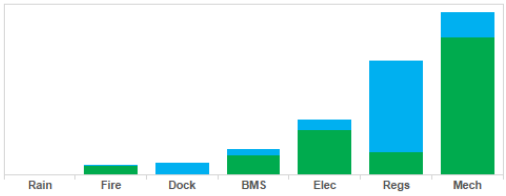
Key Stats

# of Facilities	68
# of Items	1,485
# of 'Very Good' Condition Items	118
# of 'Poor' Condition Items	250
# of Items Requiring Work	721

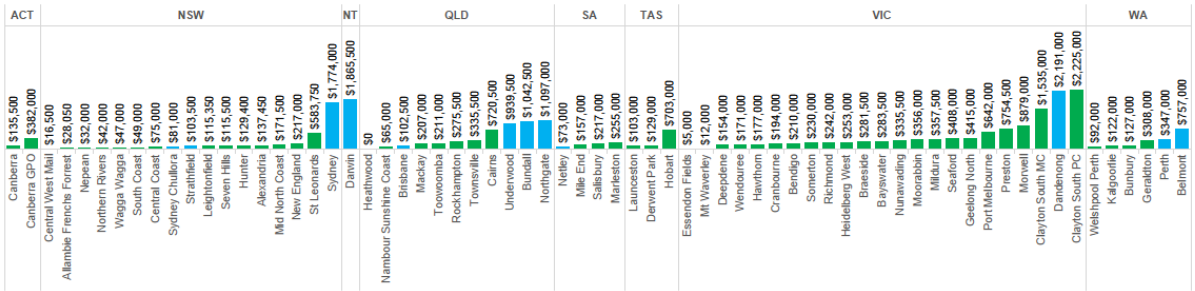
5 Year Costs

Year 1	$20,862,250
Year 2	$1,710,500
Year 3	$1,863,750
Year 4	$264,000
Year 5	$2,098,000
Total	$26,798,500

Category of Work Cost Distribution



Total 5 Year Cost per Project



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MACQUARIE UNIVERSITY
SYDNEY ~ AUSTRALIA

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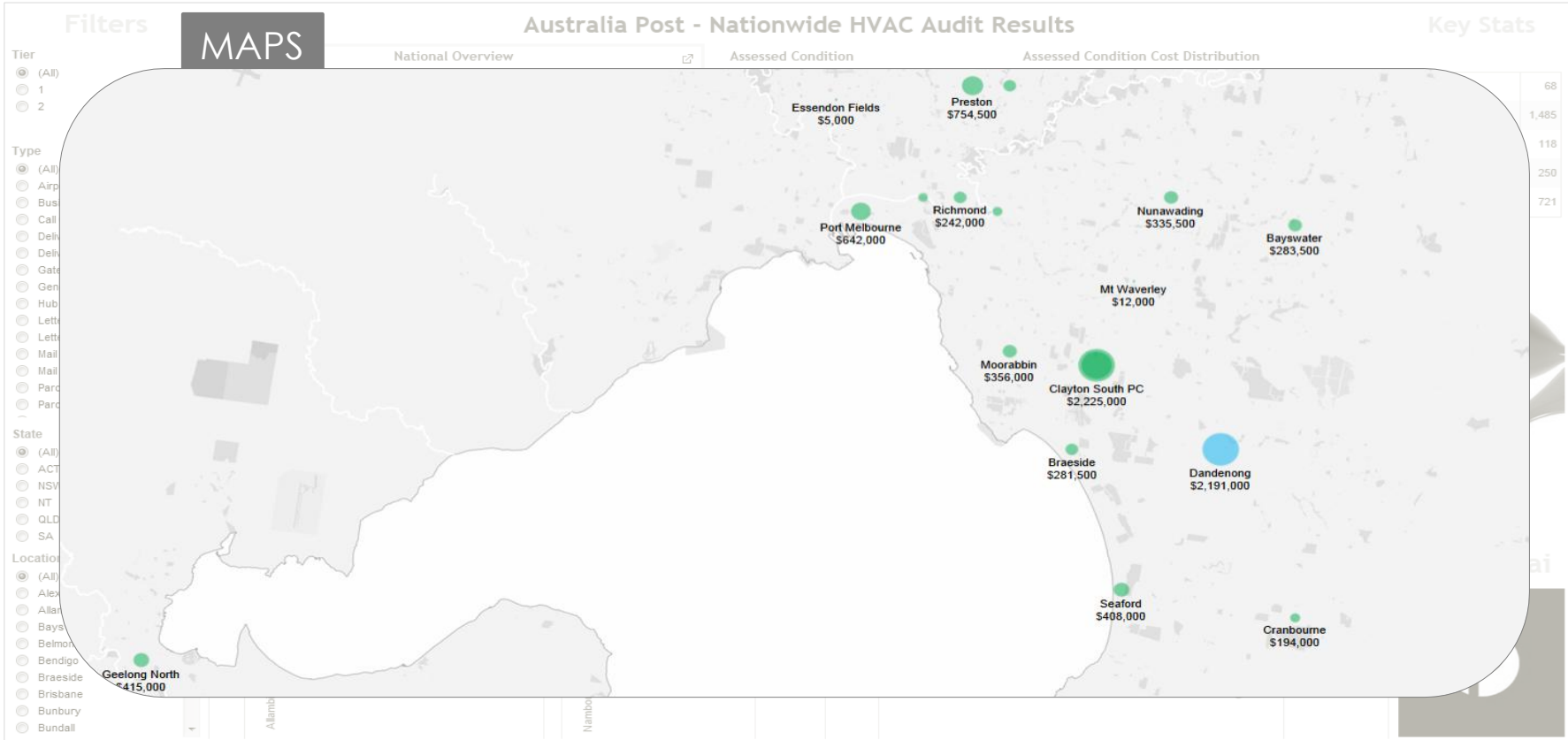
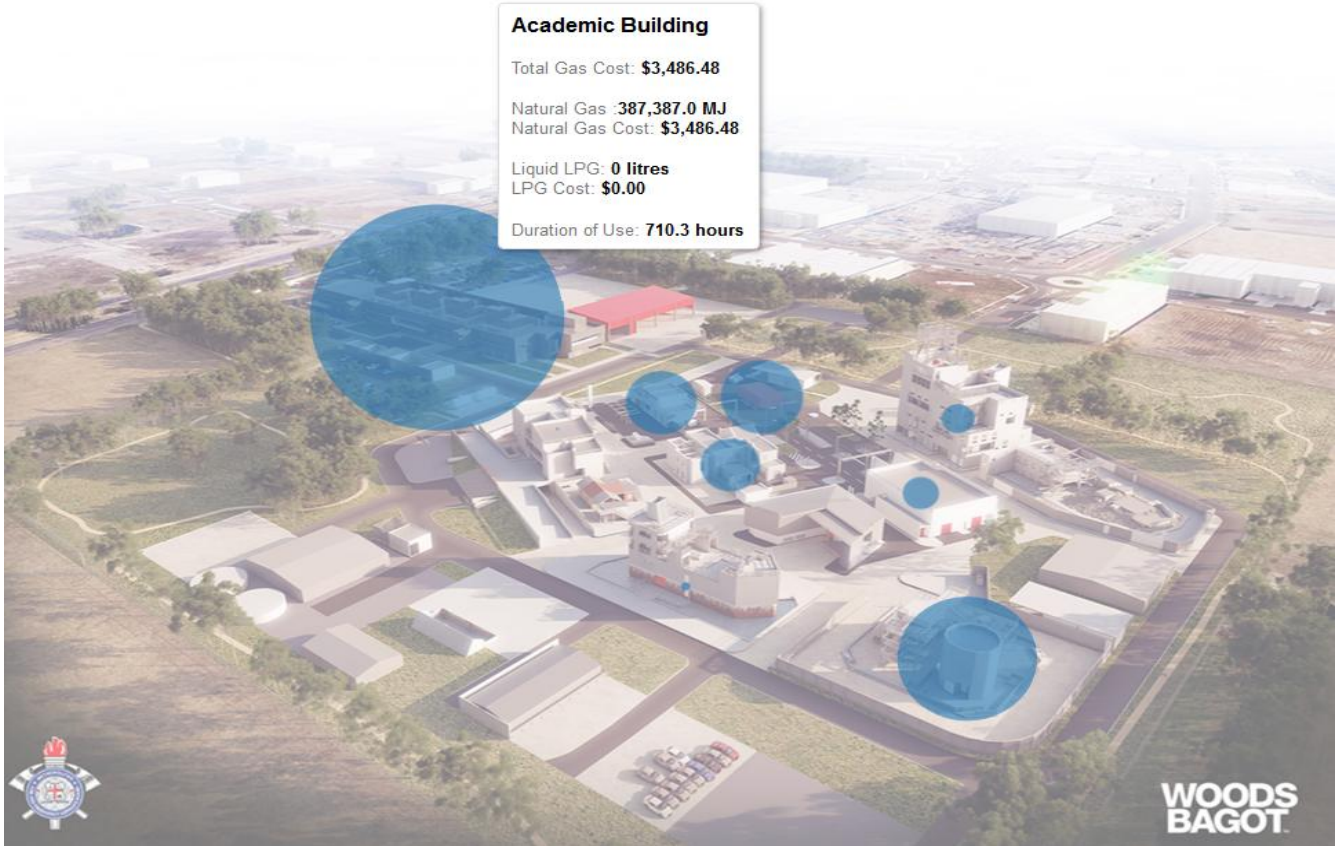
MAPS




Academic Building
Total Gas Cost: $3,486.48
Natural Gas :387,387.0 MJ
Natural Gas Cost: $3,486.48
Liquid LPG: 0 litres
LPG Cost: $0.00
Duration of Use: 710.3 hours
WOODS BAGOT

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