

ENERGY AUDIT REPORT

University Of Wollongong Main Campus Site Report

Prepared by



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August 2007*

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APPENDIXES

- 1. Summary of Proposed changes to the building assets at October 2006**
- 2. Itemised List of Energy Management Initiatives**

1. EXECUTIVE SUMMARY

The Main Campus of the University of Wollongong consumed 25,911 MWh of electricity and approximately 23,500 GJ of gas at a total cost of approximately \$2,050,000 (ex GST). This equates to an average energy consumption index of 687 MJ per square metre and to annual greenhouse gas emissions equivalent to 27,197 tonnes of CO₂. An estimated breakdown of this energy consumption is shown in Figure E1 below.

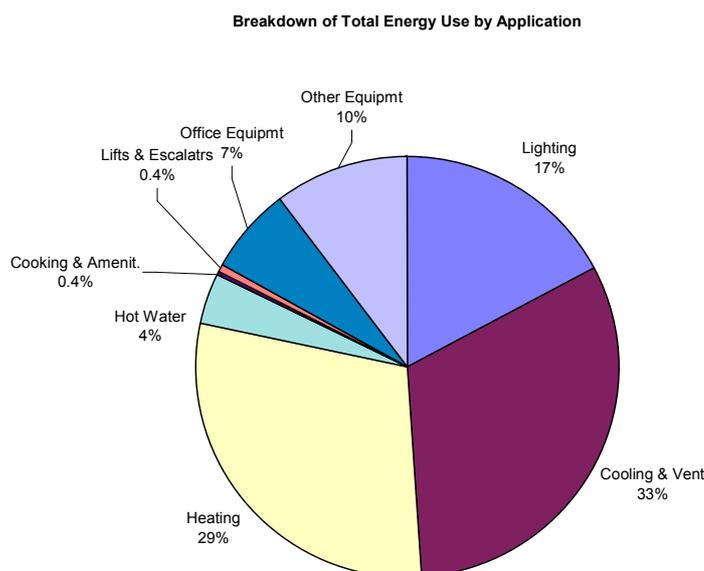


Figure E1: Estimated Breakdown of Energy Consumption

The audit of the main campus of the University identified energy efficiency cost savings worth approximately \$419,000 per annum including some minor maintenance savings due to reduced operations of systems. These savings represent approximately 24% of the energy currently used by the audited buildings. Approximately 94% of the above savings fall within the University's financial hurdle rate of 7% (IRR), at an estimated cost of approximately \$1,070,000 (not including the metering system costs). The main categories of projects falling within this economic range are listed in Table E1. It is recommended that these projects be implemented over the next 3 years.

The remaining projects are estimated to cost more than \$697,000 to produce the estimated annual cost savings of approximately \$36,200. Table E2 provides a breakdown of the main categories of projects falling within this economic range.

In addition to the above energy efficiency works, it is recommended that a utilities metering system be implemented across the campus to provide monitoring, metering and apportioning of energy use and efficiency as required under the Energy Savings Action Plan and to carry out the other functions required under the University's energy management programs. This is estimated to cost approximately \$300,000 and should be implemented in the first year to assist in the monitoring of the program and to provide tenant metering and cost recovery. This initiative is included with the cost-effective projects in Table E1.

Notes on savings quoted above and in the report:

- (1) Savings for items are based on the average energy rates (excluding GST) for the past 12 months except for initiatives subject to off-peak rates*
- (2) Refer to the body of the report for additional notes and qualifications on the above estimates*
- (3) All costs and savings estimates are based on information available and investigations possible at the time of the audit. Each requires confirmation in subsequent feasibility studies.*

Table E1: Energy Saving Projects falling within the 7% Hurdle Rate

Area of Project	Implement' Cost	Savings					Payback
		Energy Costs	Maintenance Costs	Energy	% of tot Energy	Emissions	
	\$	\$ pa	\$ pa	GJ pa		T CO2-e	yrs
Implement identified cost-effective HVAC ¹ initiatives	702,530	262,280	1,847	17,906	16.9%	3,486	2.7
Implement identified cost-effective DHW ² and Staff Amenities initiatives	69,985	11,070	0	1,578	1.5%	151	20.8
Implement identified cost-effective Utilities initiatives	10,000	37,587	0	1,879	1.8%	491	0.3
Implement identified cost-effective Lighting initiatives	166,727	21,059	9,279	1,091	1.0%	298	5.5
Implement identified cost-effective Office and Other Equipment initiatives	Nil	10,000	0	477	0.4%	131	immediate
Implement identified cost-effective Pool system initiatives	40,930	12,224	0	1,565	1.5%	159	3.3
Implement identified cost-effective Power Factor Correction initiatives	80,625	17,100	0	0	0.0%	0	4.7
Implement a site-wide metering system	300,000	n/a	n/a	n/a	n/a	n/a	n/a
Total	1,370,798	371,320	11,125	24,497	23.1%	4,717	3.6

(1) – Heating, Ventilation and Air Conditioning

(2) – Domestic Hot Water

Table E2: Energy Saving Projects falling outside the 7% Hurdle Rate

Area of Project	Implement' Cost	Savings					Payback
		Energy Costs	Maintenance Costs	Energy	% of tot Energy	Emissions	
	\$	\$ pa	\$ pa	GJ pa		T CO2-e	yrs
Identified but currently uneconomic HVAC initiatives	451,550	19,526	0	1,004	0.9%	263	23.1
Identified but currently uneconomic DHW and Staff Amenities initiatives	17,000	660	0	44	0.0%	12	25.8
Identified but currently uneconomic Lighting initiatives	228,620	11,989	3,127	572	0.5%	157	15.1
Identified but currently uneconomic Power Factor Correction initiatives	18,750	906	0	0	0.0%	0	20.7
Total	715,920	33,082	3,127	1,620	4.9%	432	19.8

(1) – Heating, Ventilation and Air Conditioning

Energy Audit

University of Wollongong – Main Campus

2. Introduction

2.1 Background

The University of Wollongong, being a major consumer of energy as designated by DEUS, is required to prepare an Energy Savings Action Plan for the Main Campus under the Energy Administration Amendment (Water and Energy Savings) Act 2005 to the requirements of the NSW Department of Energy, Utilities and Sustainability (DEUS).

The necessary steps in preparing an Energy Savings Action Plan are:

- Determine baseline energy use
- Conduct an Energy Management Review
- Undertake a Technical Review, in the form of a Level 3 Energy Audit in accordance with AS/NZS 3598:2000
- Complete an Energy Savings Action Plan

2.2 Scope of Works

This report covers all energy use by the Main Campus at Northfields Avenue, Wollongong which is defined by all of the buildings and services managed by the University's Buildings and Grounds Division. Energy audits were also conducted at Building 37 (Kooloobong) and Building 121 (Graduate House), these buildings are managed by a separate entity to the Building and grounds Division and are therefore not covered by this report; separate reports have been prepared for these buildings. Also, in the case of tenanted buildings, the report only covers the services managed by the University, which typically consist of house services such as central heating, cooling and ventilation, hot water and lifts.

This report includes the determination of baseline energy use, the Technical Review which is a Level 3 Energy Audit in accordance with AS/NZS 3598:2000 and other reviews associated with the preparation of an Energy Savings Action Plan for the site. The Energy Management Review has already been prepared by others and has been incorporated into this report.

A Level 3 Energy Audit provides a detailed analysis of energy usage, the savings that can be made and the cost of achieving these savings. A Level 3 Energy Audit is expected to provide a firm estimate of savings and cost. Accuracy of figures would be within +10% for costs and -10% for benefits. However, refer to section 2.4 for factors which affect the accuracy of these estimates.

2.3 Methodology

Baseline Energy Use

Baseline energy use was established from monthly electricity and gas consumption and cost for the 2005 calendar year.

Business activity indicators used are building gross floor area and equivalent full time students, these indicators are standard for the higher education sector and are used for current reporting requirements.

Energy Management Review

The Energy Management Review was conducted by Energetics using their One-2-Five Energy diagnostic program

Technical Review

Surveys of the building loads were undertaken to enable a model of the energy use across the site to be constructed and a breakdown of energy consumption and demand levels to be obtained.

The validity of the model was checked against historical electricity and gas consumption.

The following performance analysis techniques were used during the process of this project:

- EMET's EMET~IBER program (endorsed by the Property Council of Australia and in use throughout Australia for over 15 years) was used for a detailed diagnostic analysis of the building's performance including individual components of plant (eg- heating, cooling, ventilation etc.)
- EMET's ELM program was used to determine the breakdown of energy use within each building and across the site to allow a detailed assessment of saving potential for each initiative.

Energy related greenhouse gas emission factors used in the report were obtained from the Australian Greenhouse Office "AGO Factors and Method Workbook, December 2005" – and correspond to the following:

Electricity (NSW full fuel cycle emission factor) – 0.985 kg CO₂-e/kWh

Natural gas (NSW direct/point source EF for combustion emissions) – 71.3 kg CO₂-e/GJ

Energy Savings Action Plan

The energy savings action plan is the result of the aggregation of initiatives identified in the Technical Reviews of the individual buildings and the campus wide initiatives covered in this Main Campus report.

2.4 Sources of Information, Assumptions and Qualifications

The information contained in this report is based on a range of sources that have selectively been evaluated; these sources include site historical energy consumption data, production data, site control system data, daily plant run time and lost time records, individual plant electrical readings, site observations, and discussions with site personnel.

Site drawings and operating and maintenance manuals have been reviewed, where available, to gain an understanding of the installed plant and equipment. Where practical and appropriate, information has been confirmed by inspection of the installed plant.

Recommendations and observations are based on visual inspections of plant and equipment. Dismantling of plant or carrying out detailed technical inspections was outside the brief of this audit.

The information and recommendations stated in this report are based on the above techniques and limitations. However these estimates can be affected by a multitude of external factors, which are subject to change. As a result, each recommendation should be reviewed at the time of consideration, to ensure that its relevance and economics are still acceptable. Some of these factors include:

- Variations in production requirements
- Addition or deletion of energy consuming equipment;
- Variation in activity levels;
- Variations in the standard of maintenance and efficiency monitoring;
- Variations in process settings
- Changes in energy tariff rates; and
- Other relevant changes.

2.5 Site Issues

Capital Management Plan Years 2006 to 2010

The University has an ongoing program of building refurbishment, reconstruction and the construction of new buildings. Inputs to this process incorporate building preventative maintenance history, Building Code of Australia (BCA) compliance and functional upgrade requirements.

The renewal and expansion of the building assets is expected to result in the increase in the total energy consumed by the site while the continual renewal of building assets is expected to result in improved energy performance as older less efficient systems are replaced.

To this end extension of the existing high voltage system is in the planning stages.

Refer Appendix 1 for a summary of proposed changes to the building assets at October 2006 for the main campus.

2.6 Acknowledgements

Throughout the conductance of this Technical Review the assistance and cooperation of the University's Buildings and Grounds Division's indoor and outdoor staff has been invaluable.

We would like to especially thank the following whose cooperation has been a significant contribution towards the completion of this report.

- Chris Hewitt – Manager Maintenance & Energy
- Peter Sparkowski – Mechanical and Electrical Maintenance Supervisor
- John McGrath – Maintenance Planner and OH&S Coordinator
- Eric Weddell – Air Conditioning Technician
- University's electricians for their assistance with the extensive data logging that was conducted across the campus

3. Buildings and Engineering Systems

3.1 General Description of the Site and Activity Levels

The Main Campus of the University of Wollongong comprises approximately 70 buildings representing a gross building floor area of 169,967 square metres during 2005. The progressive construction and refurbishment active on the site has resulted in buildings ranging in period of construction from the 1960's to the present time, most with refurbishments of less than 10 years. The gross building floor area for 2004 was 170,303 square metres.

This energy audit covers 58 of the buildings representing a gross building floor area of 168,267 square metres equivalent to 99% of the site's gross building floor area.

The Equivalent Full Time (EFT) student enrolments for 2005 were 16,179, including Wollongong University College (WUC) students. Table 3.1 below shows EFT student enrolments steadily rising from 1997 through to 2004. 2005 saw a reduction in enrolments of 1,894 or 10.5% from 2004.

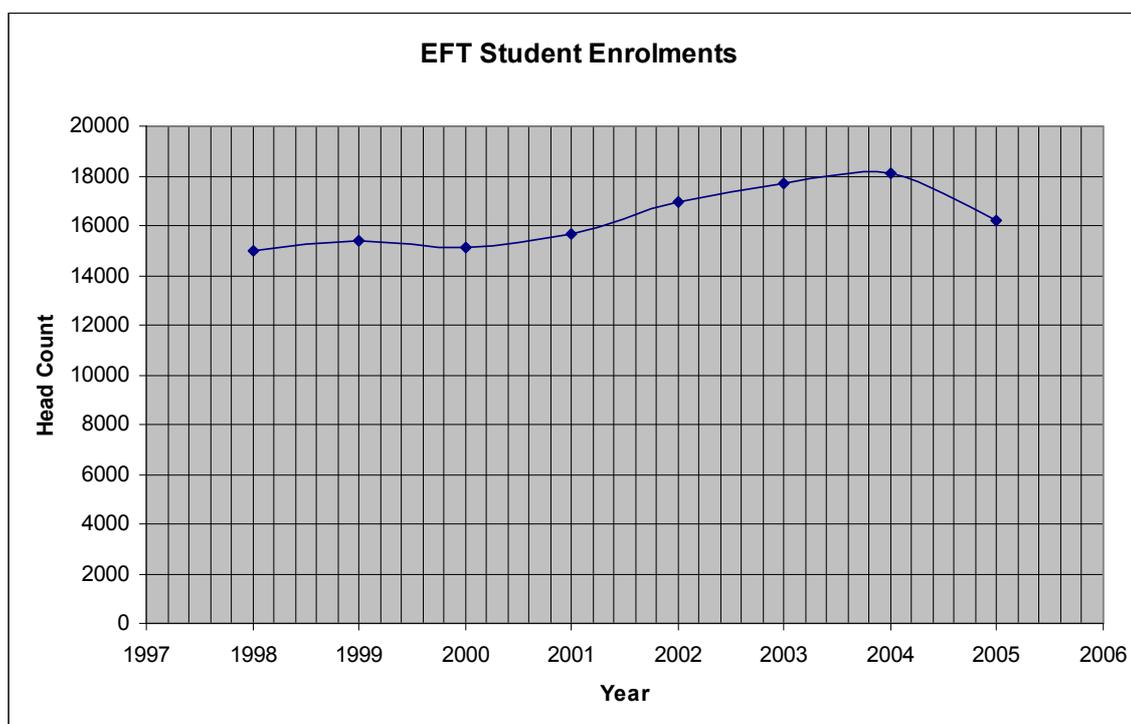


Figure 3.1: EFT Enrolments 1997 to 2005

A campus gross floor area of 169,967 square metres and 16,179 EFT students has been used as the business activity indicators in determining the energy performance indices for the 2005 baseline year.

3.2 Heating, Ventilation and Air Conditioning (HVAC)

The general policy with regards HVAC is for all areas to be ventilated to meet Australian Standards. Areas occupied by nominated senior executive staff, dedicated lecture theatres, dedicated computer laboratories and nominated laboratories are to be fully air conditioned. The types of systems in use comprise centralised chilled water and heating hot water systems; ducted reverse cycle and packaged systems; a chilled beam system; and reverse cycle room air conditioners.

Non air conditioned offices are heated by personal heaters and cooling relief is provided by ceiling fans.

Laboratories and workshops with make up air systems for fume cupboard and exhaust hoods comply with BCA standards and generally have tempered outside air heating systems.

Seminar and tutorial rooms in general have no heating or cooling.

3.3 Building Management System (BMS)

The site has a Siemens Apogee Building Management System that currently serves 18 buildings to principally provide Heating Ventilation and Air Conditioning system monitoring and control. In some cases the BMS also provides lighting control and electrical meter monitoring.

3.4 Domestic Hot Water and Staff Amenities

Domestic hot water systems are a mix of gas and electric systems and are generally as follows:

- Student and staff amenities: Local electric mains pressure systems.
- Student accommodation: Centralised gas and mains pressure electric circulating systems.
- Laboratories: Centralised gas and mains pressure electric circulating systems.
- Sporting complex: Centralised gas circulating systems.

The site also has approximately 70 boiling water units installed in lunch rooms and staff amenities areas; these systems generally are connected to a General Purpose Outlet (GPO) and remain energised at all times.

The site also has approximately 80 refrigerators installed in lunch rooms and staff amenities areas, these systems generally are less than 3 star rated out of a 5 star energy efficiency rating..

3.5 Lighting

Lighting systems are mostly linear fluorescent, with compact fluorescents used in corridors and foyers.

Automatic lighting control systems such as movement sensors, voltage reduction units and time of day control of corridor, external and security lighting have been used extensively throughout the site.

3.6 Office Equipment

Personal computers

The main campus has approximately 3,000 personal computers which are managed by different groups across the campus, consisting principally of Information Technology Services (ITS), Commerce Faculty, and Informatics Faculty.

ITS currently manages about 1,500 machines expanding to 2,000 by January 2007 as it takes over the management of additional machines on the campus. ITS currently has a policy of enabling the Energystar facility on all computers where appropriate and phasing in lower energy consuming liquid crystal monitors as leases expire.

The Commerce Faculty manages about 300 computers which are owned by the University. There is a policy of enabling the Energystar facility on all computers. The machines are automatically woken up between 2am and 5am for software updates.

The Informatics Faculty manages about 450 computers which are replaced every three years. There is a policy of enabling the Energystar facility on a roll out basis, approximately 50% of the machines have the Energystar facility enabled.

Computers in other areas in general are left operating, particularly in locations where older computers are in use such as research laboratories.

ITS advise that the most appropriate way to promote energy savings initiatives such as Energystar is via the IT Forum.

Photocopiers

The Main Campus has 133 combination photocopier/fax/printers of which approximately 100 are networked via the campus Ethernet, within the next twelve months almost all machines will be connected to the network as machines are upgraded on lease expiry.

All of the machines have an energy saver facility which sets the machine to energy save mode after a programmable time period of inactivity. The time period is currently set at the maximum of four hours and is centrally programmed for those machines connected to the network.

Energy use under different modes of operation for these units is as follows:

(model AF2015/18/18D – model AF1035 in brackets):

- Warm-up – 1.28kW (1.5 kW)
- Copying – 1.28kW (1.5kW)
- Standby – 130 W (500 W)
- Energy Saver – 10 W (223 W)
- Auto-off – 1 W (10 W)

4. Energy Load Profiles and Energy Consumption Patterns

4.1. Summary of Main Campus Energy Consumption and Performance

The Main Campus of the University of Wollongong consumed 116,771 GJ of energy for the twelve months ending December 2005. This consumption level resulted in Greenhouse gas emissions of 26,737 tonnes of Carbon Dioxide.

This energy consumption was required to service a total building gross floor area of 169,967 square metres and 16,179 Equivalent Full Time Students (EFTS).

The corresponding energy performance indices were 687 MJ/m² and 7,217 MJ/EFTS.

The maximum electricity demand, based on the sum of the recorded monthly maximum demand levels for the nine supplies to the site, was 6,161 kVA in summer and 4,742 kVA in winter.

Table 4.1 below provides a comparison of annual energy consumption, cost and performance for the 2004 and 2005 calendar years. It shows that all of these factors were higher during 2005 compared to 2004, while the gross building floor area decreased slightly and the EFTS reduced by 10%.

Table 4.1: Comparison of Energy Consumption, Cost and Performance

Year	Energy Source	Total Consumption		Annual Cost	Consumption Indices		Emissions
		(MWh)	(GJ)		\$(¹)	(MJ/m ²)	
2004	Electricity	24,670	88,812	1,789,239	521	4,914	24,300
	Natural Gas		21,481	136,016	126	1,189	1,532
	Total		110293	1,925,255	648	6,103	25,832
2005	Electricity	25,911	93,280	1,916,467	549	5,765	25,522
	Natural Gas		23,492	130,033	138	1,452	1,675
	Total		116772	2,046,500	687	7,217	27,197

4.2. Business Activity Indicators (BAI) and Baseline Energy Use

The standard business activity indicators used by the higher education sector are gross building floor area and equivalent full time students.

The gross building floor area during 2005 was 169,967 square metres and 170,303 square metres during 2004. During 2006 the gross floor area is expected to increase due to the commissioning of the Medical School Building. During 2007 and beyond substantial increases in the gross building floor area are scheduled.

Based on the above, the 2005 gross floor area is considered representative of a stable period in relation to changes in the building gross floor area, consequently the 2005 building gross floor area of 169,967 has been used as the baseline BAI for floor area. The EFT student figure for 2005 was 16,179.

The baseline energy use for the site is summarised in Table 4.2 below.

Table 4.2: Baseline Energy Use

Baseline Energy Use		
University of Wollongong	Main Campus	Comments
Baseline Start Date	01-Jan-05	
Baseline End Date	31-Dec-05	
Baseline energy use per annum (GJ)	116,771	
Greenhouse Emissions (tonnes)	7,217	
Is baseline representative of normal Energy Use	Yes	
Impact of variation on Energy use per annum	Nil	
Baseline energy use corrected for variation (GJ)	116,771	
Baseline Activity Indicator 1	Building gross floor area (m ²)	Note 1
Quantity of Site Business Activity Indicator 1 per annum	169,967	m ²
Baseline Energy use Key Performance Indicator 1 (KPI 1)	687	MJ/m ²
Business Activity Indicator 2	Equivalent Full Time Students	Note 1
Quantity of Site Business Activity Indicator 2 per annum	16,179	EFTS
Baseline Energy use Key Performance Indicator 2 (KPI 2)	7,217	MJ/EFTS
Demand		
Baseline summer peak Electrical use (kVA)	6,161	Note 2
Baseline winter peak Electrical use (kVA)	4,742	Note 2
Note 1: The university sector uses two Business Activity Indicators, gross building floor area and equivalent full time students. Gross building floor area is the index most applicable to measuring energy performance.		
Note 2: Summer & winter peak electrical use is based on the summation of the monthly peak for the nine supplies to the site		

4.3. Electricity

4.3.1 General Description

The Main Campus is supplied by ten low voltage supplies metered by revenue meters. All of these supplies are totally independent of one another.

Power factor correction equipment is installed on some of the low voltage supplies. Table 4.3 contains a schedule of the electrical supplies and identifies those which have power factor correction installed.

Table 4.3: Schedule of Electrical Supplies

LV Substa	Revenue Meter No.	NMI	Meter location	Power Factor Correction
2	5006900	NEEE 00910	UOW Switchroom 2, Building 16	Yes
2	5012410	NEEE 00910	UOW Switchroom 2, Building 16	Yes
3	5013891	NEEE 003522	UOW Switchroom 3, Building 19	Yes
3	5014473	NEEE 003066	UOW Switchroom 3, Building 40	Yes
4	5017551	NEEE 0044560	UOW Switchroom 4, Building 25	Yes
5	5024576	NEEE 003065	UOW Switchroom 5, Building 64	Yes
6	5010073	NEEE 073067	UOW Switchroom 6, Building 66	Yes
7	5005230	NEEE 003069	UOW Switchroom 7, Building 1	Yes
7	5006183	NEEE 003068	UOW Switchroom 7, Building 1	Yes
8	525601	NEEE 2615-6	UOW Switchroom 8, Building 30	No

4.3.2 Electricity Consumption, Cost and Performance

The electricity consumption for the calendar year 2005 was 25,911 MWh or 93,278 GJ and corresponds to Greenhouse gas emissions equivalent to 25,522 tonnes of Carbon Dioxide.

Table 4.4 provides a comparison of annual electricity consumption, cost and performance for the 2004 and 2005 calendar years. It shows electricity consumption increased by 5% during 2005, the electricity MJ/m² also increased by 5% while MJ/EFTS increased by 17% in association with a decrease in EFTS enrolments of 10%.

The average cost of electricity for the campus for the 2005 calendar year was 7.4 cents per kWh

Table 4.4: Comparison of Electricity Consumption, Cost and Performance

Year	Energy Source	Total Consumption		Annual Cost (\$)	MJ/m ²	MJ/EFT Student	Tonnes of CO ₂
		MWh	GJ				
2004	Electricity	24,670	88,810	1,789,239	521	4,914	24,300
2005	Electricity	25,911	93,278	1,916,467	549	5,765	25,522

4.3.3 Seasonal Patterns of Electricity Use

Figure 4.1 shows monthly campus electricity consumption for the 2004 and 2005 calendar years. The profiles show no clear seasonal variation in energy consumption and 2005 consumption levels being consistently greater than 2004 levels after April 2005.

The reason for the increased consumption level after April 2005 has not been established, it is not due to the commissioning of new or the refurbishment of existing buildings.

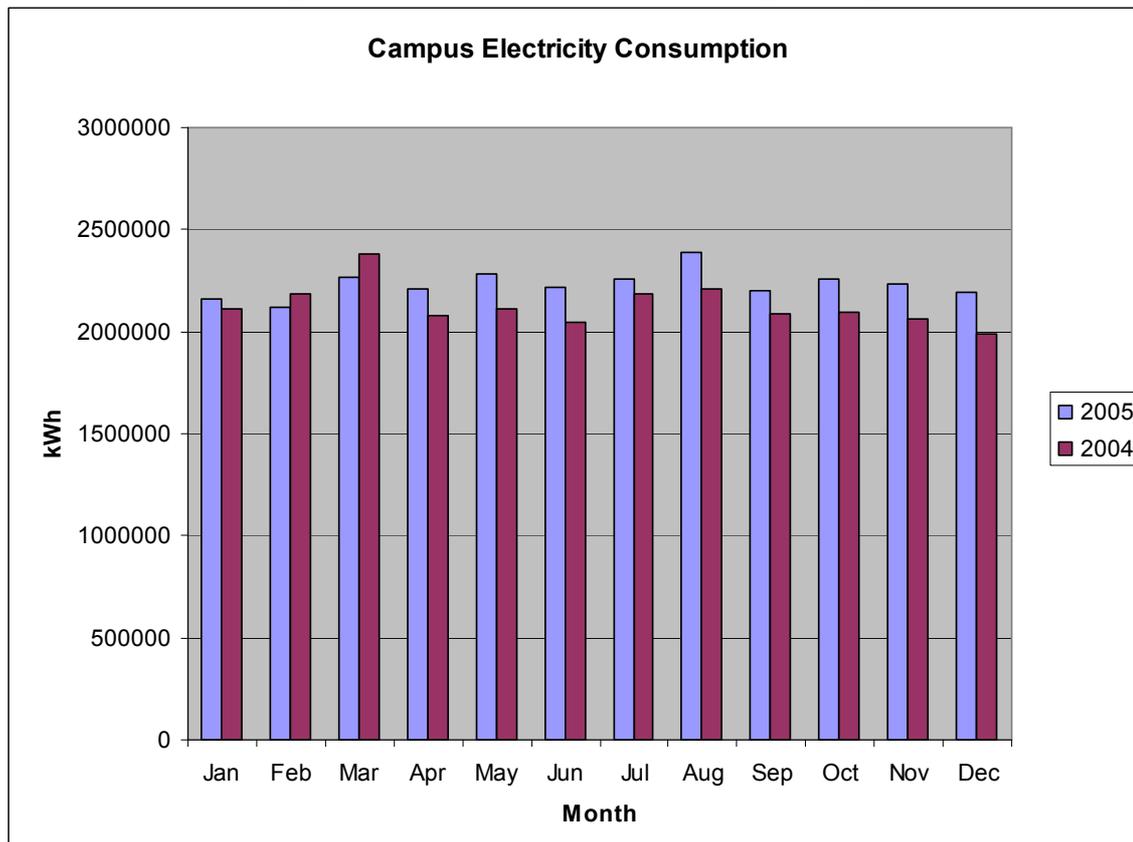


Figure 4.1: Campus monthly electricity consumption

Figure 4.2 shows monthly campus maximum demand for the 2004 and 2005 calendar years, the profiles show winter demand to be approximately 15% less than summer demand.

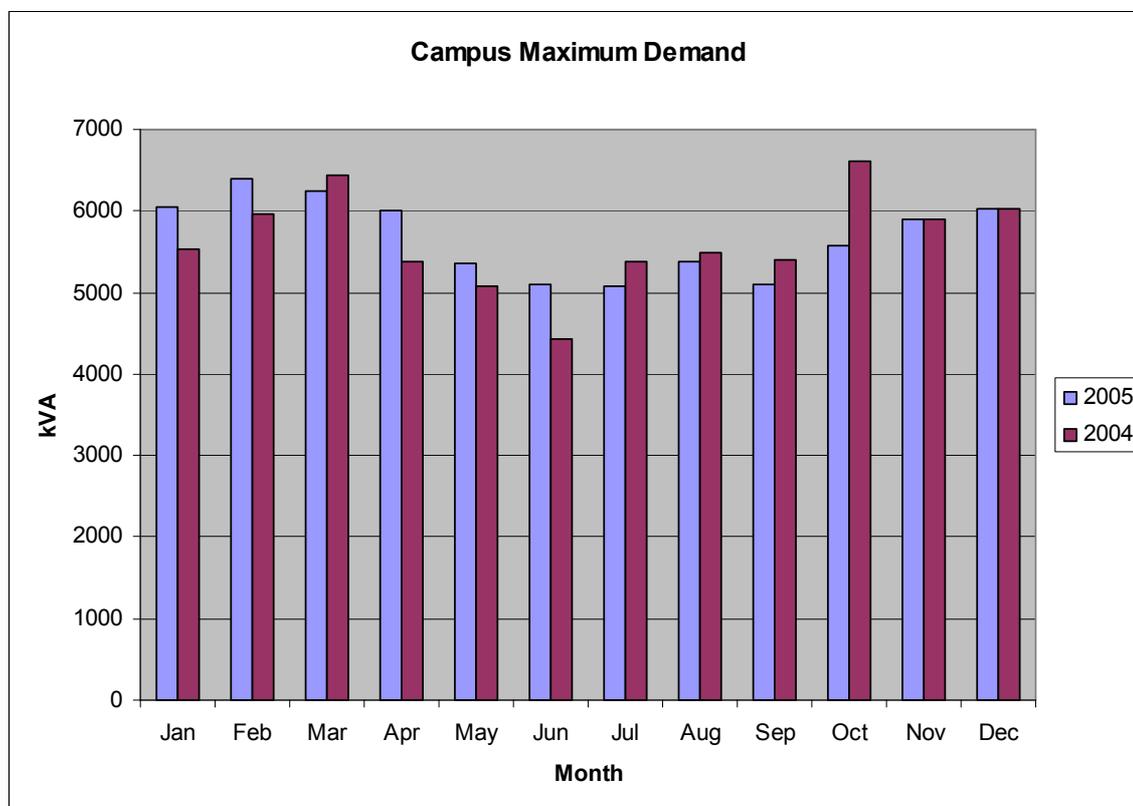


Figure 4.2: Campus monthly electricity consumption

4.3.4 Electricity Tariffs

The Main Campus has ten supplies which are billed under a contestable time of use demand based tariff, the average cost of electricity for these supplies during 2005 was 7.4 cents per kWh, this was 2% higher than the average cost of electricity for the 2004 calendar year. Figure 4.3 shows the rates paid for electricity by a range of consumers of comparable consumption level to those of the University. The graph shows that the rates charged to the University are on the low end of the range.

No additional green energy is purchased by the site above the that relating to compulsory charges passed on by the retailer for RECs and NGACs.

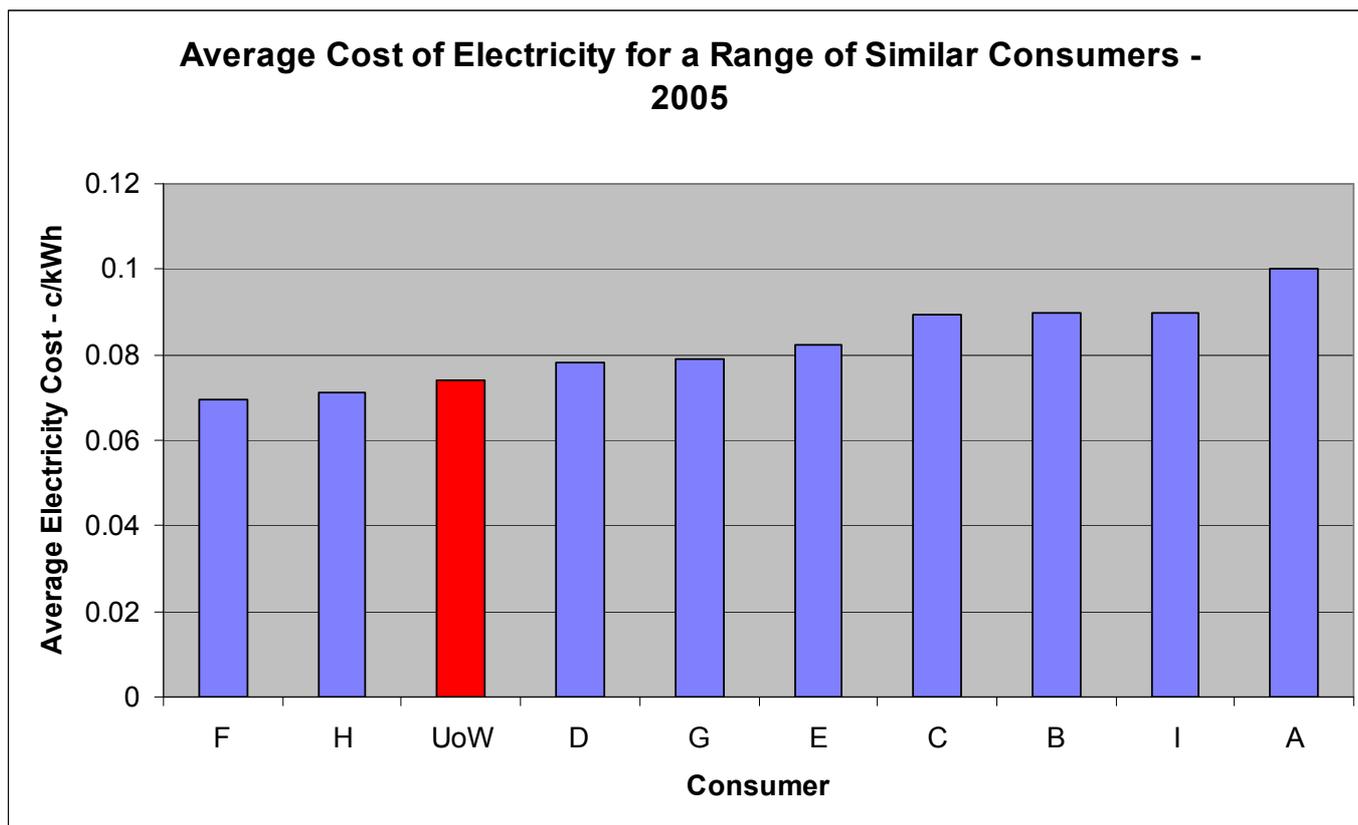


Figure 4.3: Comparison of Average Cost of Electricity for a Range of Similar Consumers

It should be noted that Figure 4.3 is an indicative price comparison only as the prices do not cover exactly the same period, location, level of activity or consumption patterns. The two sites showing lower rates of electricity consist of a research centre and a major commercial building of lower total electricity consumption. The sites with higher costs include one university and several commercial buildings all of which have lower consumption compared to UoW.

4.4. Natural Gas

4.4.1 General Description

The main campus is supplied by natural gas from a single meter located at the rear of Building 31 and reticulated via a ring main to buildings within the university ring road. The Graduate House accommodation complex is supplied by a separate meter.

4.4.2 Natural Consumption, Cost and Performance

The natural gas consumption for the calendar year 2005 was 23,492 GJ and corresponds to Greenhouse gas emissions equivalent to 1,675 tonnes of Carbon Dioxide.

Table 4.5 provides a comparison of annual natural gas consumption, cost and performance for the 2004 and 2005 calendar years. It shows that natural gas consumption increased by 9% and the gas

consumption index in MJ/m² increased by 10%. The gas MJ/EFTS index increased by 22% in association with a decrease in EFTS enrolments of 10%.

The average cost of natural gas for the campus for the 2005 calendar year was \$5.48/GJ, due to the consumption based tariff the lowest price was \$4.32/GJ in July and the highest \$11.75/GJ in January.

Table 4.5: Comparison of Natural Gas Consumption, Cost and Performance

Year	Energy Source	Total Consumption (GJ)	Annual Cost (\$)	MJ/m ²	MJ/EFT Student	Tonnes of CO ₂
2004	Natural gas	21,481	136,016	126	1,189	1,532
2005	Natural gas	23,492	130,033	138	1,452	1,675

4.4.2 Seasonal Patterns of Natural Gas Use

Figure 4.4 shows monthly campus natural gas consumption for the 2004 and 2005 calendar years. The profiles show increased consumption during cooler months due to heating systems and increased consumption during 2005 compared with 2004 after April 2005.

The reason for the increased consumption level after April 2005 has not been established, it is not due to the commissioning of new or the refurbishment of existing buildings.

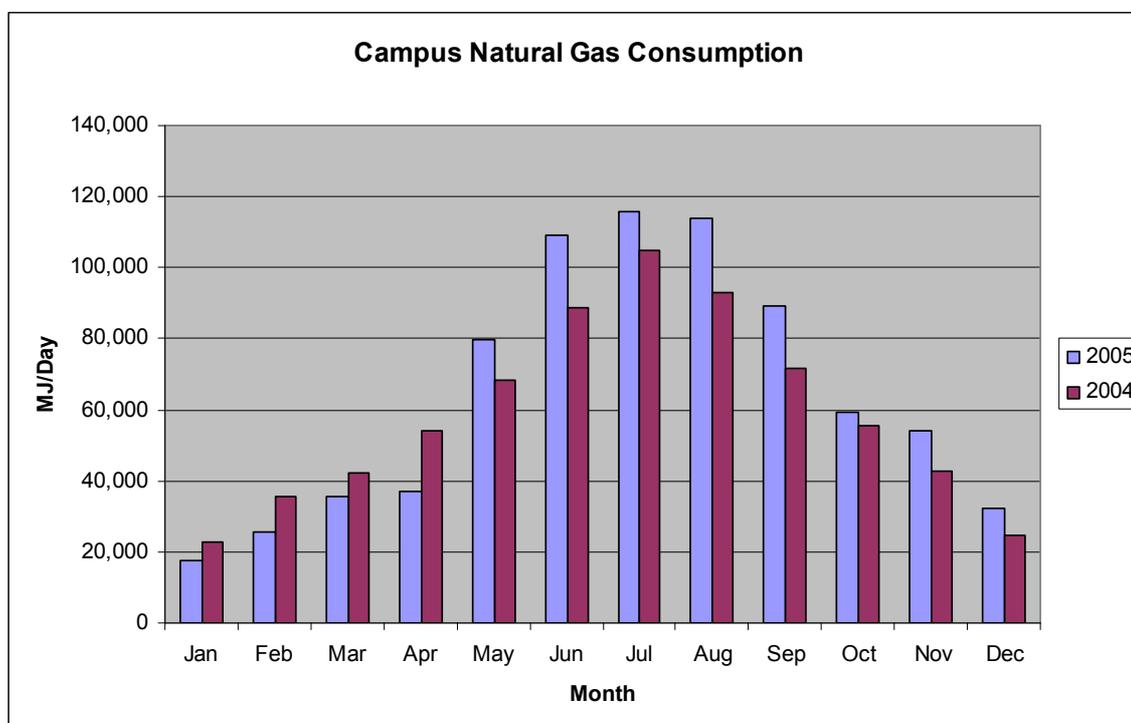


Figure 4.4: Campus monthly natural gas consumption

4.4.3 Daily Patterns of Natural Gas Use

Figure 4.5 shows campus daily natural gas consumption for January and July 2006. The profiles show no substantial difference in gas consumption from a weekend to a weekday indicating that systems are operating when not required on weekends. This substantiates findings in the individual building reports of boilers operating on a 24 hour basis 7 days a week during winter.

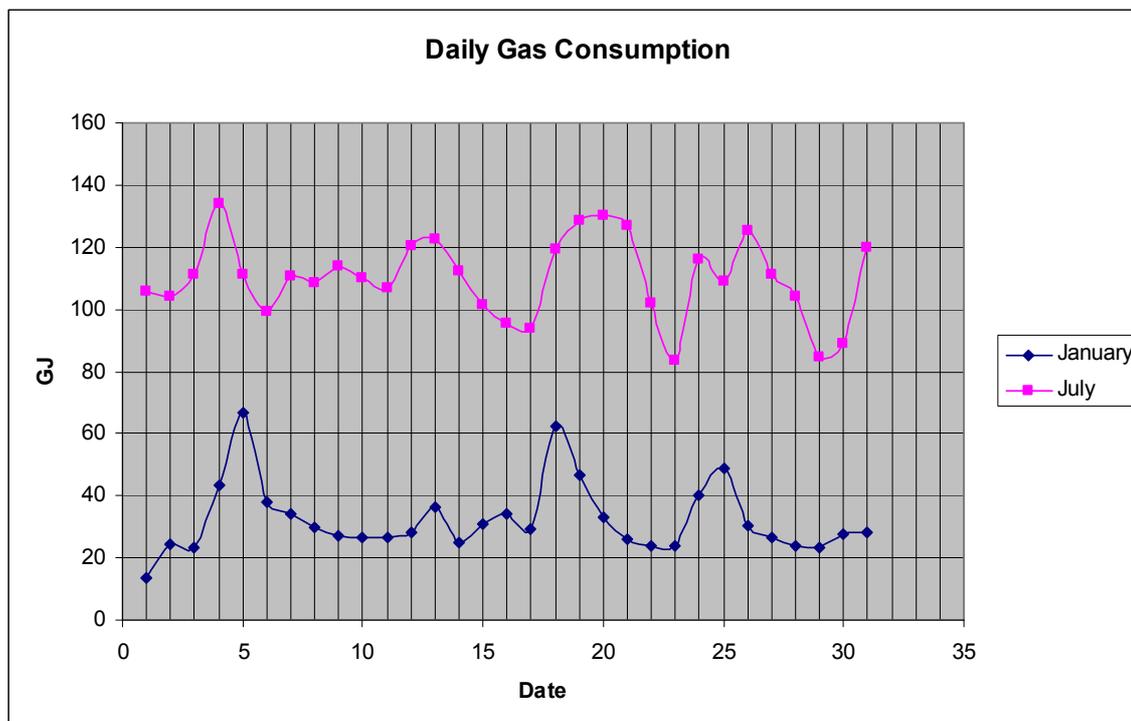


Figure 4.5: Summer and Winter Daily Gas Consumption

4.4.4 Natural Gas Tariffs

The price of gas is based on a variable consumption based component, a monthly fixed cost component and a network cost component, consequently the average cost of gas is lower during periods of higher consumption. Figure 4.6 shows the rates paid for gas by a range of consumers of comparable consumption level to the University. The graph shows that the rates charged to the University are on the lowest end of the range.

The university negotiated a new gas supply contract in late 2006.

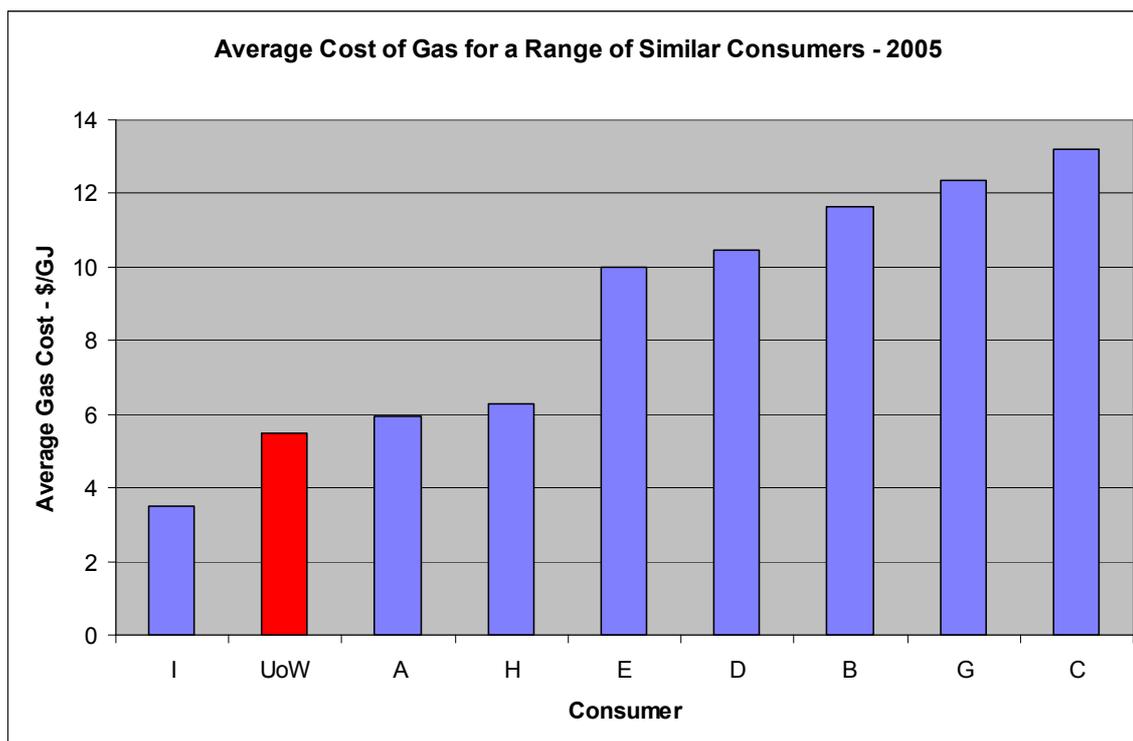


Figure 4.6: Comparison of Average Cost of Natural Gas for a Range of Similar Consumers

It should be noted that Figure 4.3 is an indicative price comparison only as the prices do not cover exactly the same period, location, level of activity or consumption patterns. The site showing lower cost is a university with consumption levels approximately 6 times those of UoW. The two sites showing costs of around \$6 per GJ comprise a research centre and a major commercial building, one with higher consumption and one much lower than UoW. The remainder of the sites are major commercial buildings.

4.5. Breakdown of Energy Use and Application

4.5.1 Energy Use by Building and Energy Source

Figure 4.7 shows the estimated energy consumption for each of the audited buildings by energy source. These consumption levels were derived by a combination of metering data, site observations, measurements and modelling using EMET's diagnostic and modelling programs, as noted in the Methodology clauses.

The largest consumer is Building 39 followed by Building 16 and Building 13. Building 13 is also estimated to be the larger consumer of natural gas.

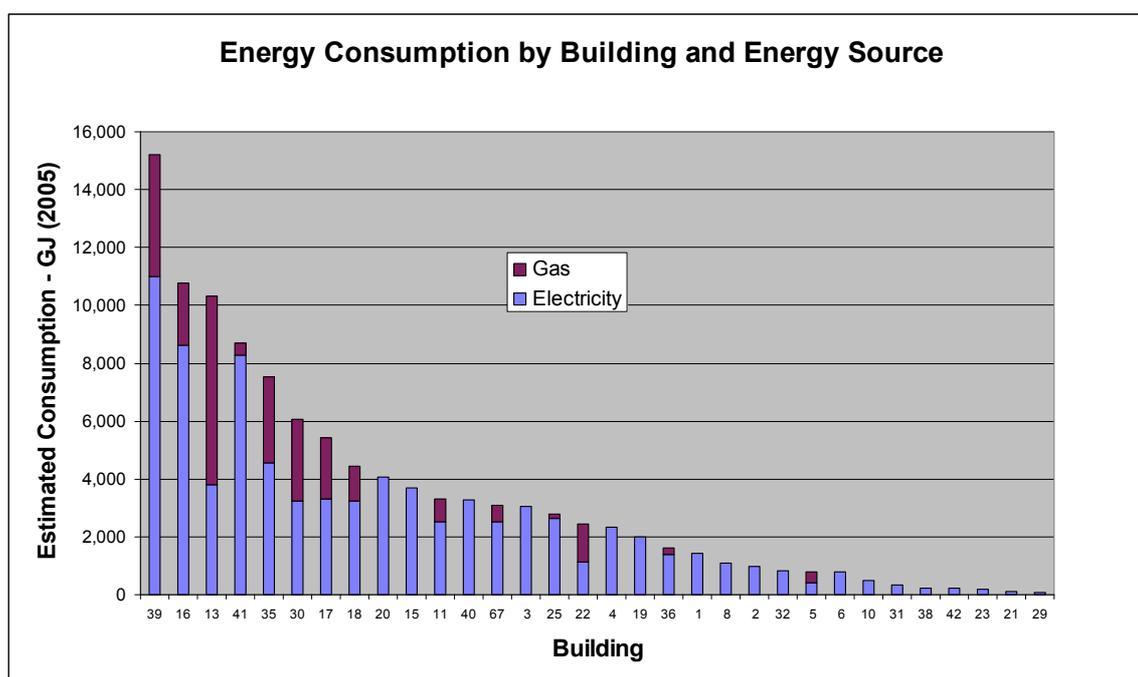


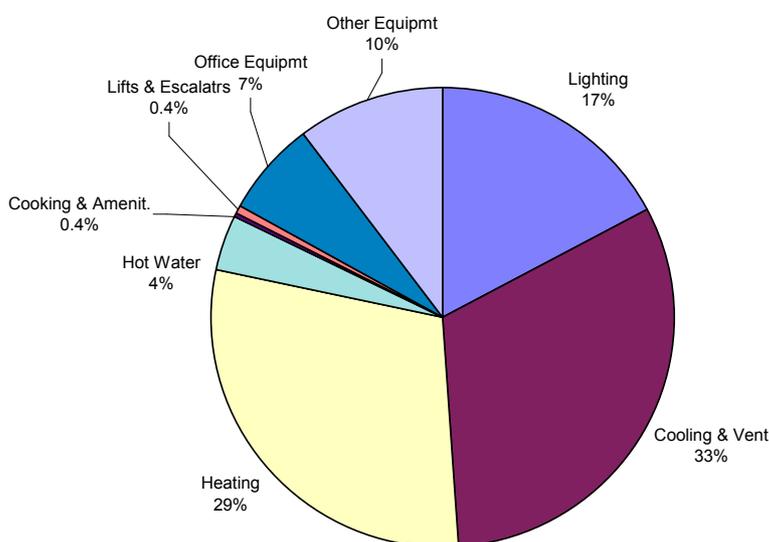
Figure 4.7: Estimated Energy Consumption by Building and Energy Source

4.5.2 Energy Use by Application

The breakdown of energy consumption and cost by application is shown in Table 4.6 and Figure 4.7. These show the most significant applications of energy across the site to be Heating, Cooling and Ventilation, Lighting and Other Equipment. The latter comprises a multitude of laboratory equipment and other specialist equipment generally related to the teaching and research activities in the buildings and generally activated manually by occupants. Office equipment and hot water delivery also constitute significant loads.

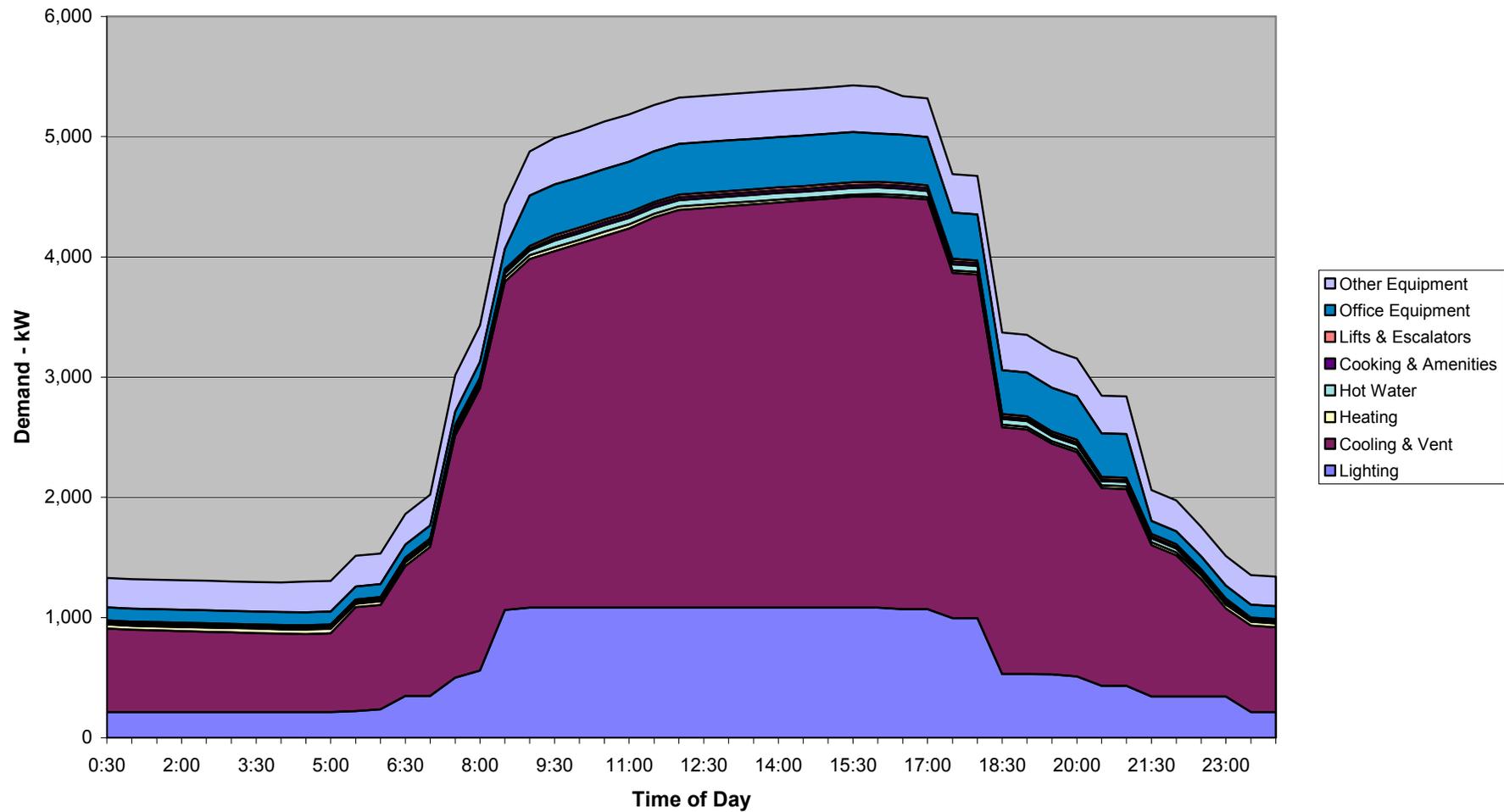
Table 4.6 - Estimated Energy Consumption, Performance and Cost by Application

Location	APPLICATION								
	Lighting	Cooling & Vent	Heating	Hot Water	Cooking & Amenit.	Lifts & Escal	Office Equipmt	Other Equipmt	Total
Consumption GJ pa	18,207	33,713	31,274	3,926	398	411	7,170	10,925	106,024
Performance MJ/m2 pa	112	208	193	24	2	3	44	67	654
Cost \$ pa	381,414	706,271	344,046	35,481	8,339	8,613	150,201	227,090	1,861,454

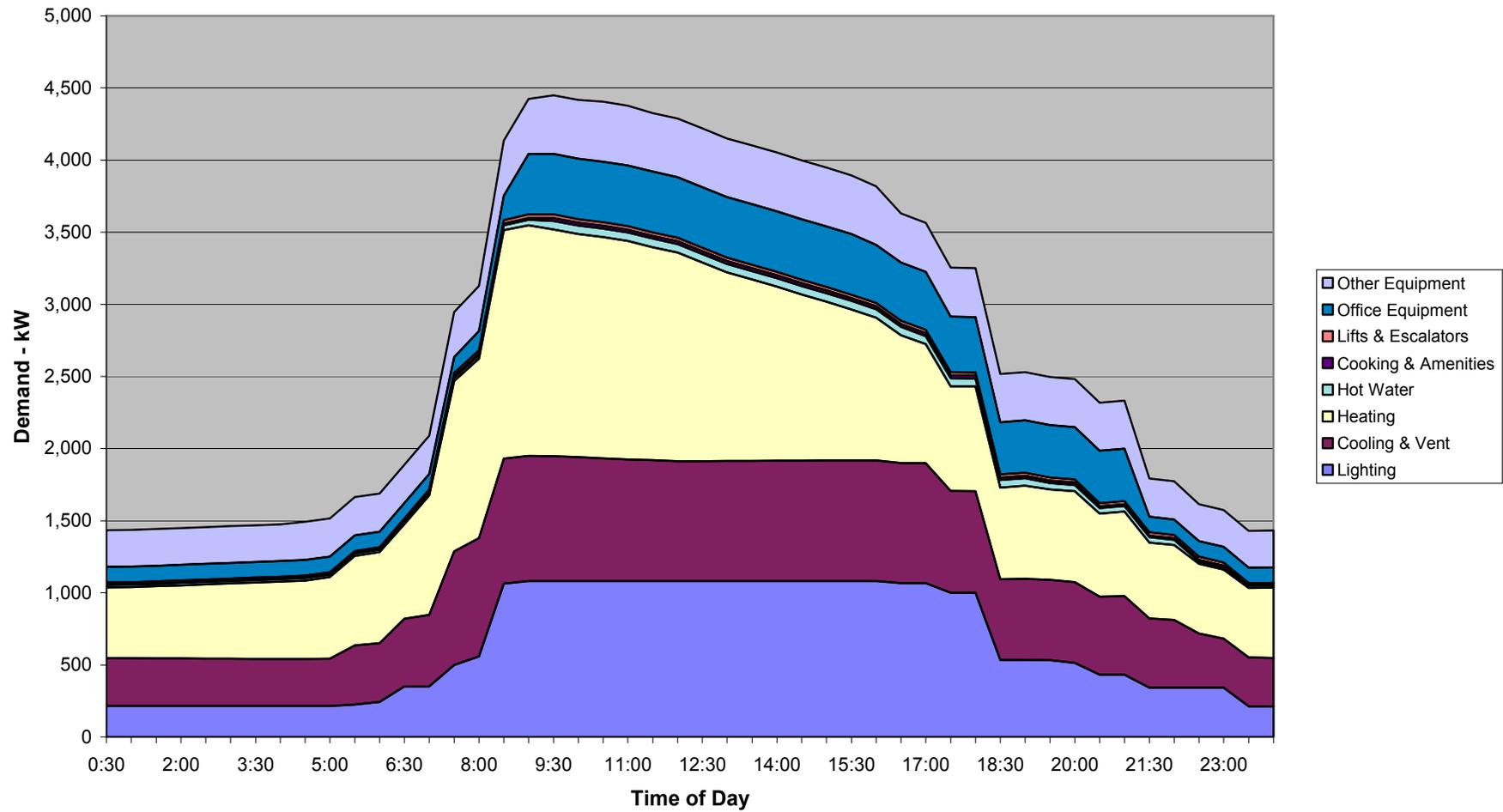
Breakdown of Total Energy Use by Application**Figure 4.7 – Breakdown of Total Energy Use by Application**

Figures 4.8 and 4.9 show the simulated breakdown of the weekday electrical demand under peak Summer and Winter conditions respectively. The patterns show the major loads to be heating, cooling and ventilation systems and lighting. It should be noted that the charts show the typical demand patterns during Summer and Winter, with peak demand levels reached on days of extreme weather and/or activity.

Simulated Electricity Demand Profile - Peak Summer Day

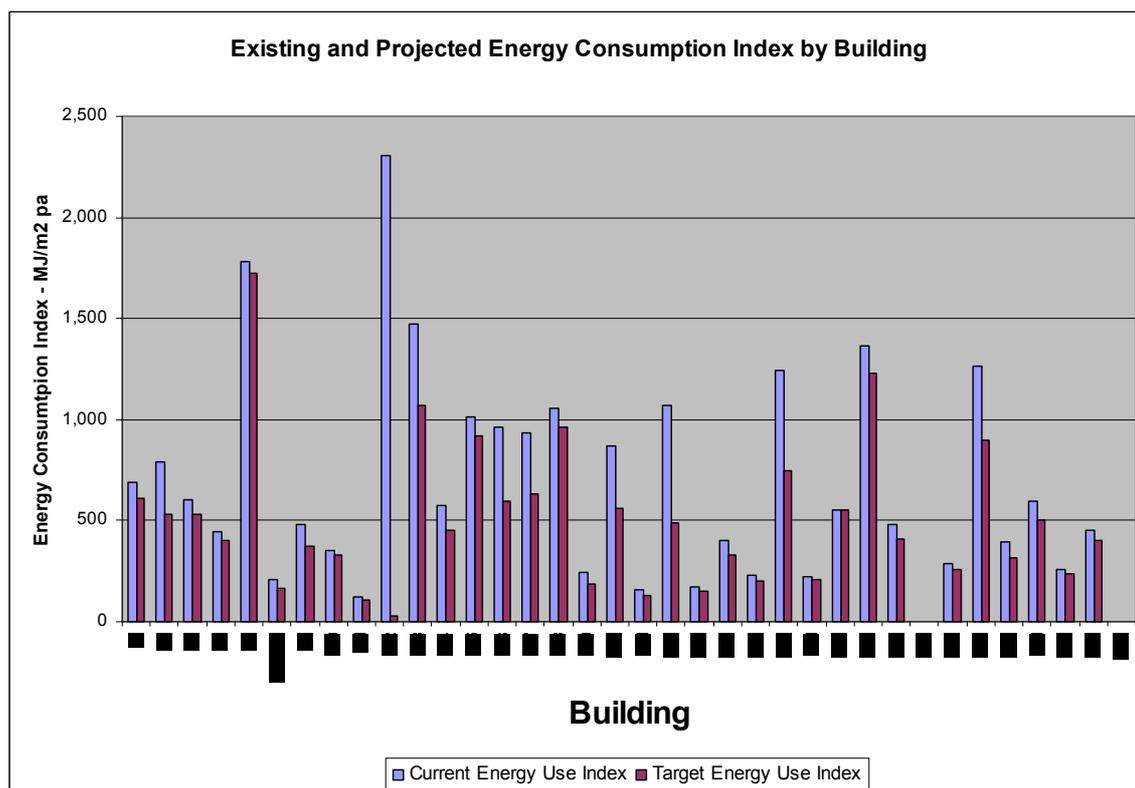


Simulated Electricity Demand Profile - Peak Winter Day



4.6. Energy Performance Benchmarks and Targets

The average energy use index for the audited buildings for their estimated 2005 consumption was 640 MJ/m² per annum. It is estimated that this index would be reduced to 456 MJ/m² per annum after the implementation of all of the energy management initiatives identified in the energy audit. Figure 4.10 shows the current energy use index by building as well as the projected index (target) following the identification of the energy initiatives identified. Note that some buildings, such as building 12 contain recommendations for metering and subtracting energy consumption for which the University is not responsible or not under its control.



Notes: B 12 - The major reduction shown is due to the repair of a major gas leak and the metering and hand-over of substantial electricity consumption related to the tenant.
 B 22 - Substantial reduction is due to changes to the operations of HVAC systems
 B 30 - Substantial reduction is due to changes to the operations of HVAC systems
 (Refer to individual building reports for details)

Figure 4.10: Current and Target Energy Consumption Index by Building

Table 4.7 shows a breakdown of this energy target by energy source and application, based on the results of this audit. The figures show the most significant improvement potential to be in the Heating, Cooling and Ventilation systems and Office Equipment.

Table 4.7: Target Energy Consumption by Application

APPLICATION	Energy Source	Annual Consumption		Annual Cost (\$pa)	Perform. Index (MJ/m ²)	Proportion of Total Energy Consumption (%)
		(kWh)	(GJ)			
Lighting	Electricity	5,419,088	19,509	\$408,693	120	23%
Cooling and Ventilation	Electricity	8,181,651	29,454	\$617,038	182	34%
Heating	Electricity	1,869,122	6,729	\$140,964	41	8%
Heating	Gas		9,891	\$54,198	61	11%
Amenities	Electricity	133,762	482	\$10,088	3	1%
Lifts & Escalators	Electricity	47,134	170	\$3,555	1	0%
Office Equipment	Electricity	1,702,025	6,127	\$128,362	38	7%
Other Equipment	Electricity	3,192,233	11,492	\$240,749	71	13%
Hot Water	Electricity	218,254	786	\$16,460	5	1%
Hot Water	Gas		1,894	\$10,381	12	2%
Total		20,763,270	86,533	\$1,620,107	534	100%

Notes: (1) The costs shown are calculated on an average cost of electricity and gas as noted under methodology

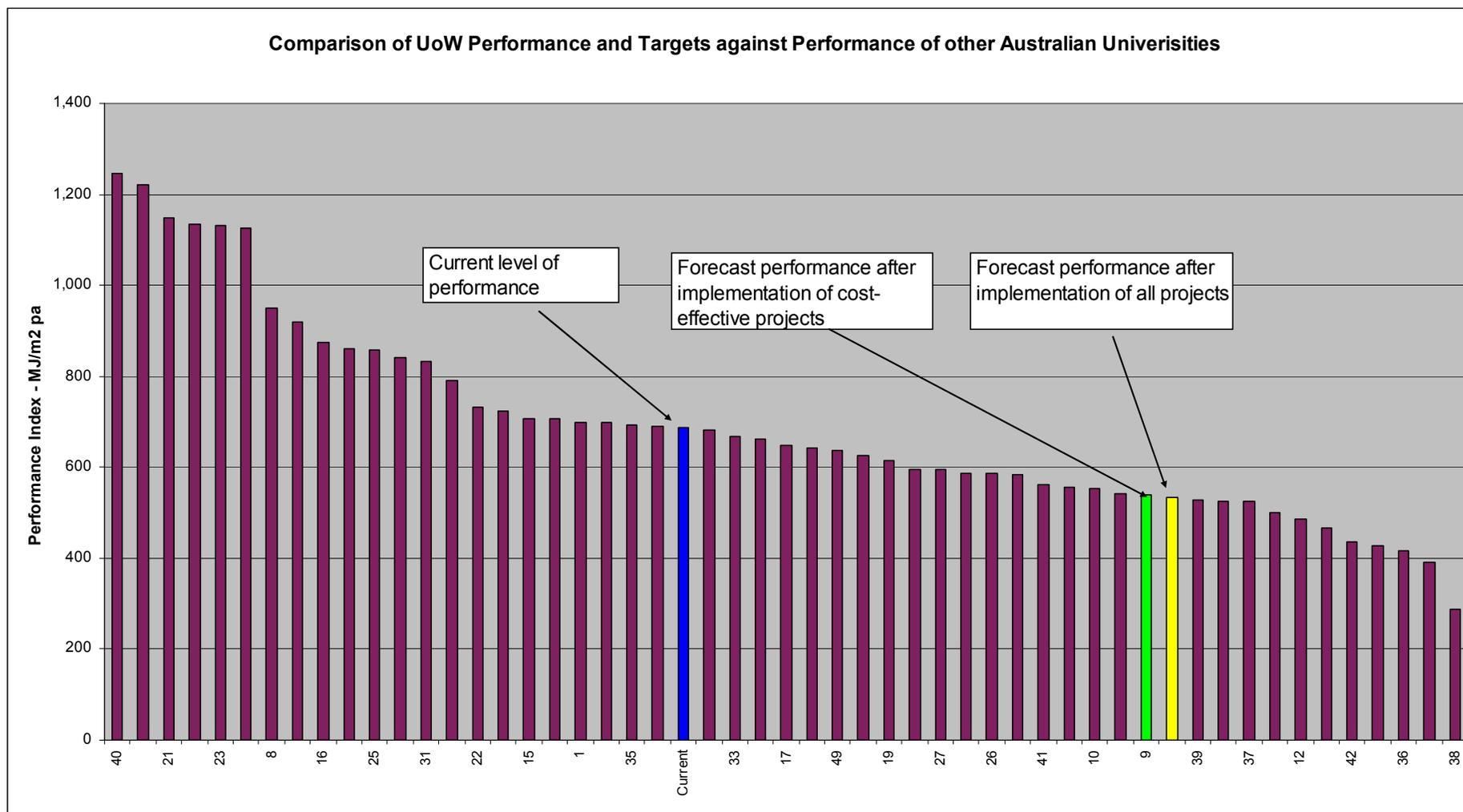
(2) Numbers do not necessarily add due to rounding off

Based on the current building types and the extent of operations carried out within the buildings, the target energy performance levels for the University are as follows:

- Current Performance - 687 MJ/m²
- Following the implementation of all projects within the University hurdle rate - 543 MJ/m²
- Following the implementation of all identified projects - 534 MJ/m²

The above levels are shown in Figure 4.11 together with the 2004 performance levels for other Australian Universities.

Note that the above targets do not represent the best practice level of performance which could only be achieved in the long term following major refurbishments of systems and services as new buildings and plant are brought on line. This performance level, based on the current level of operations and services provided is approximately 425 MJ/m².



Source: Other University data – Tertiary Education Facilities Management Association – 2004 Benchmark report

Figure 4.11: Comparison of Current and Forecast UoW performance Indexes against other universities current performance

5. Analysis of Energy Systems and Estimated Savings Potential ^{1 2}

5.1. Overview of Energy Savings Identified

The audit of the main campus of the University identified energy efficiency cost savings worth approximately \$419,000 per annum including some minor maintenance savings due to reduced operation of systems. These savings represent approximately 25% of the energy used by the audited buildings. Approximately 94% of the above savings fall within the University's financial hurdle rate of 7% (IRR), at an estimated cost of approximately \$1,070,000. The remaining 6% are estimated to cost more than \$716,000 to produce the estimated annual cost savings of approximately \$36,200. Table 5.1 shows a breakdown of costs and savings falling within and outside the University's hurdle rate.

Table 5.1: Summary of Identified Energy Saving Projects

Internal Rate of Return (IRR)	Implement Cost	Savings					Combined Payback
		Energy Costs	Maintenance Costs	Energy	% of tot Energy	Emissions	
		\$ pa	\$ pa	GJ pa		T CO2-e	
	\$						yrs
Better than 7%	1,070,798	371,320	11,125	24,497	23%	4,717	2.8
Less than 7%	715,920	33,082	3,127	1,620	2%	1,620	19.8
Total	1,786,718	404,402	14,252	26,117	25%	6,337	4.3

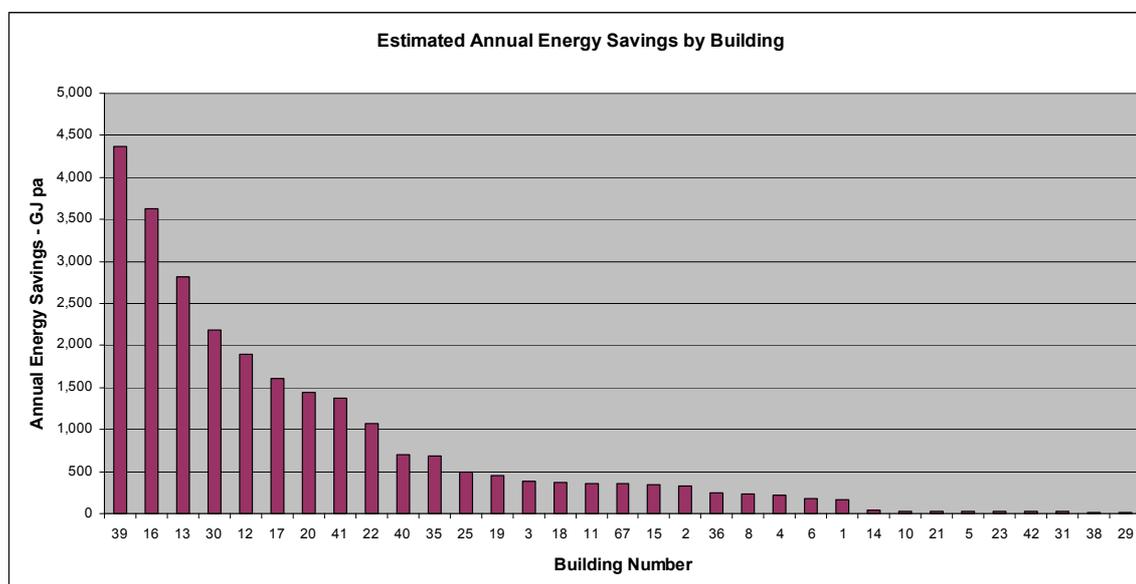


Figure 5.1: Estimated Annual Energy Savings by Building

¹ All savings and costs quoted in this report are ex-GST

² Implementation costs shown are budget estimates only. They include an allowance for the typical engineering costs involved in fully scoping and documenting the works however, this cost will depend on the complexity of the specific installation and the amount of documentation available and will therefore vary with each case

Figure 5.1 (previous page) and Table 5.2 (below) show the identified energy savings for each audited building. These the buildings with the highest potential to be buildings 39, 16, 13, 30, 12, 17, 20, 41, 22, 40 and 35, which together represent more than 80% of the identified savings. These form the group of priority buildings. Power factor correction works (PFC) are not shown on the Figure 5.1 as they do not produce direct energy savings however they represent 4.3% of estimated total cost savings and are included as a site-wide initiative in table 5.2.

Table 5.2: Estimated Annual Energy Savings by Building

Building	Implement Cost	Savings					Payback yrs
		Energy Costs	Maintenance Costs	Energy	% of tot Energy	Emission s	
	\$	\$ pa	\$ pa	GJ pa		T CO2-e	
1	18,508	3,458	291	165	11.6%	45	4.9
2	35,800	6,486	0	324	32.9%	89	5.5
3	55,026	8,025	1,023	383	12.8%	105	6.1
4	35,017	4,227	721	221	9.4%	60	7.1
5	650	179	0	26	3.2%	3	3.6
6	66,310	3,655	96	181	22.9%	50	17.7
8	500	4,851	892	240	21.7%	66	0.1
10	2,700	506	0	28	5.9%	8	5.3
11	32,520	6,665	12	362	10.9%	87	4.9
12	10,250	37,665	0	1,889	98.8%	492	0.3
13	114,016	21,132	95	2,810	27.3%	286	5.4
14	5,750	680	0	45	21.8%	12	8.5
15	62,060	7,023	623	337	9.2%	92	8.1
16	361,120	59,096	4,475	3,625	37.8%	830	5.7
17	31,700	23,781	0	1,608	32.3%	310	1.3
18	19,854	4,922	17	377	8.9%	68	4.0
19	126,414	9,457	1,014	453	22.7%	124	12.1
20	86,925	30,373	-70	1,437	35.4%	393	2.9
21	3,300	561	118	27	21.4%	7	4.9
22	32,700	12,686	-3	1,077	54.4%	166	2.6
23	2,650	461	-1	22	12.8%	6	5.8
25	42,550	8,495	322	492	17.8%	118	4.8
29	2,400	160	0	8	11.7%	2	15.0
30	40,450	26,269	145	2,189	39.7%	343	1.5
31	3,050	426	6	21	6.4%	6	7.1
35	28,500	7,422	544	693	10.0%	97	3.6
36	26,916	3,840	629	252	15.4%	50	6.0
38	2,950	421	0	20	8.5%	6	7.0
39	153,688	49,465	2,107	4,370	28.7%	647	3.0
40	112,370	14,578	1,182	697	21.4%	191	7.1
41	122,550	24,927	0	1,367	15.7%	329	4.9
42	4,550	403	15	21	9.0%	6	10.9
67	44,000	4,333	0	359	11.6%	58	10.2
Total for Buildings	1,687,743	386,628	14,252	26,128	24.6%	5,152	4.2
PFC	99,375	18,006	0	484 kVA	n/a	0	5.5
Grand Total	1,787,118	404,634	14,252	26,128	24.6%	5,152	4.3

A breakdown of the major applications of energy use expected to produce the estimated energy savings is shown in Table 5.3. Heating, Ventilation and Air Conditioning (HVAC) systems represent the largest component of energy savings at 73% of the total. This category includes comfort cooling and heating systems as well as process cooling and heating provided for specialised equipment and locations as well as specialised ventilation for areas such as laboratories.

The next major area of potential savings is Utilities which includes the metering and subtraction of energy provided to tenants, for which the University has no control, as well as the repair to a major gas leak which existed during the base year. Savings shown against Office and Other relate to improved awareness to the proper operation of systems and equipment by occupants, as well as the activation of built-in energy saver features on equipment. The remainder of savings relate to Power Factor Correction (PFC) works, and the improvement of the efficiency and operation of Pool systems, Domestic Hot Water and other staff (and occupant) amenities and Lighting systems.

Table 5.3: Sources of Energy Savings Potential by Application

Building	Implement Cost	Savings					Payback yrs
		Energy Costs	Maintenance Costs	Energy	% of tot Energy	Emission s	
	\$	\$ pa	\$ pa	GJ pa		T CO2-e	
Heating, ventilation and air conditioning	1,154,480	282,039	1,847	18,921	17.8%	3,753	4.1
Utilities	10,000	37,587	0	1,879	1.8%	491	0.3
Pool	40,930	12,224	0	1,565	1.5%	159	3.3
Domestic Hot Water and Staff Amenities	86,985	11,730	0	1,622	1.5%	163	7.4
Lighting	395,347	33,048	12,405	1,663	1.6%	455	8.7
Office	Nil	9,891	0	472	0.4%	129	immediate
Other	Nil	110	0	5	0.0%	1	immediate
PFC	99,375	18,006	0	484 kVA	n/a	0	5.5
Total	1,787,118	404,634	14,252	26,128	24.6%	5,152	4.3

Refer to the next sections for a more detailed analysis of the types of initiatives identified for each of the above areas of energy saving potential, as well as Appendix 2 for a detailed list of recommendations resulting from this energy audit.

5.2. Energy Saving Issues and Initiatives

This energy audit has identified a number of initiatives and issues, both technical and procedural, which are sources of energy losses or inefficiencies. These are discussed below, together with recommended actions and estimated savings.

It should be noted that the University is in the process of addressing many of these issues by commissioning the following standards, which are currently being finalised:

- Building Monitoring and Control Systems Design Standards
- Building Monitoring and Control Systems Commissioning Procedures & Schedules
- Mechanical Services Design Standards
- Mechanical Services Commissioning Standard
- Electrical Services design Standard
- Energy and Demand Management Standards for the Design Process

The following clauses address each of the major issues and areas of opportunities identified. The site's Building Management System is discussed separately as it is a major influence over many systems and services and has the opportunity to provide a substantial component of the savings and also assist in the monitoring and management of the energy management program of the site.

5.2.1. Building Management System (BMS)

The site has a BMS that currently serves 18 buildings to principally provide Heating Ventilation and Air Conditioning system monitoring and control, in some cases the BMS also provides lighting control and electrical meter monitoring. Table 5.4 provides a summary of buildings served by the BMS and their features.

In some cases the BMS only serves part of the building or only provides time of day control to air conditioning systems with local proprietary controls.

There are 15 larger buildings that are not served by the BMS. These buildings mostly have no air conditioning. In cases where air conditioning is installed, it is controlled by time clocks, timers or local on/off control.

The BMS installed at the site is a Siemens Apogee System which has expanded as new buildings and refurbishments have required BMS control.

Table 5.4: Summary of Building BMS Features

Building		Features				Comments
Number	Description	HVAC Monitoring & Control	Laboratory Ventilation Monitoring & Control	External Lighting Control	Electricity Metering	
1	Materials Engineering	Yes	Yes	No	No	
3	Informatics	Yes	No	Yes	No	
5	Animal House	Yes	No	Yes	No	
8	Mechanical Engineering					Scheduled for refurbishment, to include BMS
11	Uni Centre	Yes	No	No	No	Auditorium only, remainder time clocks
14	Central Lecture Theatre	Yes	No	No	No	
15	Austin Keane Building	Yes	Yes	No	No	
16	Michael Birt Library	Yes	No	No	Yes	
17	IT Resource Centre	Yes	No	No	No	
18	The Halpern Chemistry Building	Yes	Yes	No	No	Top floor to have HVAC added, BMS to be considered
20	Communications Centre	Yes	No	No	No	Office areas time clock controlled
22	Education & Clinic Building	Yes	No	No	No	
25	Creative Arts	Yes	No	No	No	
30	WUC/AEC	Yes	No	No	No	
35	Biology/Informatics	Scheduled	Check scheduled	No	No	North Wing to be upgraded to BMS control, remainder time clocks which should be considered for BMS control
36	Administration	Yes	No	No	No	
38	Graduate School of Business	No	No	No	No	Scheduled for refurbishment, to include BMS
39	Illawarra Technology Centre	Yes	No	No	No	BMS control of stage 2 and 3 only, stage 1 recommended
40	Commerce/Hope Theatre	Yes	No	No	No	BMS control of Hope Theatre only, BMS control of centralised proprietary controllers recommended
41	The Sciences Building	Yes	No	No	No	BMS control of Stage 2, stage 3 and CT scanner, Anatomy lab upgrade to include BMS.
67	The McKinnon Building	Yes	No	No	No	BMS control of central plant and R 104 and 107 only.

i) BMS documentation

The BMS installation has expanded over time as new buildings and refurbishments requiring BMS control have proceeded. During this expansion the documentation on the systems installed has tended to be generic and lacking in details on the specifics of the control algorithms, how the system is setup and what features are enabled. Further, operator access is limited to an extent that it is necessary to request the BMS service contractor to access the software to determine relatively basic information such as temperature control, dead band settings or if features such as night purge are enabled. It is understood that these requests for information are at the university's cost.

ii) Commissioning

The BMS documentation does not always reflect the system installed and can reflect the system that was offered rather than that which has been installed, in some cases there is no documentation, only a reference in the time of day schedule. To establish what actually has been installed would require the software to be analysed by the BMS service provider as outlined in item i) above.

During the audit a number of systems were identified that were not operating correctly and appear to never have operated correctly, these include:

- Boilers and chillers operating 24 hours a day when they are not supposed to
- Economy cycles not functioning correctly
- Night purge not functioning correctly

iii) Operator interface & system management

The Building's & Grounds staff monitor the BMS on a daily basis and trend selected parameters to identify system problems which are then passed on to the BMS service provider for action.

During the audit it was found that basic parameters that would normally be accessible to the end user via the Graphical User Interface (GUI) to fine tune system and identify unsatisfactory operation were not accessible. They were only accessible within the software program by the BMS service provider.

Also, attempts to identify the cause of plant such as boilers and chillers operating 24 hours a day seven days a week when the BMS time schedules indicated that these systems should not be operating were not possible due to the lack of access to the BMS via the GUI. The BMS service provider was also not able to identify the cause of these problems from the GUI, it would be necessary to undertake an analysis of the software.

iv) Time of day control

The time of day control of HVAC plant is globally programmed for public holidays and for after hours use for special occasions. The "special occasions" function is automatically cancelled after the date of the event.

It is common practice to schedule air conditioning plant to operate from around 5am for when the cleaners commence work through to when the area is not likely to be in use and for after hours push buttons to be used outside these times.

There is no facility to globally program selected time channels for university recess which occurs approximately 76 days of the year, consequently these systems continue to operate throughout the university recess.

v) Control algorithms

Control algorithms have been duplicated across the site as new BMS installations are installed and it is presumed that this practice applies to recently commissioned buildings that are still in the warranty period.

This energy audit has identified problems with the economy cycle, night purge and night setback algorithms. Problems have also been identified with chillers and boilers operating when they are not intended to in a number of buildings.

vi) Monitoring & Verification

Good energy management practice and this energy audit recommended that energy efficiency initiatives be monitored and verified for their correct effectiveness, and that building refurbishments and new buildings should consider the improvements in energy consumption at the design stage and then monitor and verify the results after the work is commissioned and handed over.

The utilisation of the BMS for monitoring & verification is a critical part of this process.

Recommendations:

Note: The University has indicated a desire that better controls be put on service providers to improve the performance of energy systems.

Develop a strategy that enables the BMS to be better used as a management tool by university staff to improve maintenance, fine tune system operation for improved performance, monitor & verify energy efficiency improvements and reduce energy consumption. The following are key steps considered necessary to develop the above strategy. Ideally, many of the steps should involve a person technically competent to understand the system(s) being controlled in each case and the level of information and interaction required to be incorporated in the systems. It would be expected that these would involve a person/organisation not linked to the BMS contractor.

- i) Review the documentation for each building so that it reflects the current installation.
- ii) Where appropriate provide additional BMS access to university staff to enable improved system monitoring, improved fault finding, on going fine tuning and better management of service contractors.
- iii) Provide appropriate training for university staff
- iv) Implement BMS commissioning procedures
- v) Incorporate monitoring and verification of energy performance at the design stage into energy efficiency improvement projects, building refurbishments and new buildings.
- vi) Revise BMS time of day control to allow global scheduling of university recess days for student accessed areas, alternatively link the Cardax system for common teaching areas to the BMS to control plant dedicated to common teaching areas.
- vii) Implement optimum start/stop strategies and set the time of day schedules to core occupancy times (typically 8am to 6pm for office areas), not cleaning periods, and utilise after hours push buttons outside core hours. For student accessed areas university recess should be considered as outside core hours unless programmed for special occasions which are automatically cancelled after the date of the event.
- viii) Modify control algorithms as recommended in this report, refer Section 5.2.2, and ensure that building design guidelines are updated.
- ix) Implement a request tracking system to monitor the progress of requests made to the BMS contractor; and a performance tracking system to measure the effectiveness of the BMS contractor.

5.2.2. Heating, Ventilation and Air Conditioning (HVAC) Systems

The building's HVAC systems are estimated to consume approximately 11,200 MWh of electricity and 14,000 GJ of gas at a total cost of approximately \$923,000 per annum and have an energy utilisation index of 335 MJ/m² per annum. This overall consumption index shows a high level of energy use for the types and extent of systems employed on the site.

Table 5.4 - Estimated Energy Use and Cost by HVAC Systems

APPLICATION	Energy Source	Annual Consumption		Annual Cost (\$pa)	Perform. Index (MJ/m ²)	Proportion of Total Energy (%)
		(kWh)	(GJ)			
Cooling and Ventilation	Electricity	8,173,084	29,423	616,392	181	28%
Heating	Electricity	3,046,709	10,968	229,774	68	10%
Heating	Gas		14,010	76,770	86	13%
Total		11,219,792	54,401	\$922,936	335	51%

The energy audit identified energy efficiency cost savings for the HVAC systems as being worth approximately \$284,000 per annum including some minor maintenance savings due to reduced operation of systems. These savings represent approximately 18% of the energy used by the audited buildings. Approximately 95% of the above savings fall within the University's financial hurdle rate of 7% (IRR), at an estimated cost of approximately \$703,000. Table 5.5 shows a breakdown of costs and savings falling within and outside the University's hurdle rate. A full list of identified energy management projects for each building is included in Appendix 2.

Table 5.5 - Summary of Costs and Savings - HVAC Initiatives

IRR	Implement Cost	Savings				
		Energy Costs	Maintenance Costs	Energy	% of tot Energy	Emissions
		\$ pa	\$ pa	GJ pa		T CO ₂ -e
Better than 7%	702,930	262,512	1,847	17,917	17%	3,490
Less than 7%	451,550	19,526	0	1,004	1%	263
Total	1,154,480	282,039	1,847	18,921	18%	3,753

Figure 5.2 shows a breakdown of the above energy savings amongst the major categories of initiatives. It should be noted that these are broad categories which often overlap (ie. an initiative may incorporate items of more than one category). Also Table 5.6 provides an overview of the type of HVAC energy management actions identified for each building.

Refer to the itemised list of initiatives in Appendix 2 and to individual building reports for further information.

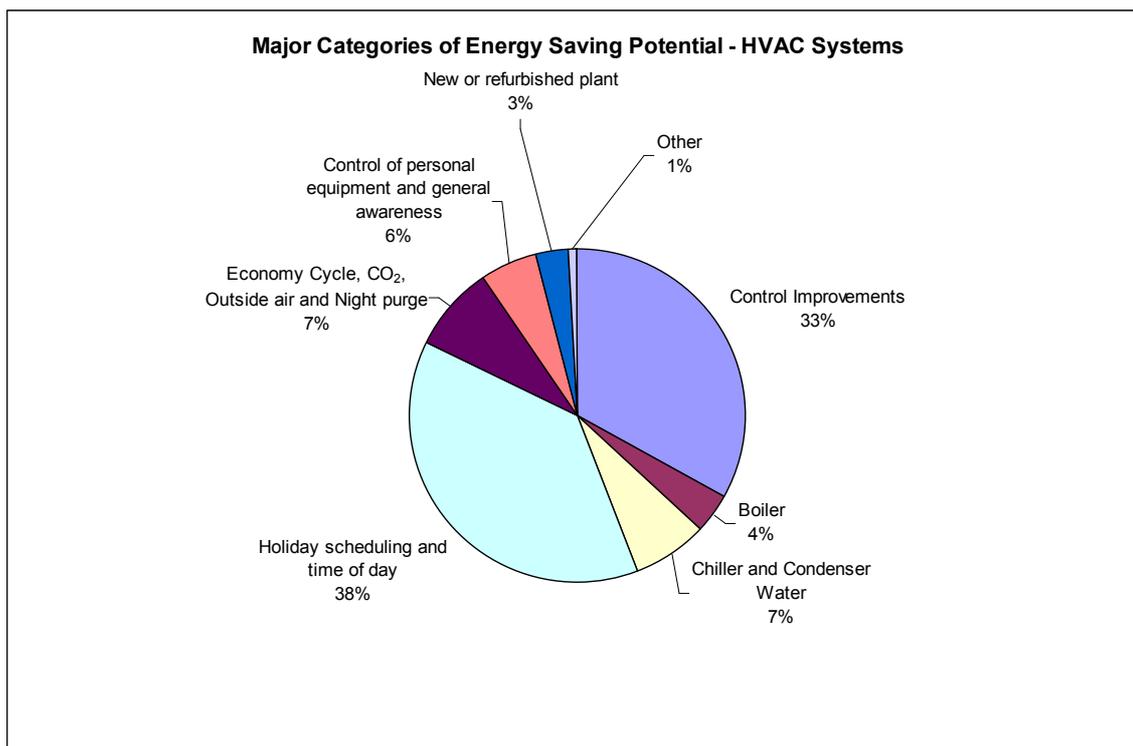


Figure 5.2: Major Categories of Energy Saving Potential – HVAC Systems

The major categories identified in figure 5.2 include:

- The improved control of operating times of plant through holiday scheduling, time of day control etc;
- Improvements to the controls which activate or operate the plant including adjustments to operating parameters, automatic (de)-activation, fine tuning etc;
- The application of improved or expansion to the use of economy cycles, outside air control, night purging functions etc;
- Specific Chiller, Boiler and Condenser system improvements;
- Better control of systems operated by occupants through awareness and additional controls;
- Other functions.

Table 5.6: Energy Efficiency Project Type for each building

Building		BMS	Energy Efficiency Opportunities												
No.	Description		BMS time of day schedule	Optimum start/stop	Condenser water temperature control	Chilled water temperature setpoint reset	Excessive chiller & boiler operation	Variable speed pump control	Economy cycle	Night purge	Space temperature Setback	Fume cupboard sash monitoring	Outside air compensation	CO2 Control	Timer control of A/C
1	Materials Engineering	Y								Y	Y				Y
2	Engineering Extension	N	Y	Y						Y	Y	Y			Y
3	Informatics	Y											Y	Y	Y
4	Engineering	N										Y		Y	Y
5	Animal House	Y													
6, 7	Engineering Laboratories	N													Y
8	Mechanical Engineering	N													
10	Kid's Uni	N													Y
11	Uni Centre	Y		Y				Y							
12	UniBar	N													
13	URAC	N												Y	
14	Central Lecture Theatre	Y	Y	Y					Y	Y	Y				
15	Austin Keane Building	Y								Y				Y	Y
16	Michael Birt Library	Y	Y	Y	Y	Y	Y	Y	Y			Y			
17	IT Resource Centre	Y	Y	Y	Y			Y	Y	Y			Y		
18	The Halpern Chemistry Building	Y	Y	Y						Y					Y
19	Arts	N												Y	Y
20	Communications Centre	Y	Y	Y	Y					Y	Y			Y	
21	Education laboratories	N													
22	Education & Clinic Building	Y	Y	Y		Y	Y		Y	Y	Y		Y		
23	Education Building	N													Y
25	Creative Arts	Y	Y			Y			Y	Y	Y		Y	Y	Y
29 & Demountables	Public Health, classrooms	N												Y	Y
30	WUC/AEC	Y	Y	Y		Y	Y		Y	Y			Y		
31	Building & Grounds	N													Y
32	Printery, Central Store	N													
35	Biology/Informatics	N	Y	Y	Y				Y	Y	Y				Y
36	Administration	Y	Y	Y	Y				Y	Y		Y			
37	Kooloobong	N													Y
38	Graduate School of Business	Y													Y
39	Illawarra Technology Centre	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y			
40	Commerce/Hope Theatre	Y	Y	Y	Y					Y					Y
41	The Sciences Building	Y	Y	Y	Y			Y	Y	Y	Y				
42	The Science Annexe	N													
67	The McKinnon Building	Y	Y	Y	Y			Y	Y		Y		Y		Y
121	Graduate House	N													Y

i) BMS time of day schedule

The BMS controls the operating times of HVAC systems in buildings with BMS control and in some cases external lighting, the current time of day schedules provide for global public holiday scheduling and special event scheduling on request to Building & Grounds, the schedules are automatically reset after the scheduled data has passed.

The start and stop times of HVAC systems are often not set to core occupancy hours, the start times of HVAC systems in some cases have been set to provide comfort conditions for cleaners, who commence work around 5am, and stop times have been set to suit after hours periods when a small number of people may be present.

It has been proposed in Section 5.2 that the facility be incorporated into the BMS time of day scheduling to enable global scheduling of student occupied areas for university recess so that these systems don't operate during these periods.

It is also proposed that time of day schedules be set to core occupancy hours for systems with economy cycle control and that after hours push button timers be used to provide air conditioning outside core occupancy hours unless automatic reset special events scheduling has been requested.

For example after hours timers would provide air conditioning when activated for cleaners, staff working out of hours or student occupied areas such as lecture theatres and tutorial rooms during university recess. Automatic reset special events scheduling would be used for events conducted during university recess such as exams, conferences and trade exhibitions.

An alternative to the above for common teaching areas is to link the Cardax system to the BMS so that HVAC plant dedicated to common teaching areas is energised from scheduled booking times. The Cardax system at this stage has not been interfaced to a Siemens BMS, the costs associated with the Cardax system to provide this link is approximately \$15,000 and the costs for the Siemens BMS is not known. In view of the uncertainty of costs, development time and implementation time this approach has not been considered.

Optimum start/stop

Optimum start stop control should be used for central plant or each package and split unit serving more than a single room independently. Small split units and room air conditioners serving one room should not be controlled by an optimum start/stop system.

Under optimum start control, the system should seek to start the air conditioning units as late as possible whilst achieving the following average space temperatures by the scheduled occupancy times:

- If cooling: Setpoint +1C
- If Heating: Setpoint -1C

If the optimum start sequence determines that cooling is required then all zone re-heats should be disabled until occupancy, conversely, if the optimum start sequence determines that heating is required, then all stages of cooling should be disabled until occupancy.

Under optimum stop control, the system should seek to utilise the residual cooling or heating capacity of the chilled water or heating water systems by shutting down primary plant as early as possible whilst not allowing the average space temperature to go beyond the following levels during the scheduled occupancy time:

- If cooling: Setpoint +2C
- If heating: Setpoint – 2C

In all cases, the fan should run on for a minimum of 15 minutes after the last heater is de-energised to allow it to cool down.

The energy audit has identified a number of buildings with optimum start/stop control listed in the Operating & Maintenance Manual. However, it has not been possible to establish if the optimum start/stop facility is enabled and the control strategy employed due to the inability to access these features from the BMS GUI. Hirotech, the mechanical services contractor, indicates

that these systems do not function and this is substantiated by the early and late starting and stopping times via the BMS time of day schedule to cater for worse case occupancies.

ii) Condenser water temperature control

The site utilises condenser water systems to reject waste heat to atmosphere from water cooled chillers and water cooled packaged air conditioners. Reducing the condenser water temperature as low as possible within the system requirements, the manufacturers guidelines and ambient dry bulb and wet bulb temperature constraints will reduce the compressor head pressure resulting in improved system efficiency and hence energy reduction.

Typically condenser water systems are set to higher temperatures than necessary, penalising chiller efficiency unnecessarily.

The opportunities identified in the reports involve better controlling the condenser water circulating temperature by various means including: converting the cooling tower fan to variable speed; modulating the fan speed and cooling tower bypass valve; changing operating setpoints in relation to ambient wet bulb temperature and to minimum temperatures acceptable to the system and manufacturer's requirements (typically 20C).

iii) Chilled water temperature setpoint reset

The site has chilled water plant installed in six buildings for space cooling, the chilled water reticulated to cooling coils is generally controlled to 6C at all times.

A chilled water temperature of 6C is typically a design temperature to which cooling coils are designed to cover the maximum design space thermal load. That is, for much of the time a higher chilled water temperature will be adequate to satisfy the space thermal load.

Increasing the chilled water temperature reduces the compressor suction pressure resulting in improved system efficiency and hence energy reduction.

The implementation of a chilled water temperature setpoint based on the load on the system allows for improved efficiencies. This is achieved by controlling the chilled water flow temperature to maintain a constant return flow temperature (typically 12C) and applying a reset strategy based on sustained changes in cooling demand (eg. reset down if any chilled water valve is >95% open and up if any chilled water valve is <80% open). Note that all figures given are typical and require fine tuning. During this operation, RH levels should be monitored and raising of chilled water temperatures prevented or reversed incrementally to maintain RH levels within acceptable limits (typically 65%).

iv) Excessive chiller and boiler operation

Four buildings, buildings 16, 22, 30 and 39, were found to have chiller and or boiler plant operating outside scheduled operating times from BMS trend data and electrical data logging.

- Building 16 electrical data logging shows chiller plant operating 24/7 during August, BMS trend data shows boiler operation 24/7 between 10/08/06 and 16/08/06 except for five hours on Monday and 7.5 hours on Tuesday, time of day schedules are set from 0400 to 2130. This operation could result from inappropriate night setback control settings.

- Building 22 BMS trend data over a seven day period from 9/08/06 to 15/08/06 shows minimal chiller operation and boiler operation through the night and during the cooler parts of the day on a seven day basis, the scheduled plant operating times are from 7am to 5pm five days a week. This operation could result from inappropriate night setback control settings.
- Building 30 trend data shows both the chiller and hot water boiler to be operating continuously over the period 10/08/06 to 16/08/06, the scheduled plant operating hours are 7am to 5pm five days a week. The boiler operation could result from inappropriate night setback control settings, this would not explain the continuous chiller operation.
- Building 39 electrical data logging shows chiller plant operating 24/7 and BMS trend data for the periods 9/06/06 to 15/06/06 and 9/08/06 to 15/08/06 show the stage 2 hot water flow temperature to be above 58°C at all times indicating there is a 24 hour heating demand on the stage 2 boiler, the scheduled plant operating hours are 7am to 6pm. The boiler operation could result from inappropriate night setback control settings, this would not explain the continuous chiller operation.

The causes of the above operation have not been confirmed due to the limited BMS access via the BMS GUI, refer Section 5.1 above.

It is recommended that the BMS software be reviewed and rectified to ensure that buildings 16, 22, 30 and 39 chillers and boilers are not enabled when the systems they service are not in operation and that all other chillers and boilers are checked to ensure that they also are only enabled when the systems they service are in operation.

v) Variable speed pump control

Pump energy consumption is proportional to the cube of the speed and proportional to flow quantity. A number of situations have been identified where the pump flow has been throttled as part of system balancing or because the pump has been sized for future expansion.

- Building 17 has a condenser water pump system that is sized for future expansion with the discharge throttled by about 50% to reduce the flow. The building heating hot water pump is also throttled by about 30%.
- Building 67 has a condenser water pump that operates when any one package air conditioner is enabled, a variable number of air conditioners operate at any one time resulting in a variable system flow requirements. The condenser water flow has been set to suit the requirements of when all package air conditioners are operating.

Controlling the flow by varying the pump speed instead of throttling the flow will result in substantial energy consumption reduction.

vi) Economy Cycle

Outside air is one of the main components contributing to the building load, modulating the outside air intake to a minimum acceptable level can lead to savings of typically 20% of HVAC system energy costs.

Outside air management should provide the primary means of temperature control within the building. For systems with a common return air plenum, such as multi zone installation or systems with central and perimeter zones, the proportion of outside air entering the various air handling units should be controlled by modulating outside and return air dampers on each unit.

The common relief air damper should be modulated to maintain a constant pressure in the return air plenum as the return air dampers are modulated to suit the loads for each air handler.

The position of the outside air dampers should generally be programmed as shown in Table 5.2.3.

Table 5.7: Schedule of operation for outside air dampers

Situation	Outside air damper position (0% represents minimum outside air damper position)
Cooling call registered and the required S/A temperature < O/A temperature < R/A temperature and R/A enthalpy > OA enthalpy	100% open
As above but the O/A temperature < S/A temperature	Modulate outside air dampers to suit supply air requirements. Disable cooling valve
No cooling or heating call registered	0%
Heating call registered and R/A temperature < O/A temperature	100%
Morning start-up during winter heating (prior to occupancy)	Completely closed outside air dampers

In addition, in potentially high occupancy areas such as lecture theatres and the like, control of the outside air quantity should be provided through a CO₂ monitoring system to ensure that excessive quantities are not provided when the occupancy levels are low, unless an outside air function is deemed appropriate as detailed above. Refer to item (ix) below.

The energy audit has identified at least 10 buildings with economy cycle controls listed in the Operating & Maintenance Manual. The control strategy used is relatively basic and does not maximise the use of outside air cooling and does not include outside air heating and is generally as follows:

During a call for cooling the economy cycle is enabled under the following conditions:

- Outside air temperature is less than 20°C
- Outside air temperature is less than the return air temperature
- The outside air humidity is less than 65%
- Outside air temperature is greater than 13°C

Hirotech, the mechanical services contractor, indicates that the economy cycles throughout the site do not function correctly due to the software installed. Site observations during the audit indicated the economy cycles in some systems were not operating correctly for the prevailing outside air conditions.

This energy audit has recommended that all existing systems with economy cycles be modified in accordance with Table 5.7 above, all modified economy cycles be commissioned and checked for correct operation and a preventative maintenance program be put in place to ensure these systems continue to operate correctly.

Further, the existing guidelines for new building construction and building refurbishments be altered to reflect the modified economy cycle control strategy and that any new installations with economy cycles that are still under warranty have the economy cycles modified in accordance with Table 5.7.

vii) Night purge

A night purge utilises outside air prior to normal occupancy hours to cool the building with all heating and cooling systems disabled; night purge is mostly used in buildings where a high level of heat build up occurs overnight or weekends.

The recommended control strategy is shown in Table 5.2.4 below and should be linked to the economy cycle control strategy if one is installed

Table 5.8: Schedule of operation for night purge

Situation	Night Purge Operation
Average internal space temperature (of the area served) >25C and outside air temperature <21C	Operate between 12am and 4am or until the average internal space temperature = <22C or =< (O/A temp + 4C)
Other conditions	No night purge operation

This energy audit has identified two buildings with night purge control strategies listed in the Operating & Maintenance Manuals. The control strategy used enables the night purge facility whenever the outside air temperature is in the range 16C to 22C between 12am and 6am, this strategy does not take into consideration the internal space temperature and could result in ventilation systems operating unnecessarily.

This energy audit has recommended that all existing systems with night purge be modified in accordance with Table 5.8 above, all modified night purge cycles be commissioned and checked for correct operation and a preventative maintenance program be put in place to ensure these systems continue to operate correctly.

Further, the existing guidelines for new building construction and building refurbishments be altered to reflect the modified night purge control strategy and that any new installations with economy cycles that are still under warranty have the night purge strategy modified in accordance with Table 5.8.

viii) Space temperature setback

Automatic temperature reset control functions can be used to minimise the energy consumption of the cooling and heating systems by resetting the space temperature setpoint based on occupancy within an area for each system; if no activity has been detected for a predetermined time period (eg. 10 minutes), then the area or room is determined to be unoccupied. Alternatively, night setback can be employed based on normal occupancy times for the area or room.

Occupancy based temperature reset control is appropriate in areas that are not occupied on a continuous basis such as lecture theatres, tutorial rooms, conference rooms, meeting rooms and laboratories.

Once an area or room has been identified to be unoccupied, the system will pre-condition the space temperature based on the following:

If the space is determined to be unoccupied then:

- If the OA temperature is above the normal setpoint, then the space temperature setpoint shall be set to 4C above the normal setpoint.

- If the OA temperature is below the normal setpoint, then the space temperature setpoint shall be set to 2C under the normal setpoint.

Where feasible, the system may be turned off completely while temperatures remain within the setback temperature.

Once activity is detected, and the area or room is identified as occupied, then the space temperature setpoint shall be set back to the normal setpoint value.

This energy audit has recommended that occupancy based setpoint control be implemented 7 buildings and that occupancy setpoint control be incorporated into the preventative maintenance programme and the existing guidelines for new building construction and building refurbishments.

ix) Fume cupboard sash monitoring

Laboratory ventilation systems require makeup air systems to operate whenever a fume cupboard sash is not closed in order to maintain a negative pressure in the space, in some cases the makeup air system is either cooled and heated or heated only.

Buildings 1 and 2 have tempered outside air makeup systems as outlined above which have been found to operate 24/7 due to fume cupboard sashes remaining in the raised position. Building 1 has BMS monitoring of the fume cupboard status, Building 2 is not connected to the BMS.

This report has recommended that the BMS be utilised to monitor and report on fume cupboard status so that fume cupboard usage can be better managed to reduce energy consumption. Trending of these systems would take place out of hours.

Further, it is recommended that new building and refurbishment guidelines include BMS monitoring and reporting on fume cupboard status.

x) Outside air compensation

Outside air compensation is used to reduce system losses in heating hot water systems by reducing the hot water temperature as the outside air temperature increases and in tempered air systems by disabling heating when the outside air temperature is greater than 18C. The proposed function operates by controlling the flow temperature to maintaining a constant return water temperature which is reset as ambient temperatures increase as described above.

Buildings 2, 4, 22, 25 and 30 have been identified as suitable for the installation of outside air compensation.

Further, it is recommended that new building and refurbishment guidelines include outside air compensation as outlined above.

xi) CO₂ control of outside air

CO₂ control of outside air is used to minimise outside air to air handling units based on air quality. The use of CO₂ control of outside air is appropriate in spaces such as lecture theatres where there is variable occupancy.

Buildings 3, 16, 17 and 25 have been identified as suitable for the installation of CO₂ control of outside air.

Further, it is recommended that new building and refurbishment guidelines include CO₂ control of outside air as outlined above.

xii) Timer control of room air conditioners

Split units and room air conditioners serving one room should have local manual start with a programmable time duration automatic shutdown of the air conditioner. Local controllers where time schedules can be programmed by the occupants are not recommended.

Room air conditioner controls throughout the site comprise the following:

- Local on off
- Remote hand held controllers with manual on off control, time of day scheduling, manual start with time duration operation.

Buildings 3, 4, 13, 15, 19, 29 and demountables have been identified as suitable for the installation push button timer control of air conditioners.

Further, it is recommended that new building and refurbishment guidelines include timer control of room air conditioners as outlined above.

xiii) Timer control of personal heaters

Personal heaters should have local manual start with a programmable time duration automatic switch off.

Personal heaters throughout the site are used mostly in non air conditioned offices throughout the site and generally consist of the following:

- Forced fan heaters with local on/off control
- Convection heaters with on/off and thermostat control

The installation of push button timer control of existing personal heaters across the site has been recommended.

Further, it is recommended that new building and refurbishment guidelines include provision for dedicated heater circuits fitted with a round earth pin socket so that only university issued heaters fitted with a round earth pin plug can be connected to the dedicated circuit. The dedicated circuit is to provide centralised reset control of the individual heaters connected to the circuit so that after a reset pulse, typically every 2 hours, the local heater has to be manually initiated.

It is also recommended that the purchasing policy be changed as follows:

- Purchase of fan forced heaters be discontinued.
- Purchase low wattage under desk convection heaters with push button timer control for office areas. The heater plug is to have a round earth pin; the socket where the heater is to be located is to be replaced with a round earth pin socket.
- Purchase halogen or infrared radiant heaters for open areas such as lunch rooms and meeting rooms where heaters are required, the heaters are to have push button timer control with an on duration no greater than 1 hour.

xiv) Other Energy Efficiency Opportunities

Energy efficiency opportunities that are building specific, i.e. not listed in Table 5.6 above, are contained in the detailed listing of projects for each building in Appendix 2.

xv) Space temperature reset based on outside air temperature

Air conditioning systems at the university are controlled to unchanging setpoints throughout the year, irrespective of ambient conditions and seasonal changes. The above recommendations have assumed a continuation of the current practice.

Consideration should be given to seasonally adjusting the control points used for comfort air conditioning systems to provide conditions more appropriate with clothing and climatisation factors applicable during the year.

The reduction of the heating setpoint by 1C during winter and the increase of the cooling setpoint by 1C during summer may be expected to produce savings in the order of 420 GJ per annum in electricity and gas combined, worth approximately \$9,400 per annum. However the application of this initiative during winter needs careful review to ensure that energy use is not actually increased in areas where substantial internal heat loads exist and limited outside air cooling is available.

5.2.3. Domestic Hot Water (DHW) and Staff Amenities

The domestic hot water (DHW) systems and staff amenities on the campus are estimated to consume approximately 360,000 kWh of electricity and 3,000 GJ of gas per annum at a cost of approximately \$43,500 and have an energy utilisation index of 26 MJ/m² per annum. Refer to Table 5.8 for the estimated breakdown of this energy use.

Table 5.8 - Estimated Energy Use and Cost by Domestic Hot Water and Staff Amenities Systems

ITEM	Consumption			Index MJ/m ²	Cost \$ pa
	Electricity	Gas	Total		
	kWh pa	GJ pa	GJ pa		
Domestic Hot Water Units	242,305	2,989	3,862	24	34,654
Refrigerators	69,378		250	2	5,232
Other Staff Amenities	48,341		174	1	3,646
TOTAL	360,024	2,989	4,285	26	43,532

The energy audit identified energy efficiency cost savings for the Domestic Hot Water and Staff Amenities as being worth approximately \$11,700. These savings represent approximately 1.5% of the energy used by the audited buildings. Approximately 97% of the above savings fall within the University's financial hurdle rate of 7% (IRR), at an estimated cost of approximately \$70,000. Table 5.9 shows a breakdown of costs and savings falling within and outside the University's hurdle rate. A full list of identified energy management projects for each building is included in Appendix 2

Table 5.9 - Summary of Costs and Savings – Domestic Hot Water and Staff Amenities

IRR	Implement , Cost	Savings				
		Energy Costs	Maintenanc e Costs	Energ y	% of tot Energ y	Emission s
		\$ pa	\$ pa	GJ pa		T CO ₂ -e
Better than 7%	69,985	11,070	0	1,578	1.5%	151
Less than 7%	17,000	660	0	44	0.04%	12
Total	86,985	11,730	0	1,622	1.5%	163

Note: no cost is allocated to the changes in domestic fridges as this would take place at the time of replacement.

Figure 5.3 shows a breakdown of the above energy savings amongst the major categories of initiatives.

Refer to the itemised list of initiatives in Appendix 2 and to individual building reports for further information.

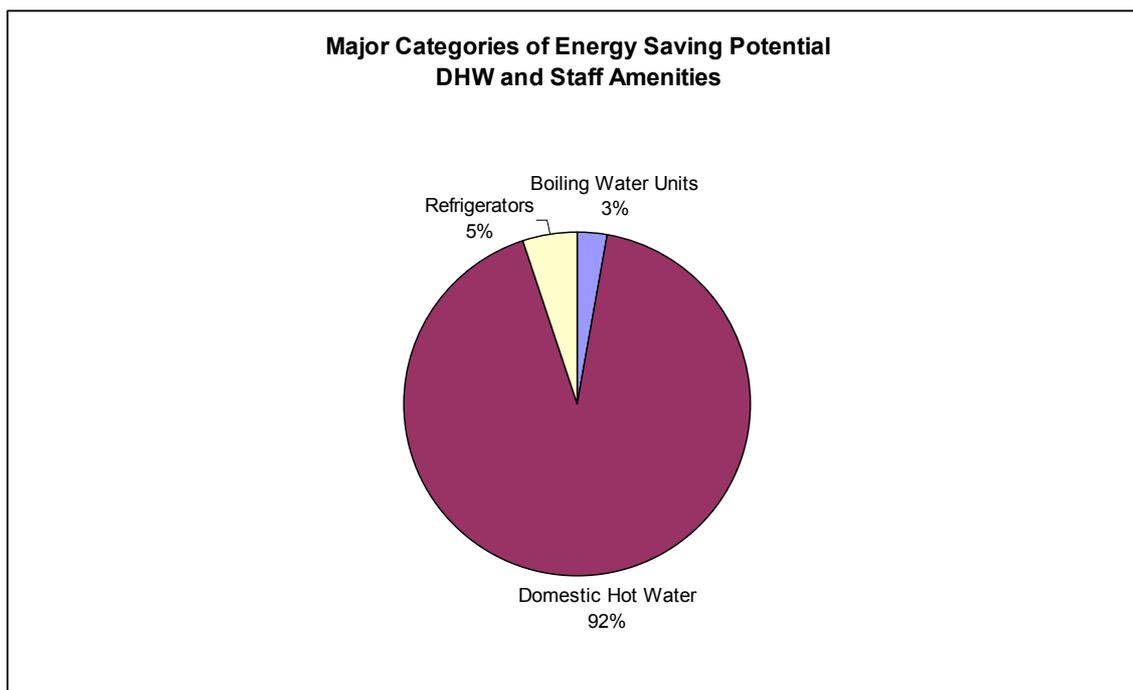


Figure 5.3: Major Categories of Energy Saving Potential – Domestic Hot Water Systems and Staff Amenities

The opportunities identified within these major categories are described below.

5.2.4. Domestic hot water

Domestic hot water is mostly provided by local electric mains pressure storage units and circulating gas systems in areas of high usage such as commercial kitchens (Buildings 11, 12 and 69) or showers (URAC, building 13), or specialised areas such as building 5 (animal house) and buildings 18 (chemistry) and 41 (Science building).

Opportunities identified are as follows:

- Time control of circulating systems to reduce system losses when there is no demand for hot water
- Solar systems with gas or electric backup for URAC.

Further, it is recommended that new building and refurbishment guidelines include timer control of circulating hot water systems as outlined above, preferably controlled via the BMS time of day schedule.

A detailed listing of domestic hot water projects for each building are contained in Appendix 2

5.2.4.1. Boiling water units

Boiling water units are extensively used throughout the site in staff amenities, these units remain energised at all times, normally being plugged into a GPO.

The opportunity identified is to energise the boiling water units via a push button timer to reduce system losses during periods of low utilisation.

Further, it is recommended that new building and refurbishment guidelines include timer control of boiling water systems as outlined above, preferably controlled via the BMS time of day schedule.

5.2.4.2. Refrigerators

Refrigerators throughout the site are generally rated at three stars or less, there are approximately 80 refrigerators used in staff amenities.

It is recommended that existing refrigerators be replaced with 5 star rated refrigerators on failure and that the purchasing policy be changed so that only 5 star rated refrigerators are purchased.

5.2.5. Lighting

The lighting systems on the site are estimated to consume approximately 5,060,000 kWh of electricity per annum at a cost of \$380,000. This level of energy use corresponds to an average energy utilisation index of 112MJ/m² per annum, which is considered to be reasonable for the type of applications and activities involved on the site.

A comprehensive upgrade of the lighting systems was conducted by NDYLIGHT in 2003. The upgrade covered many of the larger buildings on the site, namely 11, 16, 17, 19, 20, 25, 35, 39, 40, 41 and 67. The upgrade mostly covered the following initiatives:

- Voltage regulator units
- Movement detectors
- Daylight cells
- Replacement of existing fittings
- Lamp removal

Earlier improvements in to other buildings have resulted in the extensive use of movement sensors in corridors and intermittently occupied areas such as tutorial rooms, offices, lecture theatres and staff amenities.

This energy audit identified energy efficiency cost savings for the Lighting systems as being worth approximately \$45,500 per annum including some minor maintenance savings due to reduced operation of systems. These savings represent approximately 1.6% of the energy used by the audited buildings. Approximately 66% of the above savings fall within the University's financial hurdle rate of 7% (IRR), at an estimated cost of approximately \$166,700. Table 5.10 shows a breakdown of costs and savings falling within and outside the University's hurdle rate. A full list of identified energy management projects for each building is included in Appendix 2

Table 5.10 - Summary of Costs and Savings - HVAC Initiatives

IRR	Implement , Cost	Savings				
		Energy Costs	Maintenance Costs	Energ y	% of tot Energ y	Emission s
		\$ pa	\$ pa	GJ pa		T CO2-e
Better than 7%	166,727	21,059	9,279	1,091	1.03%	298
Less than 7%	228,620	11,989	3,127	572	0.54%	157
Total	395,347	33,048	12,405	1,663	1.57%	455

Table 5.11 shows a breakdown of the above energy savings amongst the major categories of initiatives. These represent an extension to the recent program of initiatives. It should be noted that these are broad categories which often overlap (ie. an initiative may incorporate items of more than one category).

Figure 5.11: Major Categories of Energy Saving Potential – Lighting Systems

Type of Recommendation	Implement , Cost	Savings				
		Eng y Costs	Maintenance Costs	Energ y	% of tot Energ y	Emission s
		\$ pa	\$ pa	GJ pa		T CO2-e
Daylight Control	8,650	1,895	381	90	0.09%	25
De-Lamp Fittings	26,268	4,123	3,227	197	0.19%	54
Movement Detector Control	31,045	2,655	82	127	0.12%	35
Higher efficacy Lamps	47,550	5,651	1,974	270	0.25%	74
Refurbish Systems	216,320	11,835	3,839	565	0.53%	155
Replace Systems	23,000	1,008	644	48	0.05%	13
Timer Control	13,214	1,692	43	81	0.08%	22
Voltage Regulators	16,950	2,362	1,943	198	0.19%	54
Total	395,347	33,048	12,405	1,663	1.57%	455

Note: The majority of initiatives under “Refurbish Systems” relate to planned refurbishments where little or no additional cost is included.

5.2.6. Office and Other³ Equipment

The office and other equipment on the site are estimated to consume approximately 5,000,000 kWh of electricity per annum at a cost of \$18,000. This level of energy use corresponds to an energy utilisation index of 111MJ/m² per annum, which is considered to be moderately high. Refer to Table 5.12 for the estimated breakdown of this energy use.

Table 5.12 - Estimated Energy Use and Cost by Office and Other Equipment

ITEM	Consumption		Index	Cost
	kWh pa	GJ	MJ/m ²	\$ pa
Office Equipment	1,991,597	7,170	44	150,201
Other Equipment	3,002,726	10,810	67	226,457
TOTAL	4,994,323	17,980	111	376,658

5.2.6.1. Personal computers

The main campus has approximately 3,000 personal computers, approximately 2,750 of these are managed by ITS, the Commerce Faculty and the Informatics Faculty, these groups have or are in the process of enabling the Energystar facility on all computers and phasing out CRT monitors.

A significant number of the remaining 250 or so computers, based on site observations, are likely to remain on at all times.

5.2.6.2. Combined Photocopiers/Printers

The Main Campus has 133 combination photocopiers/printers which are mostly linked via the campus network. The energy saver time out facility after equipment use is centrally programmed at the maximum time of 4 hours.

The energy saver time out facility should be centrally programmed to an optimum time, typically 5 minutes.

5.2.6.3. Other Office Equipment and Systems

A large proportion of general office equipment and many items of other occupant activated plant and equipment was found to be running continuously or for extended periods of time when not being utilised. A general awareness campaign and the use of dedicated shut-down procedures for laboratory services and systems would reduce the incidence of this unnecessary load.

³ Other equipment refers to specialised occupant equipment which is not part of building services and typically includes laboratory equipment and services.

Recommendations:

- Through the campus IT Forum Group formulate a campus wide policy to enable the Energystar facility, improve staff and user awareness of office systems and phase out CRT monitors.
- Implement a staff/occupant awareness program and dedicated shut-down procedures to reduce unnecessary operation of equipment.

Summary of Costs and Savings – Office and Other Equipment

ITEM	Implement ' Cost	Savings				Payback yrs
		Energy Costs	Energy	% of total Energy	Emission s	
	\$	\$ pa	GJ pa		T CO2-e	
Office Equipment	Nil	9,891	472	0.44%	129	immediate
Other Equipment	Nil	110	5	0.00%	1	immediate
TOTAL	Nil	10,000	477	0.45%	131	immediate

6. Maximum Demand Management

6.1. Power Factor Correction

The main campus has nine substations, all of which have power factor equipment installed. The average power factor is in the range 0.91 to 0.99. Table 6.1 summarises an analysis of the power factor for each of the substations

Table 6.1: Power factor correction analysis

Substation	Average Power Factor	Maximum Demand Reduction	Correction required	Cost Savings	Project Cost	Payback
		kVA	kVAr	\$	\$	Years
2	0.98	68	250	\$906.50	\$18,750.00	20.7
3	0.99	0	0	\$0.00	\$0.00	n/a
4	0.93	67	225	\$3,515.79	\$16,875.00	4.8
5	0.95	62	175	\$2,995.90	\$13,125.00	4.4
6	0.92	84	250	\$4,437.98	\$18,750.00	4.2
7-1	0.91	68	200	\$3,055.92	\$15,000.00	4.9
7-2	0.97	12	50	\$300.52	\$3,750.00	12.5
Building 30	0.92	26	75	\$1,359.96	\$5,625.00	4.1
Building 37	0.99	1	0	\$0.00	\$0.00	n/a
Building 40	0.91	30	100	\$1,433.76	\$7,500.00	5.2

Power Factor correction works for substation 2 fall outside the University's hurdle rate of 7%IRR. The remainder, at a total cost of \$80,600, are estimated to produce a combined electricity demand reduction of 348 kVA, resulting in annual cost savings of \$17,100.

6.2 Maximum Demand Control

Building 20 has provision for shedding of air conditioning plant based on a programmable current and Building 16 has provisions in the software for demand load shedding of mechanical plant, this system is not currently enabled. Load shedding based on a current level may not necessarily achieve maximum demand reduction.

An effective maximum demand control system for the campus needs to monitor the maximum demand for each revenue meter or substation so as to shed loads associated with the revenue meter or substation on the approach of a maximum demand event for that system. That is, as the demand approaches the maximum demand for that month loads are shed in a prioritised order in attempt to prevent the current maximum demand for that month being exceeded. In the event that the maximum demand for that month is exceeded that demand becomes the target against which loads are shed.

The following illustrates some typical ways in which loads can be shed on the approach of a maximum demand event:

- i) Load limiting of air conditioning compressors
- ii) Cycling of cooling and heating systems
- iii) Increase cooling setpoints in summer and reducing heating setpoints in winter
- iv) Increasing chilled water temperatures
- v) Decreasing heating hot water temperatures
- vi) Widening dead bands on heating and cooling systems

Sheddable loads should be shed in a priority order based on the criticality of the load.

A maximum demand control system for the Main Campus would be best implemented via the BMS as the potential sheddable loads are mostly already interfaced to the BMS.

It is proposed that a maximum demand control system be evaluated once the major HVAC control and operational issues identified as part of this Technical review are rectified.

7. Utilities Metering

7.1. Proposed Utilities Metering System Upgrade (Water, Electricity and Gas)

The NSW Energy Administration Amendment (Water and Energy Savings) Act 2005 requires Energy and/or Water Savings Action Plan participants to report on their progress towards implementing cost-effective energy efficiency improvements on an annual basis, and revise their Energy and/or Water Savings Action Plans every four years.

This energy audit has identified baseline consumption and performance levels for the main campus and for each building, the main campus baselines are based on revenue meter data and the building baselines are based on sub-meter data or estimates where the sub-meter data does not exist or is considered unreliable.

The audit has also identified target consumption and performance levels for the campus and for each building against which energy performance improvement measures can be compared.

The proposed metering system upgrade is to address the following issues:

- i) Provide sub-metering for tenant billing purposes, based on both network and retailer billing rates for both electricity and gas.
- ii) Generate monthly and annual reports on the campus energy consumption and performance as part of the University's energy management program and annual reporting responsibilities to DEUS
- iii) Generate monthly and annual reports on individual building's energy consumption and performance as part of the University's energy management program incorporating monitoring and verification of the implementation of energy efficiency opportunities.
- iv) The requirements of future meter requirements for new and refurbished buildings in terms of establishing baselines, verifying design energy performance and incorporation into the proposed energy management reporting system.
- v) Provide a similar monitoring and reporting regime for the University's Water Saving Action Plan requirements

The University of Wollongong has recognised the need for an improved metering system and has commissioned tender documents be prepared in conjunction with this Energy Savings Action Plan for a utilities metering system covering electricity, natural gas and water.

The system will apply to buildings consuming more than 5% of campus energy consumption or where reporting to DEUS is applicable. The system is required to link in with the University's Strategic Plan and provide notional energy charges to faculties for posting on the University's intranet.

7.2. Electricity

The Main Campus is supplied electricity via ten revenue meters.

The site has numerous electricity sub-meters that are mostly intended to monitor individual building consumption. The sub-meters are mostly a synchronous disc type more than 20 years old, some recent installations include sub-meters on mechanical services plant and a BMS based energy monitoring system on the mechanical service plant in Building 16.

The metering system is generally in poor condition with a significant number of meters not functioning, not reading correctly, incorrect or no K factor or not commissioned properly. In some cases meters are not clearly identified in relation to the load being metered.

Selected meters are read on a monthly basis and the results compiled on a spreadsheet. The readings for URAC, Building 13 and Kooloobong (Building 37) are used for tenant billing purposes; no other tenants on the main campus are billed for their energy consumption on a user pays basis. No other use is currently made of the monthly meter readings.

Graduate House, Building 121 pays for its electricity directly with the electricity provider.

Revenue meter data for the main campus is available from the electricity retailer as 30 minute interval data.

7.3. Natural Gas

The main campus is supplied by natural gas via one revenue meter. Graduate House (Building 121) has a separate meter and pays for its natural gas directly to the natural gas service provider.

The main campus has nine natural gas sub-meters that supply free standing buildings. There is also provision for the installation of additional sub-meters in a number of areas.

URAC (Building 13), UniCentre (Building 11) and UniBar (Building 12) meters are read on a monthly basis and used for tenant billing purposes, none of the other gas meters are read on a regular basis.

Revenue meter data for the main campus is available from the gas retailer as 24 hour interval data.

8. Energy Management

8.1. Current Status

A Diagnostic Review of energy management at the University of Wollongong was completed on June 15, 2005 by Energetics using the One-2-Five energy management rating tool. The review ranked the university at one star out of a five star range suggesting that there is limited focus on energy.

The recommended actions of the Diagnostic Review are paraphrased below together with the actions taken before and subsequent to the Diagnostic Review.

1. Understanding of performance and opportunities

Conduct a baseline study (“energy audit”) to establish energy consumption by major users and opportunities for savings.

Action taken:

- This Technical Review has established baselines and targets and identified energy consumption by major users and opportunities for savings.
- Prior to the Diagnostic Review extensive lighting control projects were implemented aimed at reducing energy consumption

2. Plans

Implement an annual planning process that identifies all priority projects, schedules, responsibilities and budgets.

Action taken:

- This Technical Review has identified cost effective prioritised costed projects which are to be incorporated into the university’s five year Capital Management Plan which is reviewed annually.

3. Awareness and training

Conduct basic energy-awareness activities within the organisation, focusing on cost savings and environmental issues associated with energy use. Disseminate the information using tools such as the organisation web site or newsletter.

Action taken:

- A campus energy management working party has been set up; energy management issues are reviewed and delegated to divisional groups.
- The university’s intranet is to be used to disseminate information on the ESAP; this has already been implemented for the Water Savings Action Plan (WSAP).

4. Demonstrated corporate commitment

- a) Arrange for an executive-level officer to sign an energy policy or directive containing specific goals and objectives for improving energy efficiency and reducing energy costs.
- b) Ensure that energy management activities and progress made towards goals are contained in the organisation's energy directive/policy

Action taken:

- Prior to the Diagnostic Review the role of Energy Manager was incorporated into the Maintenance Manager's role.
- An Environmental Policy came into effect on 23rd of June 2006; one of the aims of the policy is to "focus particularly on minimisation of energy and water consumption, waste management, including recycling, and endeavour to become a community leader in these areas".
- The preparation of design standards to address energy efficiency requirements for new and the refurbishment of existing buildings is in progress (refer to comments on these work-in-progress documents in Section 9).

5. Metering and Monitoring

Regularly monitor the energy use of all major facilities/cost centres/energy intensive end users.

Action taken:

- The university has commissioned the documentation of a utilities metering system to be prepared concurrently with this Technical Review
- The key requirements of the metering systems identified during this review include (refer also to the Section 7 above):
 - i. A user pays principal for tenants
 - ii. Monthly and annual report generation on campus energy consumption and performance against target as part of the university's energy management program.
 - iii. Monthly and annual report generation on individual building's energy consumption and performance against target as part of the university's energy management program.
 - iv. Monitoring and verification of the implementation of energy efficiency opportunities.

8.2 Energy Initiatives to Date

A comprehensive review of lighting systems across the campus has been carried out. The majority of recommendations from these have been implemented across the campus. In addition, a number of air conditioning projects including a chilled beam system and other programs have been completed. It is estimated that these are accruing savings of approximately 9,300 GJ per annum. A series of additional projects with the potential to save 3,553 GJ per annum are at various stages of processing.

The preparation of a series of design standards, which address (among other matters) the energy efficiency aspects of new developments and refurbishments, has been commissioned.

8.3 Energy Initiatives Proposed

Section 5 and Section 6 above outline site wide energy efficiency and management opportunities and the individual building reports provide details on specific energy efficiency opportunities applicable to each building.

The energy initiatives proposed are broadly summarised as follows:

- Improve the operation and utilisation of the BMS for improved control, monitoring and line management of energy systems
- Fine tune time of day control of HVAC plant and incorporate university recess scheduling and after hours control
- Modify existing BMS control algorithms and carry these changes through to the building Design Standards
- Incorporate energy efficiency requirements in the university's purchasing policies
- Install a utilities metering system to provide inputs into the university's Energy Management Program by generating monthly and annual reports on campus and individual building energy consumption and performance against targets.

8.4 Energy Performance Indicators

Baseline energy consumption and performance has been established as part of this Technical Review for the main campus for the 2005 calendar year and performance benchmarks and targets have been established for each building. Load profiles have also been established for peak summer and winter demand days.

The inputs required to compare actual consumption and performance against baseline consumption and performance are as follows:

Campus:

- i) Building gross floor area
- ii) Monthly and annual campus energy consumption derived from energy accounts
- iii) Record of changes to the site impacting on energy consumption

Buildings:

- i) Monthly and annual electricity consumption for each building derived from utility meter readings.
- ii) Record of changes to the building impacting on energy consumption

- iii) Daily load profiles derived from the utilities metering system with alarm outputs when the expected load profile envelope is exceeded.

8.5 Energy Use Monitoring and Reporting System

The energy use monitoring and reporting system is required to receive data inputs from the utilities metering system and manual data entry to generate reports that provide the following outputs:

- i) Report on changes in business activity indicators
- ii) Performance against baseline and target
- iii) Identification of areas of poor performance
- iv) Highlight savings achieved

8.6 Monitoring and Verification of Energy Efficiency Measures

Energy efficiency projects need to be monitored before the project commences and after the project is completed to verify that expected improvements have been achieved. There also needs to be ongoing monitoring to ensure that the expected improvements are maintained, the ongoing monitoring would be provided by the energy use monitoring and reporting system subject to a revision of the targets that should be determined as part of a new project.

Documentation for new buildings and building refurbishments should include estimates of energy consumption and performance at the design stage which should be monitored and verified after building commissioning is complete.

9. Design Standards

The University has commissioned the preparation of a number of design standards to provide guidance and direction for new developments and refurbishments on the site. Among other issues, these standards address the energy aspects of the proposed works. Currently, design standards are being prepared for:

1. Building Monitoring and Control Systems
2. Mechanical Services
3. Building Elements
4. Energy Saving Items

At the time of writing this report, the above documents are at various stages of preparation. The following comments apply to the documents at the time of inspection.

In general, It is recommended that the procedures called up in the BCA, to ensure that the entire design is modelled and its performance compared against target energy consumption, be called up in these standards and provision be made for energy modelling and assessment of all major components at the time of design to ensure that the final project is optimised.

9.1 Building Monitoring and Control Systems

The standard is focused on the technical issues of design and installation of the system. Many energy management functions are called up as being required however, no details are provided with respect to the operating parameters, user interface requirements, documentation and other operating factors which have been identified as lacking in the system during this energy audit.

An example of this is the economy cycle which is called up in the standard but its specific operation and control/adjustment parameters are not specified, possibly resulting in unoptimised operation, as is currently the case across the campus.

Documentation and operator access issues which were found lacking in this energy audit have also not been addressed in this document. Similarly, metering and monitoring parameters need to be better specified including the ability to set targets hourly, weekly, monthly and alarming of unusual consumption etc.

Other areas where the existing BMCS has been identified as lacking in this energy audit (refer to the relevant clauses) should also be addressed in the standard.

BCA 2006 contains a number of provisions applicable to the University and should be called up in lieu of the 2005 edition.

9.2 Mechanical Services

As for the BMCS standard, this document focuses on the technical issues of design and installation on a general basis. No specific provisions are included for ensuring energy efficiency, specifying target consumption levels, undergoing design review sessions which include energy efficiency etc.

The design temperature selections appear to be too extreme and not representative of normal design conditions (eg. design day ambient temperature for cooling is 37C) which will lead to excessive capacities in the system designs.

An issue noted during the energy audit was the inefficient operation of systems oversized possibly for future expansion or due to excessively conservative design. Where this is required, a modular approach to the design may be considered more appropriate.

Comfort condition settings for heating and cooling also appear to be too restrictive at a maximum of 22.5C and minimum of 20C. These are not in line with general energy efficiency policies.

The provisions of BCA 2006 should be called up in the standard and existing areas of conflict with this document should be resolved. In addition, items of equipment and plant which are nominated in the standard need to be checked for compliance against the efficiency requirements contained in the BCA.

9.3 Building Elements

This standard covers items of construction, including insulation, material finishes and other areas which affect the overall energy use of the building. Energy efficiency is mentioned as one consideration in the choice of the elements.

It is recommended that the procedures called up in the BCA, to ensure that the entire design is modelled and its performance compared against target energy consumption, be called up in this standard and provision be made for energy modelling and assessment of all major components at the time of design to ensure that the final project is optimised.

9.4 Energy Saving Items

This document is in its early stages of preparation and only includes a brief description and main advantages and disadvantages of a number of lighting control devices.

It is recommended that the final document be expanded to cover control devices and systems across all areas of energy use and that the discussion of each item be expanded to cover the applications where these systems should be used; provisions for installation; operation; on-going maintenance; programming etc as appropriate for each item.

It should be noted that many of these devices and their applications are further specified in the Building Code of Australia. Reference to this document should be included and any anomalies between the two documents should be addressed.

10. Implementation Strategy

A number of cash flow analyses were conducted to develop an optimised implementation strategy for the cost-effective (within the university's 7% hurdle rate) energy management works identified during this energy audit. The options analysed included:

1. Each recommendation carried out in order of cost effectiveness
2. HVAC projects (being the major contributor to total savings) given priority
3. Buildings with most savings first
4. Each type of project (eg. HVAC control improvements) carried out across the campus in order of cost-effectiveness (by project type)

Following is a comparison of effective investment cost for each of the above options assuming all savings achieved from projects previously carried out are made available to assist in financing subsequent projects.

Table 10.1 – Comparison of Effective Investment Cost by Type of Implementation

Implementation Type	Effective Investment Cost
1. Projects by cost effectiveness	\$724,331
2. HVAC priority ¹	\$892,856
3. Buildings with most savings first	\$885,584
4. Project Type	\$815,637

Note: the HVAC propriety projects achieve a positive cash flow by year 2 compared to year 3 for the other strategies, due to the larger number of projects included in the initial year.

The analysis shows that the individual project approach provides the optimum results in providing the quickest return on investment. However this approach is not practical in all cases as it does not make allowances for the administrative and implementation efficiencies found in carrying out like-projects on a site-wide scale, as per option 4 (Project Type). Also, some individual projects will not achieve the predicted cost-effectiveness if they are not carried out at the appropriate time (eg. when the building is being refurbished or the plant is to be upgraded etc), which is a condition on many of these cases.

The following program of implementation was found to provide the best combination of priority project types (option 4), combined with some individual projects of high cost-effectiveness (option 1), where these can be effectively undertaken separately. The project-type approach focuses on HVAC projects initially, as the major source of potential, while also ensuring that all energy management options are implemented in buildings and systems which are refurbished during the time of this work program.

Table 10.2 – Suggested Program of Implementation

Project Number	Measure Description	Cost to Implement	Savings - GJ	Total Cost savings	Internal rate of return	Time required to implement	Planned completion date
1	HVAC - Control Improvements	258,050	6,004	79,157	30.7%	1 yr	Dec-07
2	HVAC – Boiler Systems	29,900	702	4,439	14.8%	3 yrs	Dec-09
3	HVAC - Chiller and Condenser Water Systems	116,700	1,260	25,844	22.1%	1 yrs	Dec-07
4	HVAC - Holiday scheduling and time of day	92,650	7,205	101,507	109.6%	1 yr	Dec-07
5	HVAC - Economy Cycle, CO ₂ , Outside air and Night purge	57,000	1,522	27,963	49.1%	1 yr	Dec-07
6	HVAC- Control of personal equipment and general awareness	123,150	837	17,223	14.0%	3 yrs	Dec-09
7	HVAC - New or refurbished plant	800	235	4,743	592.9%	4 yrs	Dec-10
8	HVAC - Other	24,680	153	3,483	14.1%	4 yrs	Dec-10
9	DHW ² and Staff Amenities initiatives	69,985	1,578	11,070	0	3 yrs	Dec-09
10	Specific Utilities initiatives	10,000	1,879	37,587	>100%	1 yr	Dec-07
11	Lighting initiatives	166,727	1,091	30,338	0	3 yrs	Dec-08
12	Office and Other Equipment initiatives	Nil	477	10,000	>100%	4 yrs	Dec-10
13	Pool system initiatives	40,930	1,565	12,224	0	2 yrs	Dec-08
14	Power Factor Correction initiatives	80,625	348 kVA	17,100	0	3 yrs	Dec-09
15	Implement a site-wide metering program	300000	n/a	n/a		1 yr	Dec-07
Total		1,371,198	24,508	382,677	27.90%	1,371,198	

Table 10.2 shows the projected simple cash flow resulting from the application of the above implementation program. It shows that the program becomes self-funding after year 1 following an initial investment of approximately \$835,000 and assuming that all energy and maintenance cost savings are retained to fund subsequent projects.

Table 10.3 – Projected Simple Cash Flow of Recommended Program

Year	2007	2008	2009	2010	Subsequent years
Implementation Cost	-\$834,600	-\$207,857	-\$303,860	-\$24,880	
Annual Savings		\$275,744	\$321,992	\$375,509	\$382,678
Net cost	-\$834,600	\$67,887	\$18,132	\$350,629	\$382,678

Energy Audit

University of Wollongong – Main Campus

APPENDIXES

- 1. Summary of Proposed changes to the building assets at October 2006**
- 2. Itemised List of Energy Management Initiatives**

*Energy Audit***University of Wollongong – Main Campus****Appendix 1: Summary of Proposed changes to the building assets at October 2006**

Building	Description	Proposed Works	Scheduled Works
1	Materials Engineering	Process chiller for instrument cooling	2007
2	Engineering Extension	Refurbishment	No date scheduled
6		Demolish existing and replace with new building	2008 Start
8	Mechanical Engineering	Refurbishment including lighting, lab upgrade to PC2 and air conditioning of top floor	Start 2007
15	Austin Keane Building	Max Olsen Labs (grnd floor NE) air conditioning to be added	2007
16	Library	Part refurbishment & extension, additional air handling plant and external glass areas will impact on existing plant operation	Tenders to be issued late 2006
18	The Halpern Chemistry Building	Air conditioning to be added to the top floor	No date scheduled
19	Arts	Minor upgrade, old room air conditioners and package units to be replaced	2010
20	Communications Centre	Major upgrade	Complete 2006
31	Buildings & Grounds	Trial system to remove heat/cool peaks	No date scheduled
32	Printery and Central Store	The Printery is to be located off site and the site redeveloped as a medical research facility	No date scheduled
35	Biology/Informatics	North Wing laboratory HVAC plant replacement, air balance and converted to BMS control	2006/2007
36	Administration	Minor works, additional air conditioning to meeting room	In progress
38	Graduate School of Business	Interior refurbishment and addition of air conditioning	2007
41	Anatomy lab	Medical research anatomy lab to be refurbished and made PC2 compliant. Works include HVAC and electrical upgrade	Tenders to be issued late 2006
	Medical School	New building	Complete October 2006
	Animal Holding Facility	New building to be constructed on the West side of Robson Road	Start 2007
	Oval 2 Field House	New building with expected high lighting and air conditioning loads	Start 2007
	Western Carpark	Additional security lighting and CCTV	2007
	Creative Arts and B & G Carparks	Additional security lighting and CCTV	2007
	South West Carpark	Additional security lighting and CCTV	2007

APPENDIX 2 – Itemised List of Energy Management Initiatives

(Note: The individual items included below are summarised and abbreviated for the purposes of presentation. Refer to the specific building reports which provide further background and details to each recommendation)

Building	Category of Initiative	Recommendation	Cost	Savings					Payback
			\$	Energy \$ pa	Maintenance \$ pa	GJ pa	% of tot Energy	t CO ₂ -e pa	yrs
Site-Wide	Meters	Install a site-wide utilities metering and monitoring system	300,000	n/a	0	n/a	n/a	n/a	n/a
1	HVAC	Install a monitoring system via the BMS to track fume cupboard doors that are open for more than a specified period of time, the system should also monitor the makeup air fan to ensure it shuts down outside normal working periods. Trending of these systems would take place out of hours.	5,900	1,844	0	88	6.2%	24	3.2
1	HVAC	Install push button timer control of personal heaters	7,000	805	0	38	2.7%	11	8.7
1	DHW	Install time of day control on the domestic hot water circulating pump via the BMS.	650	99		5	0.3%	1	6.6
1	Ref	Replace the refrigerators with 5 star units when due for replacement	0	42		2	0.1%	1	0.0
1	Light	Delamp areas of high light levels	1,008	134	204	6	0.4%	2	3.0
1	Light	Daylight link the link corridor between building 1 and building 4 on level 1 and level 2	1,200	229	87	11	0.8%	3	3.8
1	Off	Implement Energy Star and a staff awareness program	0	127	0	6	0.4%	2	0.0
1	HVAC	Implement night setback on the 100% outside air system (AHU-RF-01) that provides make up air to the laboratories to cover the situation when fume cupboards are left operating after hours. If appropriate the heating could be turned off out of hours instead of night setback.	2,500	168	0	8	0.6%	2	14.8
1	BWU	Install push button timer control to boiling water units	250	10		1	0.0%	0	25.1
2	HVAC	Implement night setback on the tempered air system serving Lab G04 and the four packaged air conditioners serving Labs 102, 104, 106 and 108 to cover the situation when fume cupboards are left operating after hours. If appropriate the heating could be turned off out of hours instead	12,500	5,001		239	24.2%	65	2.5

Building	Category of Initiative	Recommendation	Cost	Savings					Payback
			\$	Energy \$ pa	Maintenance \$ pa	GJ pa	% of tot Energy	t CO ₂ -e pa	yrs
		of night setback.							
2	HVAC	Implement outside air compensation on the tempered air system serving Lab G04 and the four packaged air conditioners serving Labs 102, 104, 106 and 108 to disable heating when the outside air temperature is above 18C or the room temperature is greater than 21C.	2,000	486		23	2.4%	6	4.1
2	HVAC	Install push button timer control of personal heaters	7,000	586		39	4.0%	11	11.9
2	Ref	Replace the refrigerators with 5 star units when due for replacement	0	18		1	0.1%	0	0.0
2	Off	Implement Energy Star and a staff awareness program	0	84	0	4	0.4%	1	0.0
2	HVAC	Install audible alarms on the laboratory doors to ensure doors remain closed at all times.	4,250	132		6	0.6%	2	32.2
2	HVAC	Install a monitoring system via the BMS to track fume cupboard doors that are open for more than a specified period of time, the system should also monitor the air handling plant to ensure that it shuts down outside normal working hours. Trending of these systems would take place out of hours.	9,800	169		11	1.1%	3	58.1
2	BWU	Install push button timer control to boiling water units	250	10		1	0.1%	0	25.1
3	HVAC	Disable the teaching and computer lab time of day control and operate the air conditioning from the adjustable push button timers	8,100	1,850	0	88	2.9%	24	4.4
3	DHW	Install low flow taps with automatic shut off in the student toilets on levels 1 and 2	0	121		6	0.2%	2	0.0
3	Ref	Replace the refrigerators with 5 star units when due for replacement	0	41		2	0.1%	1	0.0
3	Light	Install push button timer control on the staff room lighting and ceiling fans?	450	72	16	3	0.1%	1	5.1
3	Light	Install auto transformer control on the ground floor car park lighting	1,600	614	13	29	1.0%	8	2.6
3	Light	When the building is due for a bulk lamp replacement with triphosphors, conduct a lighting survey and selectively delamp	8,122	1,665	968	79	2.6%	22	3.1
3	Light	Replace the fluorescent tubes in stairs 1 to 3 with T5 28 watt tube kits with electronic ballasts	2,704	454	26	22	0.7%	6	5.6
3	Off	Implement Energy Star and a staff awareness program	0	1,080	0	52	1.7%	14	0.0

Building	Category of Initiative	Recommendation	Cost	Savings					Payback
			\$	Energy \$ pa	Maintenance \$ pa	GJ pa	% of tot Energy	t CO ₂ -e pa	yrs
3	HVAC	Install shut-off dampers on O/A intakes to air-conditioners to close when the each unit is not operating and automate the speed control on the O/A fan.	21,300	1,335	0	64	2.1%	17	16.0
3	HVAC	Install push button timer control of personal heaters	12,250	772		37	1.3%	10	15.9
3	BWU	Install push button timer control to boiling water units	500	21		1	0.1%	0	23.6
4	HVAC	Control the air conditioners in rooms 1.18 and 1.19 using the average of the two temperature sensors to avoid conflicting operations.	1,950	232		11	0.5%	3	8.4
4	HVAC	Install outside air compensation on the tempered air system that serves room G29 so that there is no heating when the outside air is greater than 18C or the room temperature is greater than 21C.	1,500	164		8	0.3%	2	9.2
4	HVAC	Seal the exhaust vent above the fan coil unit discharge in room 141	400	192		9	0.4%	3	2.1
4	HVAC	Convert the time control of the air conditioner serving lecture room G31 to push button timer control.	700	112		5	0.2%	1	6.3
4	Ref	Replace the refrigerators with 5 star units (if due for replacement during this time)	0	82		4	0.2%	1	0.0
4	Light	Delamp areas of high light levels	1,217	168	208	8	0.3%	2	3.2
4	Light	Daylight link the first floor walkway lights below the atrium. (13 by quad by 18 watt lights)	800	208	130	10	0.4%	3	2.4
4	Light	Install PIR control of the lights in the following areas: G31, 118, 119, 120, 122, 123A, 123C, 141, 142 and G02 of the North wing.	4,250	340	292	16	0.7%	4	6.7
4	Light	Install push button timer control of the lights in the staff lunch room 124	250	33	33	2	0.1%	0	3.8
4	Light	Install reduced voltage control of the workshop high bay lights	3,200	432	59	21	0.9%	6	6.5
4	Off	Implement Energy Star and a staff awareness program	0	1,032	0	49	2.1%	13	0.0
4	HVAC	Install push button timer control of personal heaters	19,600	969		65	2.8%	18	20.2
4	BWU	Install push button timer control to boiling water units	750	30		2	0.1%	1	25.1

Building	Category of Initiative	Recommendation	Cost	Savings					Payback
			\$	Energy \$ pa	Maintenance \$ pa	GJ pa	% of tot Energy	t CO ₂ -e pa	yrs
5	DHW	Install time of day control on the laboratory hot water circulating pump	400	145	0	24	3.0%	2	2.8
5	Ref	Replace the refrigerators with 5 star units when due for replacement	0	21	0	1	0.1%	0	0.0
5	Off	Implement Energy Star and a staff awareness program	0	2	0	0	0.0%	0	0.0
5	BWU	Install push button timer control to boiling water units	250	11	0	1	0.1%	0	23.6
6	Ref	Replace the refrigerators with 5 star units (if due for replacement during this time)	0	21	0	1	0.1%	0	0.0
6	Light	Undertake lighting survey and selectively delamp areas of high light levels	660	27	45	1	0.2%	0	9.2
6	Light	Install PIR control of the lighting in the toilet and shower area	800	116	10	6	0.7%	2	6.3
6	Off	Implement Energy Star and a staff awareness program	0	102	0	5	0.6%	1	0.0
6	HVAC	Upgrade the animal house air conditioning systems	55,200	2,928		140	17.7%	38	18.9
6	HVAC	Install push button timer control on personal heater circuits	7,000	346		23	2.9%	6	20.2
6	Light	Install reduced voltage control of high bay lights in G18 and G18A	2,400	104	41	5	0.6%	1	16.5
6	BWU	Install push button timer control to boiling water units	250	11		1	0.1%	0	23.6
8	HVAC	Undertake the scheduled HVAC refurbishment	0	4,319		214	19.3%	59	0.0
8	Ref	Replace the refrigerators with 5 star units when due for replacement	0	84		4	0.4%	1	0.0
8	Light	Undertake the scheduled refurbishment of Lighting systems	0	228	892	11	1.0%	3	0.0
8	Off	Implement Energy Star and a staff awareness program	0	200	0	10	0.9%	3	0.0
8	BWU	Install push button timer control to boiling water units	500	20		1	0.1%	0	25.1
10	HVAC	Install push button timer control on personal heaters	2,450	192		13	2.7%	3	12.8
10	DHW	Install time of day control on the domestic hot water circulating pump	250	168		8	1.7%	2	1.5
10	Ref	Replace the refrigerators with 5 star units when due for replacement	0	146		7	1.5%	2	0.0
11	HVAC	Automate the Auditorium outside air occupancy control and incorporate economy cycle operation.	7,000	4,425	0	237	7.1%	58	1.6
11	HVAC	Install thermostatic control on the level 3 plant room exhaust fans so that they only operate when the condenser units are in operation.	1,000	380	0	18	0.5%	5	2.6
11	DHW	Install time of day control on the domestic hot water circulating pump via the BMS	400	131	0	24	0.7%	2	3.1

Building	Category of Initiative	Recommendation	Cost	Savings					Payback
			\$	Energy \$ pa	Maintenance \$ pa	GJ pa	% of tot Energy	t CO ₂ -e pa	yrs
11	Light	Replace the mercury vapour lamps in the colonnade and auditorium foyer with fluorescent and metal halide downlights respectively; the colonnade lighting is to be controlled by photocell	15,270	1,192	0	57	1.7%	16	12.8
11	Light	Install PE cell control of the top two levels of the multi-level carpark	850	442	12	21	0.6%	6	1.9
11	HVAC	Convert the tenant condenser water system serving the central area of the building to variable speed and control based on wet bulb temperature	8,000	96	0	5	0.1%	1	83.7
12	DHW	Install time clock control of the DHW circulating pump	250	79		10	0.5%	1	3.2
12	Gas	Repair Gas Leak	0	632		115	6.0%	8	0.0
12	Elec	Install electricity metering and charge tenancy	10,000	36,954	0	1,764	92.2%	483	0.3
13	HVAC	Install local push button timer control to replace the on/off control and keyswitch control of the air conditioners and fan coil units serving Aerobics rooms G09 and 106, stretch aerobics room 199 and the four fan coil units servings room 105	3,600	1,415	0	94	0.9%	26	2.5
13	HVAC	Install reset control on AC-1, FC-1, 2, 3 and 4 so that they are shut down when the Centre closes.	6,100	701	0	47	0.5%	13	8.7
13	Pool	Install a variable speed control on the pool filter pumps to operate to maintain a constant flow across the filters between back-flushing.	11,500	4,941	0	236	2.3%	65	2.3
13	Pool	Install solar preheating of the gas fired pool heating system	29,430	7,283	0	1,329	12.9%	95	4.0
13	DHW	Install time of day control of the domestic hot water system circulating pumps	1,300	843	0	152	1.5%	11	1.5
13	DHW	Convert the gas fired domestic hot water system to a solar storage system with gas boost heating	59,485	4,266	0	787	7.6%	56	13.9
13	DHW	Install AAA rated showers and fittings	0	627	0	114	1.1%	8	0.0
13	Light	Install occupancy sensor control of the lighting in rooms 108B, 106 and G09.	1,200	522	63	25	0.2%	7	2.0
13	Light	Install PE control of the carpark lighting	700	344	7	16	0.2%	4	2.0
13	Light	Daylight link the perimeter lights in the exercise area (room 105).	700	189	25	9	0.1%	2	3.3
14	HVAC	Set the time of day schedule to the hours and days that the building is	2,750	383		26	12.3%	7	7.2

Building	Category of Initiative	Recommendation	Cost	Savings					Payback
			\$	Energy \$ pa	Maintenance \$ pa	GJ pa	% of tot Energy	t CO ₂ -e pa	yrs
		normally occupied while the university is in session, install an after hours control through a local momentary switch to provide a maximum of one hour operation of the air conditioning system outside core hours.							
14	HVAC	Implement space temperature setback when the lighting system is not enabled. Turn off the ventilation when the wider settings are satisfied.	3,000	297		20	9.5%	5	10.1
15	HVAC	Install local on/off control and space temperature adjustment of the Biomechanics laboratories	5,000	1,638	0	78	2.1%	21	3.1
15	HVAC	Control the air conditioning in intermittently occupied areas with push button timers at all times	3,500	1,492	0	71	1.9%	19	2.3
15	HVAC	Install roof insulation above rooms G20 and G21	2,980	283	0	13	0.4%	4	10.5
15	Ref	Replace the refrigerators with 5 star units when due for replacement	0	42	0	2	0.1%	1	0.0
15	Light	Install movement control of the lights in seminar/post graduate areas (rooms 107, 108, 111, 113, 206 and 222). ELM 12	3,000	549	180	26	0.7%	7	4.1
15	Light	Replace 36 watt fluorescent tubes in stairways with T5 kits. ELM 26	2,480	351	0	17	0.5%	5	7.1
15	Light	Delamp the lighting in corridors in conjunction with a lighting survey. Refer ELM item 24 and item 27, delamp say 50% in link corridors and 30% in other corridors. Note changes in ELM are highlighted in green	2,200	218	280	10	0.3%	3	4.4
15	Off	Implement Energy Star and a staff awareness program	0	408	0	19	0.5%	5	0.0
15	HVAC	Setback the space temperature outside normal occupancy hours in the North Wing ground floor area served by the tempered air system	6,000	106	0	7	0.2%	2	56.4
15	HVAC	Install push button timer control of personal heaters	26,250	1,370	0	65	1.8%	18	19.2
15	BWU	Install push button timer control to boiling water units	250	8	0	1	0.0%	0	30.8
15	Light	Replace linear fluorescent light fittings in G99 (covered walkway area) with compact fluorescent downlights and daylight link. (ELM 6, 7, 8)	10,400	557	163	27	0.7%	7	14.5
16	HVAC	Energy savings introduced due to reduced operations on chillers for building 17	0	2,025	0	224	2.4%	61	0.0
16	HVAC	Set the time of day schedules to suit the minimum occupancy periods of the areas served	5,000	21,463	0	1,238	13.0%	280	0.2
16	HVAC	Disable night setback and establish the cause of continuous boiler and chiller operation	9,000	4,056	0	347	3.7%	53	2.2

Building	Category of Initiative	Recommendation	Cost	Savings					Payback
			\$	Energy \$ pa	Maintenance \$ pa	GJ pa	% of tot Energy	t CO ₂ -e pa	yrs
16	HVAC	Alter the economy cycle algorithm to maximise the use of outside air cooling, while maintaining the required RH limits within the library	4,300	5,882	0	411	4.3%	77	0.7
16	HVAC	Control the chiller condensing temperature	33,300	6,057	0	289	3.0%	79	5.5
16	HVAC	Rectify chiller staging and plant operating problems	4,500	1,312	0	63	0.7%	17	3.4
16	HVAC	Convert the chilled water valves to two way and modulate the secondary chilled water pumps. Refer to the building 16 report for details on the existing primary/secondary setup.	4,500	322	0	15	0.2%	4	14.0
16	HVAC	Control the variable speed condenser water pumps (chillers 1 and 2) based on maintaining the minimum flow requirements of the chiller at partial load. Refer to the building 16 report for details on the existing variable speed condenser water pumps.	2,500	276	0	13	0.1%	4	9.1
16	HVAC	Implement outside air compensation on the leaving hot water setpoint	4,500	698	0	127	1.3%	9	6.4
16	Ref	Replace the refrigerators with 5 star units when due for replacement	0	58	0	3	0.0%	1	0.0
16	Light	Install after hours push buttons to enable cleaner control of the lighting systems	12,150	1,361	1,562	151	1.6%	41	4.2
16	Light	Refurbish the lighting systems in Rooms 101 and 201 as part of a building refurbishment	213,620	11,205	2,913	535	5.4%	146	15.1
16	Off	Implement Energy Star and a staff awareness program	0	1,377	0	66	0.6%	18	0.0
16	HVAC	Consider supplementary air conditioners as part of the building refurbishment for areas of identified with high thermal loads	67,500	2,992	0	143	1.5%	39	22.6
16	BWU	Install push button timer control to boiling water units	250	10	0	1	0.0%	0	24.3
17	HVAC	Set the time of day schedules to suit the minimum occupancy periods of the areas served and implement optimum start stop incorporating a night purge cycle and holiday scheduling.	7,000	18,050	0	1,308	26.2%	236	0.4
17	HVAC	Alter the economy cycle algorithm to maximise the use of outside air cooling	2,000	549	0	26	0.5%	7	3.6
17	HVAC	Convert the condenser water pump to variable speed control and set the speed to suit the flow requirements of the condenser water loop. Refer to the Building 17 report for details on future expansion requirements of the condenser water system.	7,800	1,122	0	54	1.1%	15	7.0

Building	Category of Initiative	Recommendation	Cost	Savings					Payback
			\$	Energy \$ pa	Maintenance \$ pa	GJ pa	% of tot Energy	t CO ₂ -e pa	yrs
17	HVAC	Convert the heating hot water pump to variable speed control and set the speed to suit the flow requirements of the reticulation loop. Refer to the Building 17 report for details on throttling of the heating hot water pump flow.	4,100	406	0	19	0.4%	5	10.1
17	HVAC	Install CO ₂ control of AHU 1 and 2 outside air dampers, while taking into consideration the minimum air flow requirements of the VAV's	8,500	3,569	0	194	3.9%	47	2.4
17	HVAC	Install occupancy based control of the Presentation room 235 served by AHU-RF-04	2,300	85	0	7	0.1%	1	27.0
18	HVAC	Implement optimum start stop control, after hours control and holiday scheduling on the air conditioning plant controlled by the BMS	2,000	786	0	52	1.2%	14	2.5
18	HVAC	Install push button timer control of personal heaters and provide low wattage under desk heaters with push button timer control for replacement and new personal heaters	10,500	2,126	0	101	2.4%	28	4.9
18	HVAC	Install night setback control of the level 1, level 2 and ground floor tempered air systems	4,500	1,337	0	152	3.6%	17	3.4
18	DHW	Install time of day control of the laboratory circulating gas hot water systems	650	309		53	1.2%	4	2.1
18	Ref	Replace the refrigerators with 5 star units when due for replacement	0	29		1	0.0%	0	0.0
18	Light	Replace stair twin-36 watt tubes with T5 kits	1,954	131	17	6	0.1%	2	13.2
18	Off	Implement Energy Star and a staff awareness program	0	198	0	9	0.2%	3	0.0
18	BWU	Install push button timer control to boiling water units	250	6		0	0.0%	0	40.8
19	HVAC	Install push button timer control on the room air conditioners and packaged air conditioners	8,700	820	0	39	2.0%	11	10.6
19	HVAC	Install push button timer control of personal heaters and provide low wattage under desk heaters with push button timer control for new heaters and replacement personal heaters	39,400	5,579	0	266	13.4%	73	7.1
19	Ref	Replace the refrigerators with 5 star units when due for replacement	0	124	0	6	0.3%	2	0.0
19	Light	Replace fluorescent tubes in stairways with 28 watt T5 kits	2,356	269	0	13	0.6%	4	8.8

Building	Category of Initiative	Recommendation	Cost	Savings					Payback
			\$	Energy \$ pa	Maintenance \$ pa	GJ pa	% of tot Energy	t CO ₂ -e pa	yrs
19	Light	De- lamp teaching area light fittings in conjunction with a bulk lamp replacement with triphosphors	7,258	1,232	1,014	59	3.0%	16	3.2
19	Off	Implement Energy Star and a staff awareness program	0	630	0	30	1.5%	8	0.0
19	HVAC	Replace all room and packaged air conditioners with new more efficient split air conditioners	67,200	740	0	35	1.8%	10	90.8
19	BWU	Install push button timer control to boiling water units	1,500	64	0	4	0.2%	1	23.6
20	HVAC	Install automatic doors on the North and South side of the building	12,800	1,082	0	52	1.3%	14	11.8
20	HVAC	Set the BMS time of day schedules to suit the minimum occupancy periods of the areas served and implement optimum start stop incorporating a night purge cycle, session and holiday scheduling	12,500	6,698	0	320	7.9%	87	1.9
20	HVAC	Install occupancy sensor control to setback the space temperature of the BMS controlled air conditioners. Shut down dedicated air conditioners to these rooms while the temperature is within the setback range	27,500	3,978	0	190	4.7%	52	6.9
20	HVAC	Set the Foyer air conditioner space temperature to the average Lecture Theatre setpoint with a dead band of 4C for heating and cooling	2,800	252	0	12	0.3%	3	11.1
20	HVAC	Install variable speed control of the Lecture Theatre air conditioners to reduce the fan speed based on space CO ₂ levels.	4,800	1,109	0	53	1.3%	14	4.3
20	HVAC	Install signage to indicate that Lecture Theatre and Cedir TV studio doors should remain closed at all times	5,000	755	0	36	0.9%	10	6.6
20	HVAC	Convert the CEDIR offices air conditioners to BMS control and other efficiency improvements. Refer to the Building 20 report for further details.	6,500	13,691	0	654	16.1%	179	0.5
20	HVAC	Establish the reason for the out of hours operation of the Lecture Theatre air conditioning and rectify	3,500	1,198	0	57	1.4%	16	2.9
20	HVAC	Foyer air conditioner load shedding. Refer building 20 report for further details	3,000	275	0	0	0.0%	0	10.9
20	Ref	Replace the refrigerators with 5 star units when due for replacement	0	62	0	3	0.1%	1	0.0
20	Light	Install PE control of the Foyer notice board lighting.	800	103	-21	5	0.1%	1	9.7
20	Light	Install reduced voltage control of the Video Conference room high bay	1,600	288	58	14	0.3%	4	4.6

Building	Category of Initiative	Recommendation	Cost	Savings					Payback
			\$	Energy \$ pa	Maintenance \$ pa	GJ pa	% of tot Energy	t CO ₂ -e pa	yrs
		lights							
20	Light	Install access lighting in the Video Conference room and operate the high bay lighting only when required	5,375	708	-107	34	0.8%	9	8.9
20	Off	Implement Energy Star and a staff awareness program	0	147	0	7	0.2%	2	0.0
20	BWU	Install push button timer control to boiling water units	750	27	0	2	0.0%	0	28.3
21	Ref	Replace the refrigerators with 5 star units when due for replacement	0	41	0	2	1.6%	1	0.0
21	Light	Install movement sensor control in the following ground floor areas: Science lab G01B, Science lab G.01 and Piano lab G.05A	1,200	178	33	8	6.7%	2	5.7
21	Light	Install movement sensor control in the following first floor areas: Visual Arts studios 101A and 101, class room 105 and resource room 102	1,600	320	85	15	12.0%	4	3.9
21	BWU	Install push button timer control to boiling water units	500	21	0	1	1.1%	0	23.6
22	HVAC	Rectify AHU 1 damper operation and alter the economy cycle algorithm to maximise the use of outside air cooling	3,800	566	0	27	1.4%	7	6.7
22	HVAC	Remove the night setback operation and replace with an optimum start/stop control in conjunction with night flush and holiday scheduling of the BMS time of day schedule for AHU 1.	10,000	10,051	0	868	43.8%	131	1.0
22	HVAC	Implement chilled water temperature setpoint reset control, while ensuring that temperatures and RH levels are maintained at acceptable levels.	6,500	581	0	28	1.4%	8	11.2
22	HVAC	Implement outside air compensation on the leaving hot water setpoint and increase deadbands on zone re-heat systems	8,500	885	0	108	5.5%	12	9.6
22	HVAC	Replace the 11kW chilled water pump motor with a 5.5 kW motor. Refer to the Building 22 report for further details.	1,800	140	0	7	0.3%	2	12.8
22	HVAC	Reposition the Zone 2 sensor located in the library away from local heat sources	900	371	0	35	1.8%	5	2.4
22	Light	Install movement sensor control of the lights in meeting room 102A, computer labs 101 and 102	1,200	90	-3	4	0.2%	1	13.7
23	HVAC	New issue heaters should be a low wattage under desk convection type with the only mode of control being push button timer, the maximum timer setting should be two hours	0	180	0	9	4.9%	2	0.0

Building	Category of Initiative	Recommendation	Cost	Savings					Payback
			\$	Energy \$ pa	Maintenance \$ pa	GJ pa	% of tot Energy	t CO ₂ -e pa	yrs
23	Ref	Replace the refrigerators with 5 star units when due for replacement	0	41	0	2	1.1%	1	0.0
23	Light	Install occupancy sensor control of the corridor lighting	800	73	-1	3	2.0%	1	11.1
23	Off	Implement Energy Star and a staff awareness program	0	68	0	3	1.9%	1	0.0
23	HVAC	Install reset control of the ground floor heater circuits	1,350	77	0	4	2.1%	1	17.5
23	BWU	Install push button timer control to boiling water units	500	21	0	1	0.8%	0	23.6
25	HVAC	AHU-1 - alter de-humidification, O/A cycle, disable night set-back, review night purge, chilled water setpoint control, O/A compensation on boiler, holiday scheduling, HHW pump control, CO2 control of O/A quantities	9,950	1,741		169	6.1%	29	5.7
25	HVAC	Link the operation of ACU-GF-01 (G18 lecture theatre) to the existing occupancy sensor so that the space temperature is set back when the room is not occupied	2,000	208		10	0.4%	3	9.6
25	HVAC	Link the operation of ACU-RF-01 (128 lecture theatre) to the existing occupancy sensor so that the space temperature is set back when the room is not occupied.	2,000	1,033		49	1.8%	13	1.9
25	HVAC	Disable the tempered air systems heating (AHU-RF-01, AHU-RF-02, AHU-RF-03 and SAF-GF-01) when the outside air temperature is greater than 18C	6,200	1,933		92	3.3%	25	3.2
25	HVAC	Incorporate public holiday and university holiday scheduling into the time of day control of AC-GF-01, AC-GF-02, AC-GF-03, AC-RF-01, AHU-RF-01, AHU-RF-02, AHU-RF-03, SAF-GF-01 and SAF-GF-02	600	436		21	0.8%	6	1.4
25	HVAC	Install push button timer control of personal heaters and provide low wattage under desk heaters with push button timer control for replacement and new personal heaters.	16,100	1,335		64	2.3%	17	12.1
25	Ref	Replace the refrigerators with 5 star units when due for replacement	0	124		6	0.2%	2	0.0
25	Light	Install push button timer control of the first floor South corridor art display spotlights, one push button timer is to be installed for each light track. (Steve, there are 5 tracks.Item 8 in ELM)	2,500	807	95	39	1.4%	11	2.8
25	Light	Install occupancy control of the ground floor lecture theatre (room 107) and room 153 lighting. Steve, room 152 has 9 twin 36 watt fittings, the	2,200	549	227	26	0.9%	7	2.8

Building	Category of Initiative	Recommendation	Cost	Savings					Payback
			\$	Energy \$ pa	Maintenance \$ pa	GJ pa	% of tot Energy	t CO ₂ -e pa	yrs
		lecture theatre has 30 x twin 36 watt fittings plus 28 x 36 watt compact fluorescents							
25	Off	Implement Energy Star and a staff awareness program	0	290	0	14	0.5%	4	0.0
25	BWU	Install push button timer control to boiling water units	1,000	39		3	0.1%	1	25.6
29	Ref	Replace the refrigerators with 5 star units when due for replacement	0	20	0	1	1.4%	0	0.0
29	Off	Implement Energy Star and a staff awareness program	0	36	0	2	2.6%	0	0.0
29	HVAC	Install push button timer control of personal heaters	2,150	94	0	4	6.7%	1	22.9
29	BWU	Install push button timer control to boiling water units	250	10	0	1	1.0%	0	26.0
30	HVAC	Alter the economy cycle algorithm to maximum the use of outside air cooling	2,000	1,519	0	73	1.3%	20	1.3
30	HVAC	Implement optimum start stop control in conjunction with night purge and set air conditioning time of day schedules to core occupancy hours	7,000	18,369	0	1,680	30.6%	240	0.4
30	HVAC	Review the night purge facility control strategy	2,300	669	0	32	0.6%	9	3.4
30	HVAC	Implement chilled water temperature setpoint reset control, while ensuring that temperatures and RH levels are maintained at acceptable levels.	6,500	3,020	0	144	2.6%	39	2.2
30	HVAC	Implement outside air compensation on the leaving hot water setpoint	8,500	974	0	178	3.2%	13	8.7
30	HVAC	Install push button timer control of the Demountables room air conditioners	7,250	554	0	26	0.5%	7	13.1
30	Ref	Replace the refrigerators with 5 star units when due for replacement	0	61	0	3	0.0%	1	0.0
30	Light	Install PE control of the lights in the ground floor foyer adjacent to S2 and the corridor on the Western side	400	49	4	2	0.0%	1	7.5
30	Light	Install PE control of the lights in the ground floor foyer G07	400	110	22	5	0.1%	1	3.0
30	Light	Install movement sensor control of the Demountable classroom lights. Refer to the Building 30 report for details on the Demountable classrooms recommendations	5,200	552	124	26	0.4%	7	7.7
30	Off	Implement Energy Star and a staff awareness program	0	340	0	16	0.3%	4	0.0
30	BWU	Install push button timer control to boiling water units	500	20	0	1	0.0%	0	24.9
30	Light	Install PE control of the lights in the ground floor foyer adjacent to S1	400	32	-5	2	0.0%	0	14.6

Building	Category of Initiative	Recommendation	Cost	Savings					Payback
			\$	Energy \$ pa	Maintenance \$ pa	GJ pa	% of tot Energy	t CO ₂ -e pa	yrs
31	HVAC	Install push button timer control of personal heaters and provide low wattage under desk heaters with push button timer control for new heaters and replacement personal heaters	2,000	238	0	11	3.5%	3	8.4
31	Ref	Replace the refrigerators with 5 star units when due for replacement	0	19	0	1	0.3%	0	0.0
31	Light	PIR and daylight link the lunch room lighting	550	84	6	4	1.2%	1	6.2
31	Off	Implement Energy Star and a staff awareness program	0	64	0	3	0.9%	1	0.0
31	BWU	Install push button timer control to boiling water units	500	21	0	1	0.4%	0	23.6
35	HVAC	Incorporate optimum start stop in conjunction with night purge and set the BMS time of day schedule to core occupancy times, utilise after hours push button control at all other times including university recess and public holiday periods	500	2,276	0	122	1.8%	30	0.2
35	HVAC	Install movement sensors to setback the lecture theatre space temperatures when the space is unoccupied while the BMS time of day schedule is enabled. Shut down the systems when the temperature is within the setback range.	1,500	242	0	23	0.3%	3	6.2
35	HVAC	An economy cycle that maximises the lecture theatre outside air cooling	500	99	0	5	0.1%	1	5.1
35	HVAC	Incorporate space temperature setback of the rooms served by SF-1	5,000	2,333	0	426	6.1%	30	2.1
35	HVAC	Control the cooling tower fan based on wet bulb temperature	1,800	270	0	13	0.2%	4	6.7
35	HVAC	Incorporate optimum start stop in conjunction with night purge and set the BMS time of day schedule to core occupancy times, utilise after hours push button control at all other times including university recess and public holiday periods	500	616	0	29	0.4%	8	0.8
35	HVAC	Install movement sensors to setback the lecture theatre space temperatures when the space is unoccupied while the BMS time of day schedule is enabled. Shut down the systems when the temperature is within the setback range. A setback of +/-2C should be used during system enabled times – subject to site testing)	1,500	192	0	9	0.1%	3	7.8
35	HVAC	An economy cycle that maximises the lecture theatre outside air cooling	500	52	0	2	0.0%	1	9.7
35	HVAC	Install push button timer control of personal heaters	8,000	761	0	36	0.5%	10	10.5

Building	Category of Initiative	Recommendation	Cost	Savings					Payback
			\$	Energy \$ pa	Maintenance \$ pa	GJ pa	% of tot Energy	t CO ₂ -e pa	yrs
35	Ref	Replace the refrigerators with 5 star units when due for replacement	0	41	0	2	0.0%	1	0.0
35	Light	Install movement sensor control of the corridor lights	6,800	462	314	22	0.3%	6	8.8
35	Light	Convert the on/off push button timer control of the lecture theatre lights to time duration control (use 2 stage control to provide warning prior to total shut-down)	1,400	60	230	3	0.0%	1	4.8
35	BWU	Install push button timer control to boiling water units	500	18	0	1	0.0%	0	28.3
36	HVAC	Install after hours push button control of the banks of Daikin air conditioners via the BMS and set the time of day schedule to normal occupancy hours and implement optimum start stop in conjunction with night purge	5,000	1,290	0	62	3.8%	17	3.9
36	HVAC	Re-label the after hours push buttons for AC 1 and AC 2 located in the level 3 foyer to identify the area served. Set the time of day schedule for the level 4 offices and foyer (AC 1 and AC 2) to core occupancy hours and utilise the after hours push buttons at all other times	1,200	196	0	25	1.5%	3	6.1
36	HVAC	Set the time of day schedule for the level 3 meeting rooms (AC 3 and AC 4) to core occupancy hours and utilise the after hours push buttons at all other times.	500	186	0	23	1.4%	2	2.7
36	Ref	Replace the refrigerators with 5 star units when due for replacement	0	62	0	3	0.2%	1	0.0
36	Light	De-lamp the triple 18 watt fittings in the corridors on levels 1, 2 and 3 by removing the centre tube in each fitting.	1,332	226	124	11	0.7%	3	3.8
36	Light	Reduce the lighting level in the level 3 stair area to the correct level during the forthcoming refurbishment	0	123	34	6	0.4%	2	0.0
36	Light	De-lamp the triple 36 watt fittings in the open plan office area (room 203) in conjunction with a light level survey by removing the centre tube of each fitting.	1,384	283	173	14	0.8%	4	3.0
36	Light	Install movement sensor control of the lighting in meeting rooms 301 to 305 inclusive.	1,200	132	30	6	0.4%	2	7.4
36	Light	Install movement sensor control of the lighting in the staff lunch room (room 207).	550	25	243	1	0.1%	0	2.1
36	Light	Replace the low level mercury vapour down lights in the level 1 foyer	0	199	26	10	0.6%	3	0.0

Building	Category of Initiative	Recommendation	Cost	Savings					Payback
			\$	Energy \$ pa	Maintenance \$ pa	GJ pa	% of tot Energy	t CO ₂ -e pa	yrs
		with more efficient alternatives at the time of refurbishment.							
36	Off	Implement Energy Star and a staff awareness program	0	470	0	22	1.4%	6	0.0
36	HVAC	Install occupancy sensor control of the meeting room 301 air conditioner (AC-3) to setback the space temperature when the room is unoccupied. Shut down the air conditioner when the temperature is within the setback range	5,300	144	0	15	0.9%	2	36.8
36	HVAC	Convert the cooling tower fan to variable speed and control the condenser water temperature to a set point of 3C above the outdoor wet bulb temperature down to a minimum of 21C by cooling tower bypass and modulation of the cooling tower fan speed	5,400	246	0	12	0.7%	3	21.9
36	HVAC	Implement outside air compensation on the leaving hot water setpoint	4,300	226	0	41	2.5%	3	19.1
36	BWU	Install push button timer control to boiling water units	750	32	0	2	0.1%	1	23.6
38	Ref	Replace the refrigerators with 5 star units when due for replacement	0	21	0	1	0.4%	0	0.0
38	Light	Introduce energy efficient measures into the lighting systems as part of the new refurbishment	2,700	279	0	13	5.6%	4	9.7
38	Off	Implement Energy Star and a staff awareness program	0	113	0	5	2.3%	1	0.0
38	BWU	Install push button timer control to boiling water units	250	9	0	1	0.2%	0	28.3
39	HVAC	Control the stage 1 air conditioners and condenser water system from the BMS	72,000	16,847	0	804	5.3%	220	4.3
39	HVAC	Operate the condenser water system within the manufacturer's recommended temperature limits	4,500	0	1,847	0	0.0%	0	2.4
39	HVAC	Replace the stage 3 condenser water pump and motor with a pump set designed for the plant installed	1,800	414	0	20	0.1%	5	4.3
39	HVAC	Alter the economy cycle to maximise outside air cooling	1,500	4,628	0	221	1.5%	60	0.3
39	HVAC	Control the cooling tower fan based on wet bulb temperature	3,800	4,165	0	199	1.3%	54	0.9
39	HVAC	Incorporate optimum start/stop in conjunction with night purge and set the BMS time of day schedule to core occupancy hours and utilise the after hours push buttons at all other times	4,000	4,208	0	512	3.4%	55	1.0
39	HVAC	Disable night setback and establish the cause of continuous boiler and	8,000	12,42	0	2,084	13.7%	162	0.6

Building	Category of Initiative	Recommendation	Cost	Savings					Payback
			\$	Energy \$ pa	Maintenance \$ pa	GJ pa	% of tot Energy	t CO ₂ -e pa	yrs
		chiller operation		3					
39	HVAC	Implement chilled water temperature setpoint reset control, while ensuring that temperatures and RH levels are maintained at acceptable levels.	6,000	2,146	0	102	0.7%	28	2.8
39	HVAC	Implement outside air compensation on the leaving hot water setpoint	4,300	1,475	0	269	1.8%	19	2.9
39	Ref	Replace the refrigerators with 5 star units when due for replacement	0	78	0	4	0.0%	1	0.0
39	DHW	Install time of day control on the domestic hot water circulating pump serving stage 1 and 2	2,900	299	0	20	0.1%	5	9.7
39	Light	Replace auto/off/manual keyswitches in rooms 151, 151A, 152, 153 and 153A of level 1 stage 3 with a local on/off switch in series with a movement sensor	2,000	219	31	10	0.1%	3	8.0
39	Light	Daylight link the walkway lights running parallel to the atrium on level 1 stage 3	1,200	54	40	3	0.0%	1	12.8
39	Light	Daylight link the compact fluorescent downlights that run parallel to the atrium on level 2 stage 3	1,200	136	80	6	0.0%	2	5.6
39	Light	Replace the resource/archives/meeting room keyswitch room 2S10 on level 2 stage 3 with push button timer control.	200	29	8	1	0.0%	0	5.4
39	Light	Replace the 36 watt fluorescent lamps in the fire stairs with T5 28 watt kits with electronic ballasts	1,488	209	0	10	0.1%	3	7.1
39	Light	Install auto transformer control of the car park lighting	1,600	316	27	15	0.1%	4	4.7
39	Light	Install auto transformer control of the Robotics workshop high bay lights	1,950	73	75	4	0.0%	1	13.1
39	Off	Implement Energy Star and a staff awareness program	0	846	0	40	0.3%	11	0.0
39	HVAC	Convert the chilled water system to a primary/secondary system. Refer to the Building 39 report for the background to this recommendation and the possible cause of problems relating to this system	32,250	780	0	37	0.2%	10	41.4
39	BWU	Install push button timer control to boiling water units	3,000	119	0	8	0.1%	2	25.3
40	HVAC	Improve the control of the Block C Theatre air conditioning system. Refer to the Building 40 report for the background to this recommendation.	24,000	1,704	0	81	2.5%	22	14.1

Building	Category of Initiative	Recommendation	Cost	Savings					Payback
			\$	Energy \$ pa	Maintenance \$ pa	GJ pa	% of tot Energy	t CO ₂ -e pa	yrs
40	HVAC	Convert the cooling tower fan to variable speed and control based on wet bulb temperature	3,000	666	0	32	1.0%	9	4.5
40	HVAC	Install push button timer control of personal heaters	17,000	3,846	0	184	5.6%	50	4.4
40	HVAC	Control the operating times of the Block A and Block B office air conditioners by timer control	8,100	1,006	0	48	1.5%	13	8.1
40	HVAC	Control the proprietary controllers in Block A East and Block B, level 2 computer labs by the BMS time of day schedule in conjunction with optimum start/stop, holiday and university recess scheduling	17,000	3,677	0	176	5.4%	48	4.6
40	Ref	Replace the refrigerators with 5 star units when due for replacement	0	169	0	8	0.2%	2	0.0
40	Light	Replace stairway linear fluorescent tubes with T5 28 watt tube replacement kits	2,232	278	0	13	0.4%	4	8.0
40	Light	Replace corridor dichroics with 9 watt compact fluorescents	23,000	1,008	644	48	1.5%	13	13.9
40	Light	Install movement sensor control of the lights in rooms 125, 126 and 131	1,200	159	24	8	0.2%	2	6.5
40	Light	Install movement sensor control of the corridor lighting	12,000	1,187	303	57	1.7%	16	8.1
40	Light	De-lamp the triple 36 watt fittings in room 131.	448	61	45	3	0.1%	1	4.2
40	Light	Selectively de-lamp the Block B computer labs and corridor in conjunction with a light level survey	2,640	109	166	5	0.2%	1	9.6
40	Off	Implement Energy Star and a staff awareness program	0	646	0	31	0.9%	8	0.0
40	BWU	Install push button timer control to boiling water units	1,750	61	0	4	0.1%	1	28.5
41	HVAC	Incorporate holiday scheduling of the Anatomy Laboratory air conditioning system and review controls as part of the forthcoming refurbishment to eliminate excessive running	0	656	0	31	0.4%	9	0.0
41	HVAC	Stage 2 BMS time of day schedule and optimum start/stop	7,000	8,724	0	416	4.8%	114	0.8
41	HVAC	Modify the outside air economy cycle to maximise the use of outside air for cooling	7,000	3,576	0	171	2.0%	47	2.0
41	HVAC	Convert the condenser water pumps to variable speed control and set the speed to suit the flow requirements of the condenser water loop	7,800	1,427	0	68	0.8%	19	5.5

Building	Category of Initiative	Recommendation	Cost	Savings					Payback
			\$	Energy \$ pa	Maintenance \$ pa	GJ pa	% of tot Energy	t CO ₂ -e pa	yrs
41	HVAC	Rectify the cooling tower staging	7,800	835	0	40	0.5%	11	9.3
41	HVAC	Incorporate space temperature setback on the stage 3 laboratory tempered air systems outside core occupancy times	12,000	1,055	0	50	0.6%	14	11.4
41	Ref	Replace the refrigerators with 5 star units when due for replacement	0	205	0	10	0.1%	3	0.0
41	DHW	Install time of day control of the circulating gas hot water systems	1,900	1,769	0	261	3.0%	26	1.1
41	Off	Implement Energy Star and a staff awareness program	0	1,355	0	65	0.7%	18	0.0
41	HVAC	Convert the cooling tower fans to variable speed and control the condenser water temperature	10,100	579	0	28	0.3%	8	17.5
41	HVAC	Modify stage 2 air conditioner control strategies. Refer to the Building 41 report for details on this recommendation.	67,200	4,686	0	224	2.6%	61	14.3
41	BWU	Install push button timer control to boiling water units	1,750	62	0	4	0.0%	1	28.3
42	DHW	Install time of day control on the domestic hot water circulating pump	700	87	0	6	2.5%	2	8.0
42	Off	Implement Energy Star and a staff awareness program	0	43	0	2	0.9%	1	0.0
42	Other	Implement a staff awareness program to ensure that all unnecessary laboratory equipment and support services are turned off when not needed.	0	110	0	5	2.3%	1	0.0
42	HVAC	Install push timer control of room air conditioners and personal heaters.	2,050	73	0	3	1.5%	1	28.1
42	Light	Install movement sensor control of the first floor laboratory lights	1,800	91	15	4	1.9%	1	17.0
67	HVAC	Install occupancy based setback on lecture theatre air conditioning	6,500	890	0	61	2.0%	12	7.3
67	HVAC	Incorporate holiday scheduling and optimum start/stop into the BMS time of day schedule	2,000	412	0	25	0.8%	5	4.9
67	HVAC	Install CO2 control of the lecture theatre outside air dampers	5,000	367	0	24	0.8%	5	13.6
67	HVAC	Install a bypass valve on the cooling tower	12,800	1,242	0	174	5.6%	16	10.3
67	HVAC	Alter the lecture theatre economy cycle to maximise outside air cooling	4,300	304	0	14	0.5%	4	14.2
67	Ref	Replace the refrigerators with 5 star units when due for replacement	0	117	0	6	0.2%	2	0.0
67	BWU	Install push button timer control to boiling water units	500	38	0	3	0.1%	1	13.3
67	DHW	Install time of day control of level 2 plant room domestic hot water circulating pump	600	318	0	21	0.7%	6	1.9

Building	Category of Initiative	Recommendation	Cost	Savings					Payback
			\$	Energy \$ pa	Maintenance \$ pa	GJ pa	% of tot Energy	t CO ₂ -e pa	yrs
67	Off	Implement Energy Star and a staff awareness program	0	232	0	11	0.4%	3	0.0
67	HVAC	Install push button timer control on personal heaters	12,300	413	0	20	0.6%	5	29.8
Sub 4	PFC	Improve Power Factor Correction	16,875	3,516	0	67 kVA	n/a	n/a	4.8
Sub 5	PFC	Improve Power Factor Correction	13,125	2,996	0	62 kVA	n/a	n/a	4.4
Sub 6	PFC	Improve Power Factor Correction	18,750	4,438	0	84 kVA	n/a	n/a	4.2
Sub 7-1	PFC	Improve Power Factor Correction	15,000	3,056	0	68 kVA	n/a	n/a	4.9
Sub 7-2	PFC	Improve Power Factor Correction	3,750	301	0	12 kVA	n/a	n/a	12.5
Sub Bld 30	PFC	Improve Power Factor Correction	5,625	1,360	0	26 kVA	n/a	n/a	4.1
Sub Bld 40	PFC	Improve Power Factor Correction	7,500	1,434	0	30 kVA	n/a	n/a	5.2