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Moore Theological College
Cogeneration Feasibility Study

Prepared for

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The success and realisation of the proposed initiatives will be dependent upon the commitment of the design team, the development of the initiatives through the life of the design and also the implementation into the operation of the building. Without this undertaking the proposed targets may not be achieved.

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Executive Summary

This report investigates the feasibility of incorporating a cogeneration system to supply the Moore College Campus development through each foreseen construction phase with hot water services (HWS) and electrical energy. Both the accumulated HWS and electrical loads where established progressively for each building stage, and independently as a standalone development.

Operating profiles for both existing and future stages were determined. Existing HWS profiles for the dining facilities and communal ladies showers used in 28 Carillon House were investigated in detail, as this was deemed early on as the largest HWS requirements for the Campus. Profiles for the existing and new build electrical loads were also created.

The construction sequence and phasing is assumed based on information provided by the Architect to date. It's noted the first stage, will be either a Library built in 3 stages, with the second part of the building constructed sometime in the future. These sub-options were not investigated. The first stage is expected for completion by 2012, and each subsequent stage is completed 4 years thereon, with stage 5 completed by 2028.

When considering the various occupancy and use patterns, the majority of the time the buildings are within term-time, and this represents 53% of the year (inc weekends). Therefore the analysis mainly focuses around this duration.

The HWS profiles peaked during serving periods, such as breakfast, lunch, and dinner, mainly for the dining room facility but also the residential properties. The HWS requirement could be smoothed with the introduction of a calorifier. For the Academic buildings, the HWS requirement was considered steadier throughout the day. Typically the HWS load necessary for each building was below the equivalent heat generated from the cogeneration units considered. The exception was during Stage 3, whereby it was assumed the dining room facility would be re-introduced. This provided an approx 55kW base heat load.

Apart from Stage 3 all other stages do not warrant cogeneration as the heat source, thus implying cogeneration could not be utilised. As a result the strategy changed and the focus steered towards potential savings in CO_2 emissions between electricity production on site via the gas-driven cogeneration unit, compared to a coal driven power station. In addition, both the energy prices of gas and electrical was obtained to determine whether the cheaper gas rates, re-couped the initial capital outlay within a reasonable period of time.

Cogeneration units operate at maximum efficiency at full load, and their efficiencies fall at part loads, with a minimum turn down of around 50% (based on reciprocating engines. Smaller micro-turbine units have an improved turn down ratio in comparison). This report assumes all cogeneration units operate at full load. All the electrical load profiles for each stage were reviewed and a number of hours were recorded for which a suitable cogeneration unit could operate. This meant the hours of operation fell between electrical peak and shoulder periods only.

Energy prices from Energy Australia and AGL were obtained. The report excludes any potential future negotiations the college undertakes to secure reduced rates. Electrical costs varied between peak, shoulder and off peak. The energy costs for electricity is: peak (2pm – 8pm) 0.3509 $/kWh and shoulder (7am – 2pm and 8pm – 10pm) $0.1419 $/kWh. The energy costs for gas is: 0.06027 $/kWh. Note electricity costs are currently 5.8 times larger than gas during peak times. Costs for maintaining the generator was 0.04$/kWh

The feasibility of cogeneration appears to fall solely on the future energy rates for both electricity and gas, and this is emphasised for every stage sequentially. A pessimistic view would prolong any reasonable payback period from 16 years to 30 years plus by stage 5, but if the cost of electricity continues to elevate at a faster rate than gas, much shorter pay back periods occur of around 6 – 10 years.

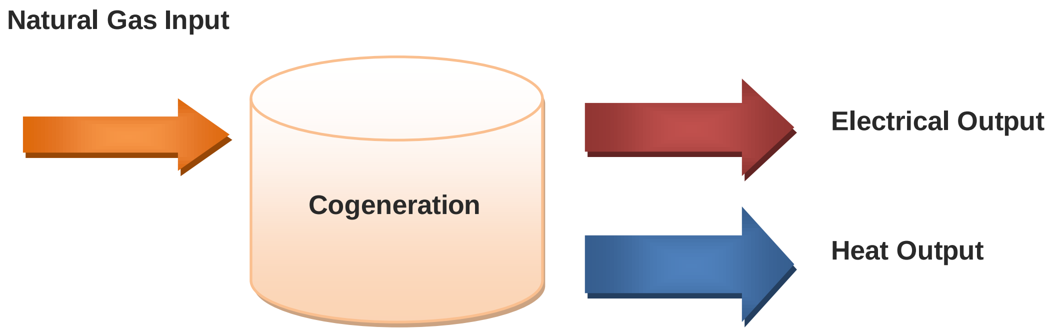
This document describes the basics of the cogeneration application. Preliminary pricing information has been assessed through discussions with manufacturers and current indications of likely future energy price rises. Whilst Cundall has endeavoured to ensure the information used is accurate we do not accept any liability in relation to the results due to the reliance of third party information and the inherent uncertainty of future energy prices.

Contents

Introduction

Cogeneration is the production of two useful fuel outputs from one source, in this case it is the generation of high temperature heat and electricity from the same process utilising natural gas as the fuel intake.

Figure 1. Cogeneration Basic Principle



This report investigates the potential for utilising cogeneration for the Moore College Campus for existing facilities and future phased buildings, such as new Academic and Residential Buildings.

Cogeneration offers economic and environmental benefits because it transforms otherwise wasted heat into a useful energy resource. With the drive from consumers and the government to reduce greenhouse gas emissions in Australia, cogeneration provides a cost effective solution that reduces the quantities of pollutants and greenhouse gases emitted in supplying electricity and heating.

With the rising costs of electricity, consumers are looking at alternative means of energy generation as a method of making savings in both costs and emissions. The types of businesses that are most likely to benefit from cogeneration are those that use large quantities of heat or steam and have a simultaneous base electrical demand such as hospitals, hotels and food processing plants.

The most important consideration for sizing the cogeneration system is to ensure that both the heat and electricity outputs can be utilised hence there needs to be a simultaneous demand for both heat and power.

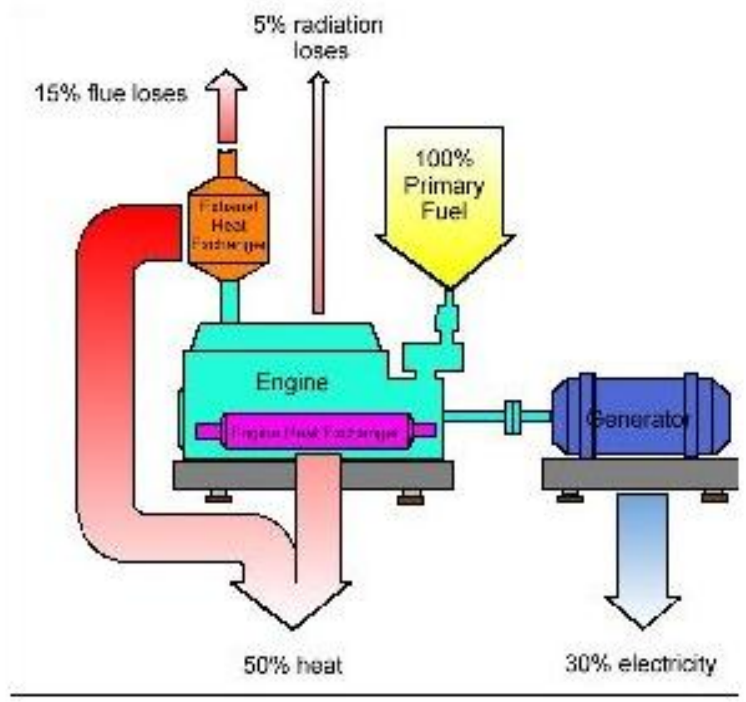
A survey was undertaken to ascertain the existing electrical and heat loads for the Campus. The Moore College has relatively limited heat demand for a campus so fit's size, limited to the main ladies shower blocks in 28 Carillon House, and kitchen dining facilities in 2-16 Carillon Avenue.

In this report the likely load profiles for Moore College Campus have been developed and analysed to determine the most suitable cogeneration application. Information with regards to the hot water and electrical consumption has been taken from the information provided by Moore College, or in the absence of such information, reasonable assumptions have been made.

The payback period will be influenced by the cost of energy prices which has been assumed an initial price rise of 12% and 20% for gas and electricity respectively. Thereon gas inflates at 4% and electricity at 7%. Ongoing maintenance costs were also factored in the report, and they will affect the overall pay back periods.

In Figure 2 below demonstrates a typical cogeneration system where gas is used by the engine to generate electricity and the resultant by product of heat is captured and used for heating requirements. The primary fuel is usually gas or diesel and the heat energy is extracted from the flue gasses and the engine coolant system. Typical efficiency for a cogeneration engine is around 50% thermal and 30% electrical.

Figure 2. Cogeneration Diagram.



1 Cogeneration Concept

Cogeneration can be utilised to provide hot water, steam and electrical energy requirements. In this application steam is not required, and exceeds to all campus heat load requirements.

- The two demands will be analysed to obtain the most effective method of sizing the cogeneration unit to ensure adequate utilisation.
- The Moore College operating profiles will be analysed to determine the base load requirements to ensure the unit is sized for effective utilisation. Cogeneration units currently have a turn down ratio of 50%. The turn down ratio is the lowest percentage of its full capacity the unit can operate at. Hence the unit can only go down to half its full operating capacity. Any demand below this threshold cannot be met by the cogeneration unit as it will have to turn off.

1.1 Cogeneration Operation

The cogeneration system will be run in parallel to the grid and existing heating system to ensure there is back up during maintenance outage. Cogeneration is most effective when it is sized for thermal demand which means the gas burned for heating is firstly utilised to generate power and therefore the electricity generated is essentially free. The savings from the production of electricity are used to offset the additional capital costs of installing a cogeneration system.

1.2 Cogeneration Considerations

Noise from the cogeneration unit can be an issue because the College Campus contains both teaching and residential properties. Therefore sufficient sound attenuation should be provided. The extent of treatment will be dependent on chosen location for the cogeneration plant.

To maximise return from cogeneration, the plant should be sized to produce the energy requirements running at full capacity for a minimum of 8-10 hours per day and operate during peak electricity tariff periods.

1.3 Cogeneration Type

There are different types of cogeneration engines in the market which are suited to different applications. The type of unit forming the basis of this feasibility analysis is a reciprocating engine which is a well known technology in the market place and offers high electrical efficiency.

There are four sources of usable waste heat from a reciprocating engine: exhaust gas, engine jacket cooling water, lube oil cooling water, and turbocharger cooling, the last three normally form the jacket cooling water system. Heat can generally be recovered in the form of hot water.

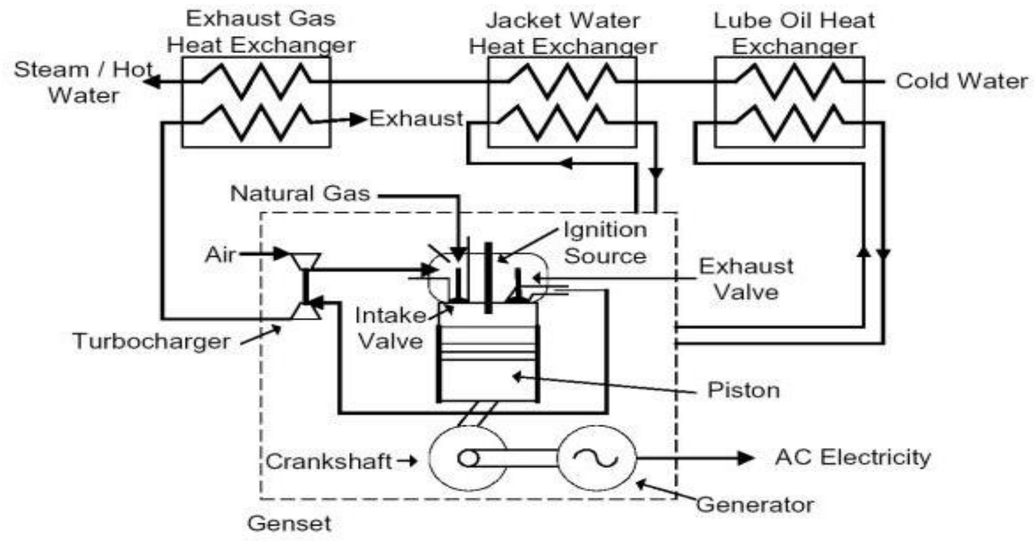
These engines also have a lower capital cost than other types of engines and some are available in a wide range of sizes suitable for this site.

The most common method of recovering engine heat is the closed-loop cooling system. These systems are designed to cool the engine by forced circulation of a coolant through engine passages and an external heat exchanger. The diagram below shows how a typical reciprocating engine works to produce electricity, heat and steam:

The diagram below provides a simple schematic of how the cogeneration unit would operate:

The cogeneration unit will produce:

- Electrical energy which can be used to feed the electrical demands for Moore College
- Hot Water at 80 °C from the engine jacket cooling system which can serve the HWS calorifier providing hot water to the communal showers and kitchen/dining facility.



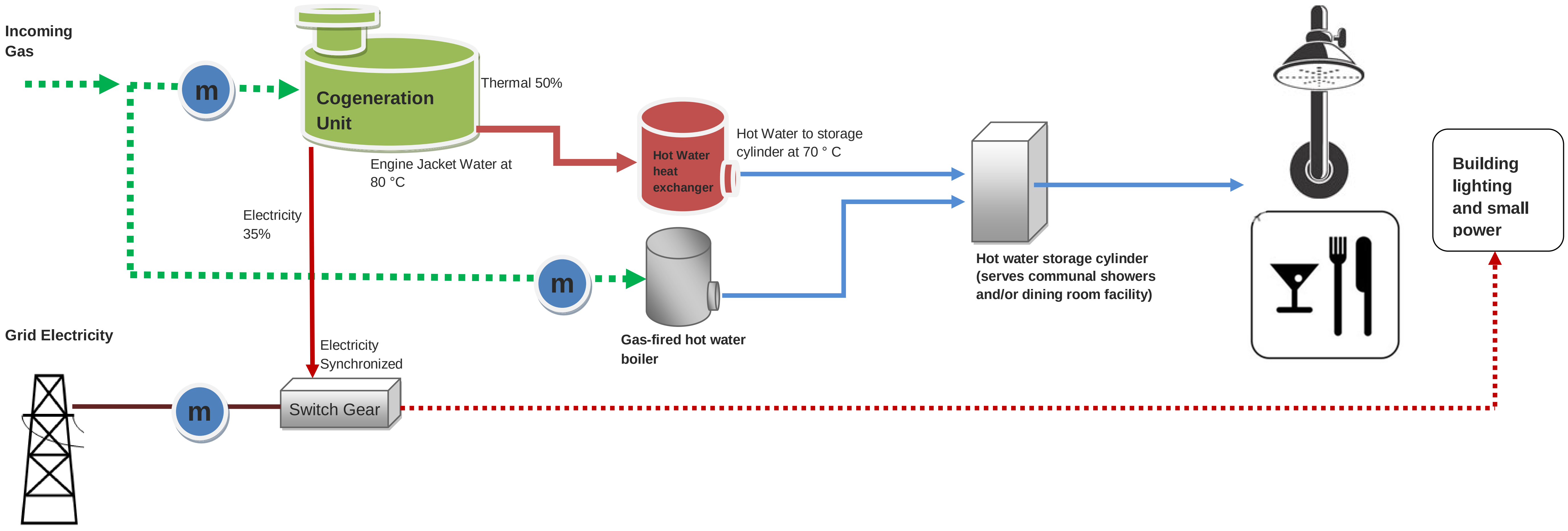
2 Proposed System

The schematic below details how the cogeneration system could be integrated into the existing systems serving Moore College and how the energy will be used: As discussed in more detail later within the report, only the Ladies communal showers and the 200 seat dining facility requires a heat load similar to that produced by the cogeneration unit.

- The intent is for the cogeneration unit to run in parallel with the existing gas fired hot water heaters/boiler which provides the hot water requirements primarily to the communal Ladies showers, and the dining facility.
- Hot water from the engine jacket cooling system at 80 °C will be utilised to feed into a hot water heat exchanger to serve the hot water storage cylinder. The hot water storage cylinder should provide a buffer during small fluctuations of the load demand, and smooth out any peak demand that would be present from example the dining room facility when it serves during breakfast, lunch and dinner.
- Ideally a steam waste heat exchanger will be used to capture the flue heat, however due to the relatively low heat demand of Moore College this isn't feasible, so the energy from the flue gases cannot be recaptured.
- The electricity produced will feed into the relevant distribution board serving the residential or academic building electricity demand. The cogeneration unit will need to be synchronized with the grid via the onboard controls.

Note the proposed system is a concept only and further design development will be required to ensure integration with the existing system.

Figure 3. Cogeneration schematic



3 Development Phasing/Staging

A notional strategy exists with regard to the future construction phasing of the Moore College Campus. This has been interpreted in summary by Table 1. It's assumed the first building is constructed by 2012, and 4 years thereafter the next stage is completed, and so on. Location of each building is highlighted in Figure 4. It is probable stage 1 shall be split into two phases which may integrate with other stages. This has been ignored at present, until the phasing strategy is agreed.

Table 1. Notional Construction Phasing & Proposed Building Use.

Stage	Site	Building NO.	Existing Use	Proposed Use	Build Year	NLA
1	A	1	2 King Street - Administration 3-11 King St Residential Other Residential	Academic / Teaching	2012	7839
2	B	2	Residential Residential	Residential Residential	2016 2016	2552 1063
3	A	8	Residential Dining Room Kitchen Teaching / Academic	Academic / Teaching Residential	2020	2443 1817
4a	B	2	Residential	Residential	2024	4500
4b	A	4	Offices Garage Residential	Academic / Teaching Retail	2024	803 553
5	B	1	Child Care Centre	Residential	2028	1519

The site is split into three defined areas, labelled 'A', 'B' and 'C'. Site C is typically old residential properties, and doesn't form part of the phased regeneration, and hence is excluded in this cogeneration study. The buildings within each site are numerically tagged. Note some existing buildings are currently not considered to be integrated into the overall Master plan and as such are also excluded from this report. These are all in Site 'A' and are buildings '2', '3', '5', '6' and '7'.

4 Profiles

Prior to discussing the on-site current heat load requirements, it's important to establish the duration of potential operation during the College throughout year.

There are numerous profiles that can be applied to this scheme, which would make this assessment extremely complex, and not necessarily provide a greater insight as to whether introducing cogeneration is economically feasible.

The load profile and energy consumption between HWS and electricity use shall vary as follows:

- Weekday / Weekend
- Term time / Holiday / Non-semester
- Summer / Winter / Mid-season

Figure 4. Proposed Site Plan

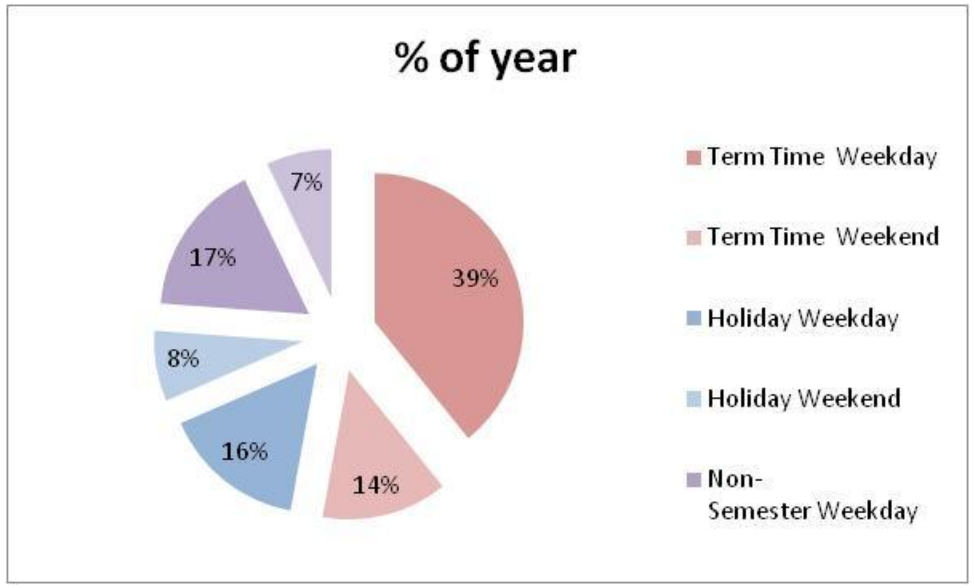
The summer/Winter/Mid-season derivatives are applied to the assumed electrical loads required for mechanical cooling, i.e. air-conditioning and ventilation.

When reviewing the term dates for 2009, it's assumed they shall remain constant in the forthcoming years. The term dates over both Moore College semesters are as highlighted in Table 2.Table **2Table 2. College Term Dates**

1st Semester	from	to
No College	1-Jan-09	15-Feb-09
Term 1	16-Feb-09	5-Apr-09
Easter Break	6-Apr-09	26-Apr-09
Term 1	27-Apr-09	1-May-09
Term 2	4-May-09	19-Jun-09
Mid Year Break	20-Jun-09	19-Jul-09
2nd Semester	from	to
Term 3	20-Jul-09	4-Sep-09
Spring Break	5-Sep-09	20-Sep-09
Term 4	21-Sep-09	30-Oct-09
Student Vacation	31-Oct-09	8-Nov-09
Exams	9-Nov-09	19-Nov-09
No College	20-Nov-09	31-Dec-09

In Figure 5 below, note the term-time (weekday and weekends) relates to 53% of the year. Consequently, if it is not energy and cost efficient to operate cogeneration plant during this period, when the majority of the students / staff are on campus, then there is no merit in considering the other periods.

Figure 5. Yearly % of College Occupation



5 Establishing Base Heat Load

For cogeneration to be a viable scheme, a constant minimum base heating load is required which ideally mimics the site's electrical load profile. In many instances a sites electrical load far exceeds the heat demand, and in such a scenario cogeneration may not be viable. Unless there's a constant cooling demand and a tri-generation scheme can be considered. The waste heat from the cogeneration plant drives the regeneration process of an absorption chiller. Due to the type and scale of proposed buildings for the campus, site-wide absorption cooling is unlikely to be a viable cooling system. This analysis and consideration is beyond the scope and focus of this report.

During a site survey it was observed two potential consumers of heat could be utilised. These were the Hot Water Services (HWS) serving both the female shower blocks in 28 Carillon House and the Kitchen/Dining facilities in 2-16 Carillon Avenue. The female showers are located in the chapel wing, and contain 2 showers at ground floor, 6 showers at 1st floor and 6 showers at 2nd floor.

There are other individual showers located in other residencies and male showers in 1 Carillon Ave. These shall be ignored within the report as the infrastructure costs to incorporate the showers would far out weigh any nett energy benefit (i.e. system inefficiencies caused by long pipework distribution and its respective heat loss and increased pump head). Another reason for not considering the heat demand from the male showers is crossing Carillon Avenue with piping and legalities this will involve.

5.1 Dining Facilities

The dining area serves approx 200 seats, and is used by the students and staff during the week and weekends, throughout term and holiday periods.

Table 3 below, shows a summary of the meal serving times, durations which all assume an approximate take-up ratio of 80%. That is to say, where potentially 85 people might attend for breakfast, 20% would not actually attend, or perhaps even bring their own food.

During weekdays, breakfast, lunch and dinner is served, whereas weekends it's assumed only breakfast and dinner is served to 45 people.

Table 3. HWS Peak Water Consumption

	Term Time					
	Weekdays			Weekends		
	Breakfast	Lunch	Dinner	Breakfast	Lunch	Dinner
Days	Mon - Fri	Mon - Fri	Mon - Fri	Sat - Sun	not served	Sat only
Time	7:00 - 9:00	12:00 - 1:45	6:00 - 6:30	7:00 - 9:00		6:00 - 6:30
Number of seats	85	370	85	45		45
Take-up ratio	0.8	0.8	0.8	0.8		0.8
Daily Demand (l/meal)	9	9	9	9		9
Total HWS volume (l)	612	2664	612	324		324
System Efficiency (%)	85	85	85	85		85
Storage Temperature (°C)	65	65	65	65		65
Water Supply Temp (°C)	15	15	15	15		15

The assumed HWS consumption rate for each meal is 9l/s per meal, as referenced within the BCA 2009 Vol 1 Table 2i. Meal times are spread out through the day, between breakfast, lunch and dinner. Each serving period the HWS usage is spilt proportionally as follows:

- 30% in food preparation
- 30% in serving
- 40% in washing-up

To calculate the actual HWS load in kW's it's assumed an overall system efficiency of 85%, with a water storage temperature of 65°C and an incoming water supply temperature of 15°C

The resultant HWS load profile is highlighted in Figure 6, which shows the majority of the load requirement is required during weekday lunchtimes, as expected when potentially 370 people can attend (over two sittings).

Over the weekend only two sittings are provided by the college, and the subsequent load profile depicted is shown by Figure 7.

These peak loads could be smoothed out with introduction of a suitable sized calorifier or some form of HWS storage. This would actually benefit the load matching with electrical requirements as discussed later in this report.

Figure 6. Dining HWS Peak Demand Profile – Term Time – Weekday

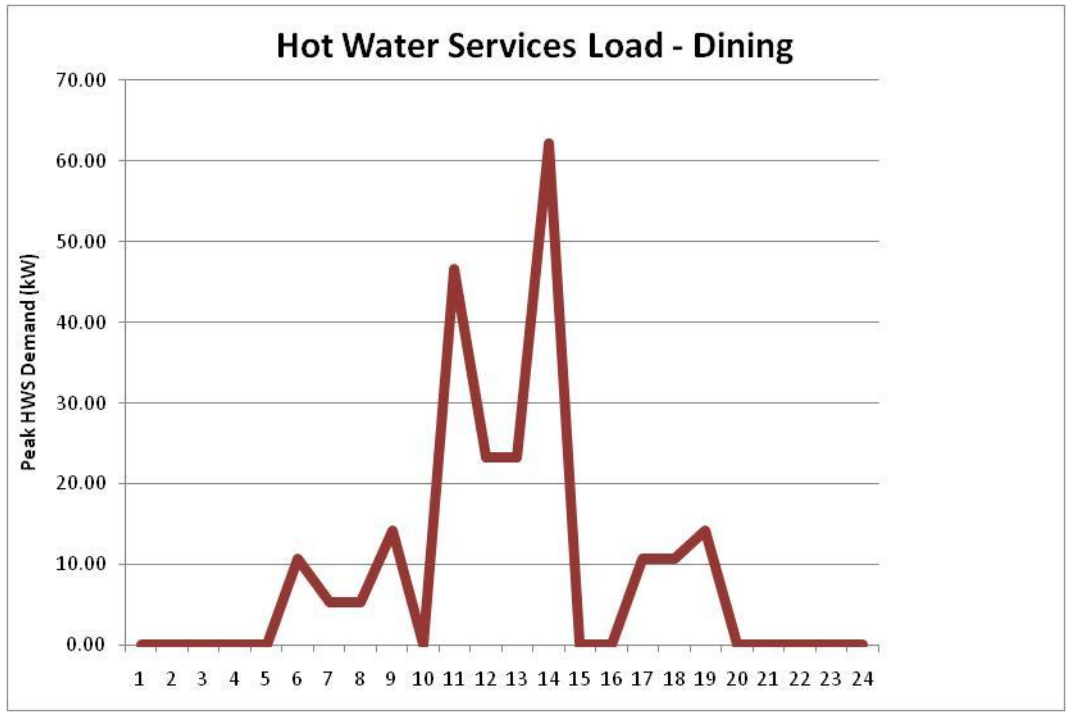
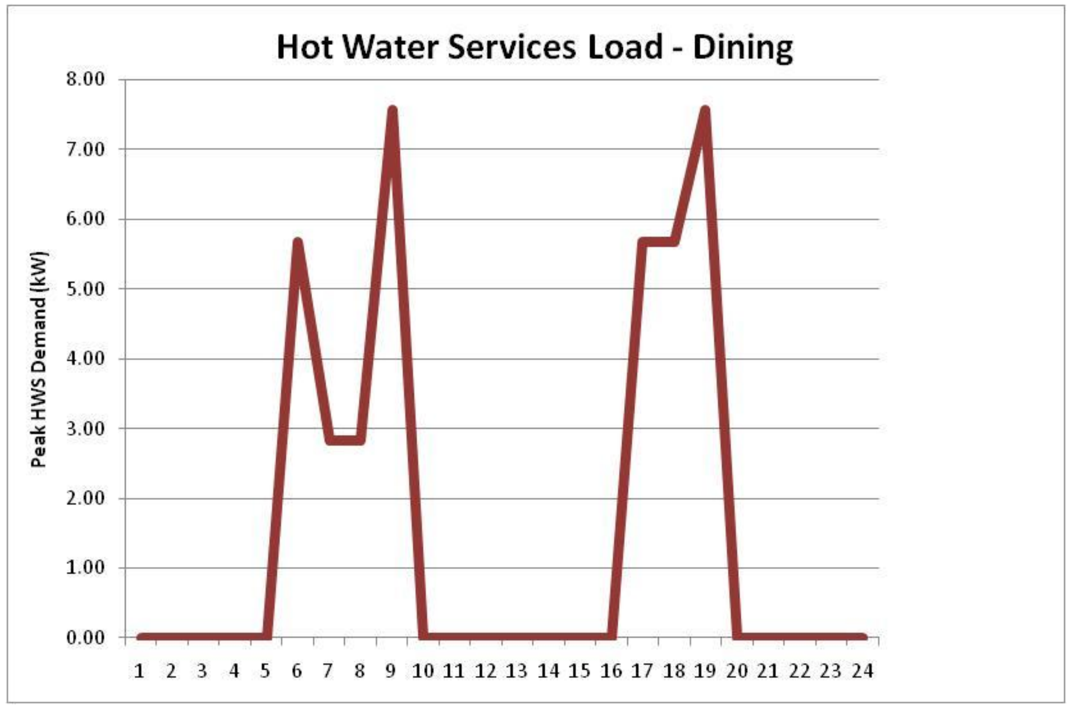


Figure 7. Dining HWS Peak Demand Profile – Term Time – Weekend



5.2 Shower Facilities

The other main heat load requirement on the campus is from the communal ladies showers used in 28 Carillon House. Whilst the showers are grouped in different areas, it's assumed they'll be supplied via the same heat source (Table 4).

Table 4 Shower HWS Consumption Details

	Term Time		Holiday (& Weekends)	
No. of Showers	14		14	
Shower usage	6	shrs/shrhead/hr	6	shrs/shrhead/hr
Shower water volume	25	l/shower	25	l/shower
Number of residents	48		21	
Shower Use Diversity	0.8		0.35	
Total HWS vol (@ peak hr)	1680	l/hr	735	l/hr
Assumed Peak Hour	8:00 to 9:00	AM	8:00 to 9:00	AM
System Efficiency	85	%	85	%
Storage Temperature	65	°C	65	°C
Water Supply Temp	15	°C	15	°C

To build a suitable profile a maximum load is established at peak hour, assumed to between 08:00am to 09:00am in the morning, and accounts for 20% of the overall daily consumption. The remaining is proportionally divided over the remaining hours throughout the day. Figure 8 and Figure 9 show this for weekday and weekend respectively.

Figure 8.Showers HWS Peak Demand Profile – Term Time – Weekday

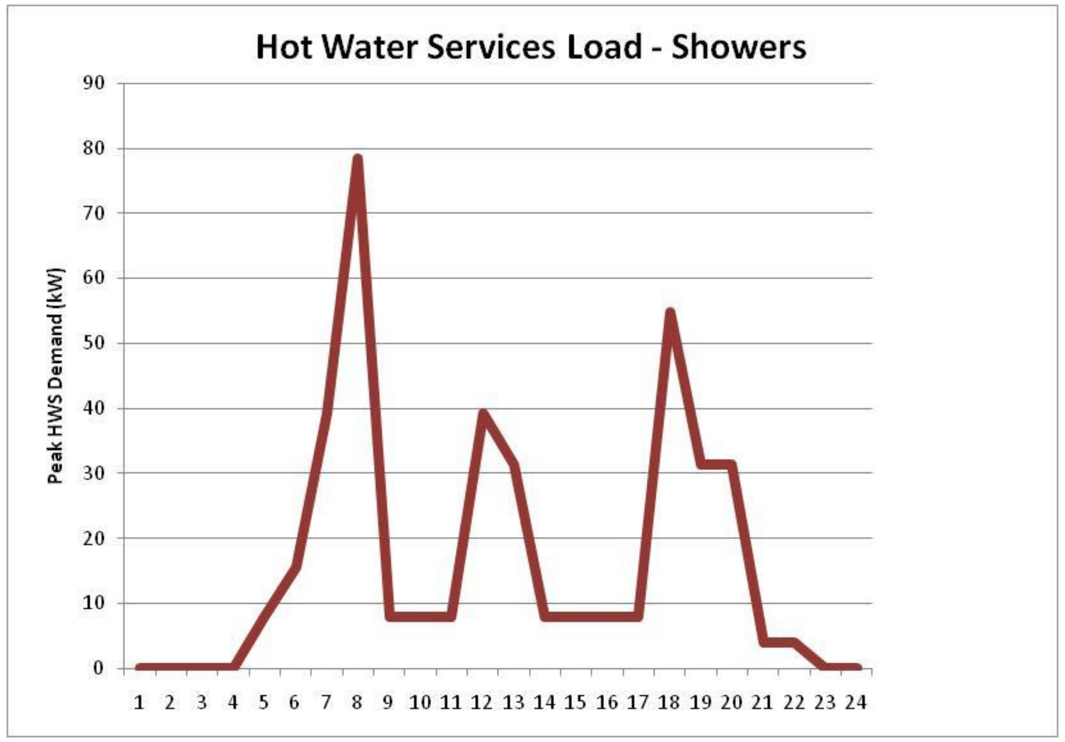
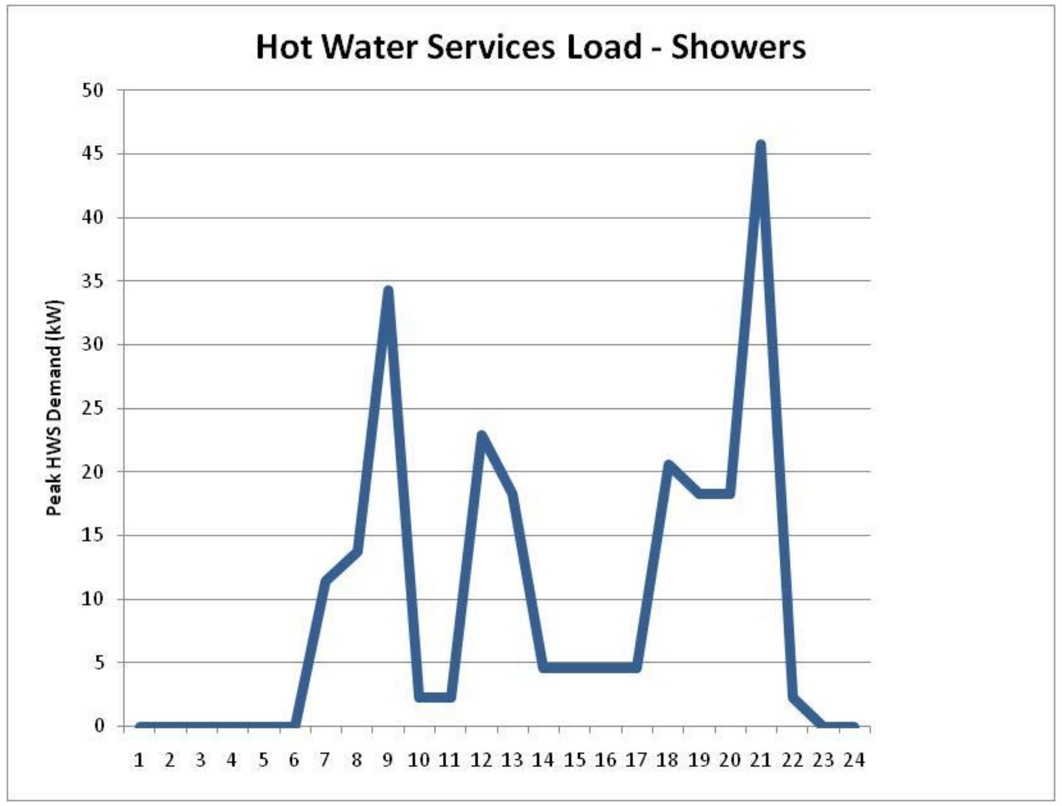


Figure 9.Showers HWS Peak Demand Profile – Term Time/Holiday – Weekends



As with the HWS serving the Dining facilities the introduction of a HWS calorifier would help smooth the load profile during the periods of use.

6 Establishing Base Electrical Load

Without access to actual meter data, to determine the base electrical load for the existing building we assumed the following electrical loads, and applied these to the known NLA's provided.

- Lighting varied from 5 to 15 W/m²
- Small power (equipment) varied from 5 to 25 W/m². Garage 50W/m² and the Kitchen up to 100W/m²
- Mechanical cooling/ventilation loads varied from 10 to 60W/m².

A summary of the overall building electrical loads are shown in Table 5.

The base electrical load for the development is summarised in Table 6, and aligns with the development phasing outlined in Table 1. This analysis also allows for different profiles for residential, Office/Academic and Retail units.

Table 5. Peak electrical load to existing buildings

Stage	Ref	Existing Building	Area m²	Max Demand (KVA)	Max Power (kW)
1	1.1	1 King Street - Administration	1000	102.1	127.6
	1.2	3-11 King St Residential	300	9.5	11.8
2	2.1	Residential	400	12.6	15.8
	2.2	Residential	400	12.6	15.8
3	3.1	Residential	2430	76.7	95.9
	3.2	Dining Room	250	7.9	9.9
	3.3	Teaching /Academic	320	11.8	14.7
	3.4	Kitchen	370	62.3	77.9
4a	4a	Residential	840	26.5	33.2
4b	4b.1	Offices	430	29.4	36.8
	4b.2	Garage	357	26.3	32.9
	4b.3	Residential	614	19.4	24.2
5	5	Child Care Centre (Uni Syd)	280	16.8	21.0

Table 6. Existing electrical loads

	Profile			Stage 1 Area				Stage 2 Area			
				1.1		1.2		2.1		2.2	
				Weekday 24hrs	Weekend 24hrs	Weekday 24hrs	Weekend 24hrs	Weekday 24hrs	Weekend 24hrs	Weekday 24hrs	Weekend 24hrs
Hour	Residential	Office/Academic	Retail	Load (kW)	Load (kW)	Load (kW)	Load (kW)	Load (kW)	Load (kW)	Load (kW)	Load (kW)
1:00:00 AM	5%	0%	3%	0.0	0.0	0.6	0.6	0.8	0.8	0.8	0.8
2:00:00 AM	5%	0%	3%	0.0	0.0	0.6	0.6	0.8	0.8	0.8	0.8
3:00:00 AM	5%	0%	3%	0.0	0.0	0.6	0.6	0.8	0.8	0.8	0.8
4:00:00 AM	5%	0%	3%	0.0	0.0	0.6	0.6	0.8	0.8	0.8	0.8
5:00:00 AM	5%	0%	3%	0.0	0.0	0.6	0.6	0.8	0.8	0.8	0.8
6:00:00 AM	10%	0%	3%	0.0	0.0	1.2	1.2	1.6	1.6	1.6	1.6
7:00:00 AM	20%	0%	3%	0.0	0.0	2.4	2.4	3.2	3.2	3.2	3.2
8:00:00 AM	50%	50%	30%	63.8	9.6	5.9	5.9	7.9	7.9	7.9	7.9
9:00:00 AM	60%	80%	90%	102.1	15.3	7.1	7.1	9.5	9.5	9.5	9.5
10:00:00 AM	70%	90%	90%	114.9	17.2	8.3	8.3	11.1	11.1	11.1	11.1
11:00:00 AM	80%	100%	90%	127.6	19.1	9.5	9.5	12.6	12.6	12.6	12.6
12:00:00 PM	90%	100%	100%	127.6	19.1	10.7	10.7	14.2	14.2	14.2	14.2
1:00:00 PM	100%	100%	100%	127.6	19.1	11.8	11.8	15.8	15.8	15.8	15.8
2:00:00 PM	100%	100%	100%	127.6	19.1	11.8	11.8	15.8	15.8	15.8	15.8
3:00:00 PM	100%	100%	100%	127.6	19.1	11.8	11.8	15.8	15.8	15.8	15.8
4:00:00 PM	90%	100%	100%	127.6	19.1	10.7	10.7	14.2	14.2	14.2	14.2
5:00:00 PM	70%	90%	100%	114.9	17.2	8.3	8.3	11.1	11.1	11.1	11.1
6:00:00 PM	70%	70%	30%	89.3	13.4	8.3	8.3	11.1	11.1	11.1	11.1
7:00:00 PM	40%	0%	3%	0.0	0.0	4.7	4.7	6.3	6.3	6.3	6.3
8:00:00 PM	5%	0%	3%	0.0	0.0	0.6	0.6	0.8	0.8	0.8	0.8
9:00:00 PM	5%	0%	3%	0.0	0.0	0.6	0.6	0.8	0.8	0.8	0.8
10:00:00 PM	5%	0%	3%	0.0	0.0	0.6	0.6	0.8	0.8	0.8	0.8
11:00:00 PM	5%	0%	3%	0.0	0.0	0.6	0.6	0.8	0.8	0.8	0.8
12:00:00 AM	5%	0%	3%	0.0	0.0	0.6	0.6	0.8	0.8	0.8	0.8
Total				1251	188	118	118	158	158	158	158

	Stage 3 Area								Stage 4a Area		Stage 4b Area						Stage 5 Area	
	3.1		3.2		3.3		3.4		4a		4b.1		4b.2		4b.3		5	
	Weekday 24hrs	Weekend 24hrs	Weekday 24hrs	Weekend 24hrs	Weekday 24hrs	Weekend 24hrs	Weekday 24hrs	Weekend 24hrs	Weekday 24hrs	Weekend 24hrs	Weekday 24hrs	Weekend 24hrs	Weekday 24hrs	Weekend 24hrs	Weekday 24hrs	Weekend 24hrs	Weekday 24hrs	Weekend 24hrs
Hour	Load (kW)	Load (kW)	Load (kW)	Load (kW)	Load (kW)	Load (kW)	Load (kW)	Load (kW)	Load (kW)	Load (kW)	Load (kW)	Load (kW)	Load (kW)	Load (kW)	Load (kW)	Load (kW)	Load (kW)	Load (kW)
1:00:00 AM	4.8	4.8	0.5	0.2	0.0	0.0	3.9	1.9	1.7	1.7	0.0	0.0	1.0	1.0	1.2	1.2	0.0	0.0
2:00:00 AM	4.8	4.8	0.7	0.4	0.0	0.0	3.9	1.9	1.7	1.7	0.0	0.0	1.0	1.0	1.2	1.2	0.0	0.0
3:00:00 AM	4.8	4.8	3.9	1.9	0.0	0.0	3.9	1.9	1.7	1.7	0.0	0.0	1.0	1.0	1.2	1.2	0.0	0.0
4:00:00 AM	4.8	4.8	1.7	0.8	0.0	0.0	3.9	1.9	1.7	1.7	0.0	0.0	1.0	1.0	1.2	1.2	0.0	0.0
5:00:00 AM	4.8	4.8	1.8	0.9	0.0	0.0	3.9	1.9	1.7	1.7	0.0	0.0	1.0	1.0	1.2	1.2	0.0	0.0
6:00:00 AM	9.6	9.6	1.6	0.8	0.0	0.0	7.8	3.9	3.3	3.3	0.0	0.0	1.0	1.0	2.4	2.4	0.0	0.0
7:00:00 AM	19.2	19.2	1.2	0.6	0.0	0.0	15.6	7.8	6.6	6.6	0.0	0.0	1.0	1.0	4.8	4.8	0.0	0.0
8:00:00 AM	48.0	48.0	1.1	0.5	7.4	1.1	38.9	19.5	16.6	16.6	18.4	2.8	9.9	9.9	12.1	12.1	10.5	1.6
9:00:00 AM	57.6	57.6	25.9	12.9	11.8	1.8	46.7	23.4	19.9	19.9	29.4	4.4	29.6	29.6	14.5	14.5	16.8	2.5
10:00:00 AM	67.1	67.1	0.0	0.0	13.3	2.0	54.5	27.3	23.2	23.2	33.1	5.0	29.6	29.6	17.0	17.0	18.9	2.8
11:00:00 AM	76.7	76.7	0.0	0.0	14.7	2.2	62.3	31.2	26.5	26.5	36.8	5.5	29.6	29.6	19.4	19.4	21.0	3.2
12:00:00 PM	86.3	86.3	0.0	0.0	14.7	2.2	70.1	35.1	29.8	29.8	36.8	5.5	32.9	32.9	21.8	21.8	21.0	3.2
1:00:00 PM	95.9	95.9	0.0	0.0	14.7	2.2	77.9	38.9	33.2	33.2	36.8	5.5	32.9	32.9	24.2	24.2	21.0	3.2
2:00:00 PM	95.9	95.9	0.0	0.0	14.7	2.2	77.9	38.9	33.2	33.2	36.8	5.5	32.9	32.9	24.2	24.2	21.0	3.2
3:00:00 PM	95.9	95.9	0.0	0.0	14.7	2.2	77.9	38.9	33.2	33.2	36.8	5.5	32.9	32.9	24.2	24.2	21.0	3.2
4:00:00 PM	86.3	86.3	0.0	0.0	14.7	2.2	70.1	35.1	29.8	29.8	36.8	5.5	32.9	32.9	21.8	21.8	21.0	3.2
5:00:00 PM	67.1	67.1	0.0	0.0	13.3	2.0	54.5	27.3	23.2	23.2	33.1	5.0	32.9	32.9	17.0	17.0	18.9	2.8
6:00:00 PM	67.1	67.1	0.0	0.0	10.3	1.5	54.5	27.3	23.2	23.2	25.7	3.9	9.9	9.9	17.0	17.0	14.7	2.2
7:00:00 PM	38.4	38.4	0.0	0.0	0.0	0.0	31.2	15.6	13.3	13.3	0.0	0.0	1.0	1.0	9.7	9.7	0.0	0.0
8:00:00 PM	4.8	4.8	0.0	0.0	0.0	0.0	3.9	1.9	1.7	1.7	0.0	0.0	1.0	1.0	1.2	1.2	0.0	0.0
9:00:00 PM	4.8	4.8	0.0	0.0	0.0	0.0	3.9	1.9	1.7	1.7	0.0	0.0	1.0	1.0	1.2	1.2	0.0	0.0
10:00:00 PM	4.8	4.8	0.0	0.0	0.0	0.0	3.9	1.9	1.7	1.7	0.0	0.0	1.0	1.0	1.2	1.2	0.0	0.0
11:00:00 PM	4.8	4.8	0.0	0.0	0.0	0.0	3.9	1.9	1.7	1.7	0.0	0.0	1.0	1.0	1.2	1.2	0.0	0.0
12:00:00 AM	4.8	4.8	0.0	0.0	0.0	0.0	3.9	1.9	1.7	1.7	0.0	0.0	1.0	1.0	1.2	1.2	0.0	0.0
Total	959	959	38	19	144	22	779	389	332	332	360	54	319	319	242	242	206	31

7 Existing HWS & Base Electrical Load

When comparing the required energy requirements for the site, Figure 10 and Figure 11 clearly highlight the base electrical load far exceeds the combined base-heating load required for the showers and dining facilities. The peak electrical load is in the region of 500kW (note term time and weekday), whereas the average HWS load is 40kW. The HWS load profile would be smoothed out with the introduction of a calorifier, as indicated by the shaded green area.

Figure 10. Existing Electrical & HWS Load Profile Compared (Weekday)

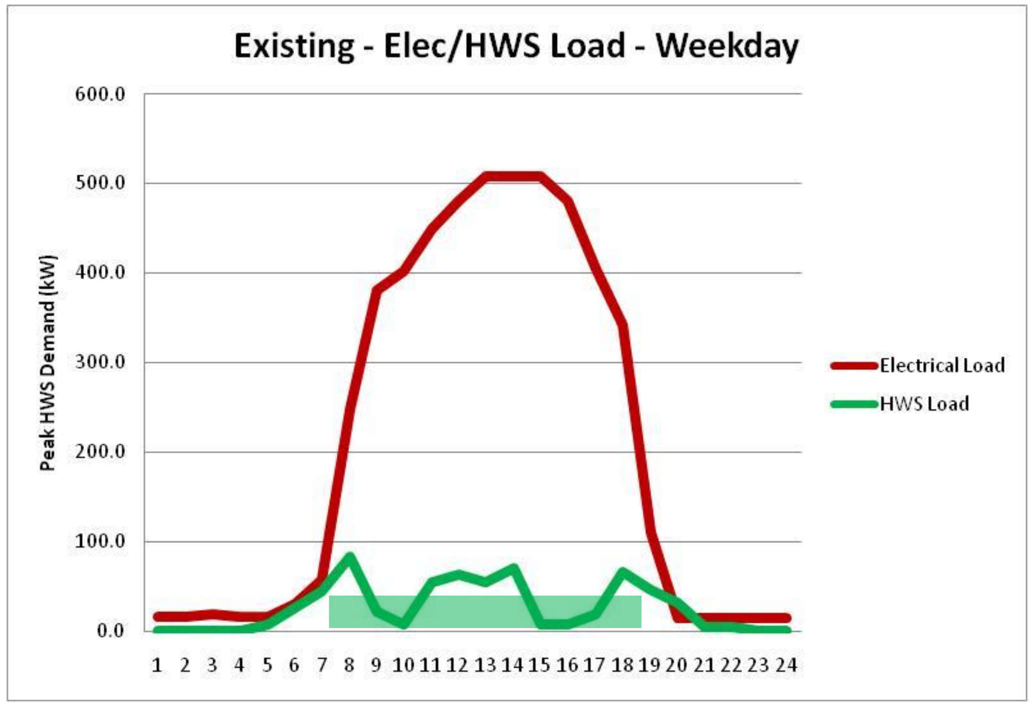
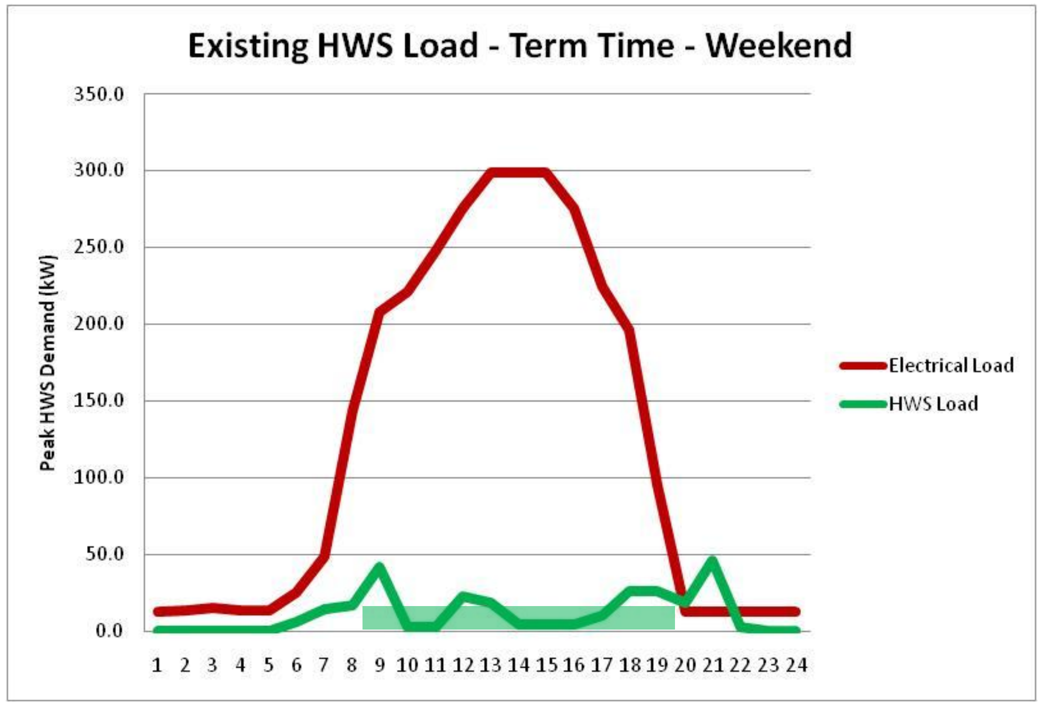


Figure 11. Existing Electrical & HWS Load Profile Compared (Weekend)



8 Centralised or Decentralised Cogeneration?

Centralised cogeneration in some instances offer advantages of over decentralised. This assumes the resultant electricity and HWS requirements provide a constant load, but only if the peak demand from the different buildings occur at different times, thus providing a smooth load for which the cogeneration plant can follow.

For Moore College the electricity load is assumed fairly constant during operating hours, and the HWS load can be averaged out by introducing a calorifier. The main observation is to note the site wide electrical load greatly surpasses the required heat load. What this does start to preclude is a large site-wide cogeneration plant to meet the electrical load requirements. The generated waste heat from any central plant would massively exceed existing HWS loads, or even any future heating requirements generated from the new residential apartments or Academic/Teaching buildings. This would require the cogeneration plant to operate consistently at a very low load (not actually feasible at these low loads even for micro-turbine cogenerators). This reduces system efficiency, and ultimately the plants longevity. To maximise plant life and efficiencies, cogeneration plant should run ideally to match a constant load close to its maximum output.

In addition, the base-heat load presented in Figure 10 and Figure 11 are during term time only, therefore as mentioned earlier in the report, if cogeneration cannot be made viable during term-time, then during holidays or out of semester time, the usage will be even lower.

There are however, two further derivatives to site wide Cogeneration that were considered, these are:

1. On-site electrical generation via gas supply to meet site-wide electrical load. Only a proportion of the heat is utilised whilst the remaining is omitted to atmosphere. The nett energy efficiency is much less than if the heat was utilised, but because the electricity is generated on site via a gas supply, the equivalent CO_2 emissions generated for the site are less than that created from a coal driven electrical power station.
2. This could be taken a step further, if the electricity generated exceeds the site demand, this electricity can be exported back to electricity grid.

Both options, and especially the latter of exporting electricity requires careful analysis, to ensure there is a pay back from capital investment and profit is made with regard to option 2. Both options must consider fluctuations in electrical and gas prices, plus on-going maintenance costs and utility connection issues (e.g. difficult to export unwanted electricity back the electrical grid).

Exporting to the electrical grid at present may not be financially attractive because the selling price of electricity is relatively low, especially when factoring the overhead running costs for the cogeneration plant (i.e. gas and maintenance costs).

For site-wide cogeneration the electrical interconnection between all existing buildings, and the subsequent de-commissioning and new connections for the new building constructed at each stage, would be a very complex and expensive process. The relative benefit, whether generating electricity for the site or exporting is far out-weighed by the internal infrastructure costs, and space the equipment would require during the very first stage. In addition connecting the heat load to the existing shower and dining facilities would also create disruption and be costly. Consequently, site-wide cogeneration has been excluded as a viable option.

Another consideration, though not discussed in detail within this report is tri-generation. This uses any excess heat to drive the refrigeration process of an absorption chiller. This would improve the system efficiencies, however a base cooling load is required. This could be considered for the new stage 1 Library building, however the additional cost of the absorption chiller system may be prohibitive. The use of trigeneration still does not provide sufficient benefits & efficiency to make a site-wide scheme viable.

9 Decentralised Cogeneration

If cogeneration is decentralised, this significantly reduces the upfront capital expenditure, and exposure to risk should the projected paybacks not materialise.

Another advantage occurs, as cogeneration plant in the future will probably offer improved efficiencies, and as the technology/strategies become more common place, equipment costs may reduce also. This permits closer load matching to each building constructed at each stage.

As centralised cogeneration is already discounted, any potential cogeneration systems for each new building shall be autonomous to the building they serve.

10 Cogeneration Strategy – Sized To Achieve Minimum Heat Load

Prior to discussing the new building stages and whether or not introducing cogeneration plant is workable, there are two strategies adopted for consideration in this scheme.

The first is to select a suitably sized cogeneration plant to meet the minimum building heat load. Typically to make cogeneration viable and offer reasonable payback periods, the plant needs to operate for as long as possible and close to its maximum output, with all heat and power produced utilised as fully as possible. This is the rationale behind why the HWS loads are used as opposed to any building heating and/or venting, as this varies seasonally, whereas the HWS loads would remain fairly constant during occupied hours year round.

Due to the high electrical demand of the site, a system sized for the base heating load would produce a small percentage of the total site electrical demand, which would therefore be fully utilised on site.

11 Cogeneration Strategy – Sized To Achieve Main Electrical Load

Another way to size cogeneration equipment is to match the main bulk of the electrical load for as long a period through the day. This strategy is identical to option 1 explained in section 8, however without the additional cost and complexities of connecting to other building over a number of years, it may offer a viable solution.

To recap, if the cogeneration plant is sized to meet the major proportion of the electrical load, the heat produced would far exceed that required by the buildings, and therefore would be rejected to atmosphere. Whilst the nett energy performance of the overall system is less than if the heat could be utilised, the electricity generated on-site via gas-fired equipment would produce less greenhouse gas emissions compared to electricity produced by a coal-fired power station.

A third option, as discussed earlier, is to over-size the cogeneration plant with the objective of exporting electricity back to the network and reducing the payback period by selling power. This introduces high upfront capital costs to install a large enough cogeneration unit and with no suitable use for the waste heat, is not considered an environmentally sound approach. This requires very careful analysis, and is beyond the intended scope of this report. In addition, whilst the cost of electricity remains fairly low within Australia, the payback periods would be many years.

Consequently, in considering the options available, providing cogeneration to meet the minimum heat load, seem most suitable for Moore College, and the report now focuses around this strategy.

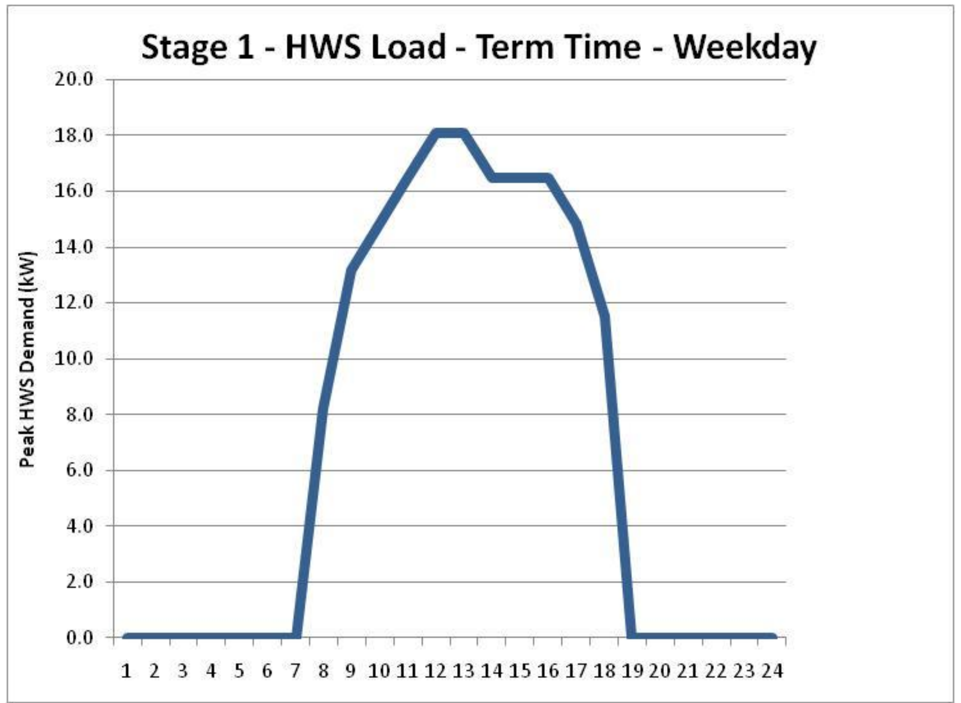
12 Stage 1 Academic/Teaching

This first phase is predicted to be completed by 2012, and shall provide 7830m² of NLA. There is a potential this particular area might be phased differently and include a Library, which will be partially built by 2012 with the remaining building constructed in the future. These scenarios have not been considered within this report.

12.1HWS Loads

The potential HWS load for this type of building / use shall be similar in its base-load of say around 14kW when comparing against the shower and dining facilities. However the actual profile as shown in Figure 12 is more steady and constant throughout the day.

Figure 12. Stage 1 HWS Peak Demand Profile – Term Time – Weekday



The load is determined with the following assumptions:

Occupancy density: 1/10m²

Daily HWS used: 4 l/person

Occupant diversity: 90% weekday / 10 weekend

12.2Electrical Loads

The electrical consumption of this building is shown in

Table 7. This also takes into consideration a notional change to mechanical plant in relation to the season e.g. the summer load shall require mechanical cooling to offset the solar gains into the building, whereas during winter this would be significantly reduced.

Table 7. Electrical Loads

NLA		7838 m2
Elec Load	Small Power	13 W/m2
	Lighting	10 W/m2
	Mech Plant	50 W/m2
Seasonal Mech load	Summer (peak)	100% Full A/C
	Mid-season	50%
	Winter	15% Vent & LTHW Pumps

In addition, we noted that a proportion of lights and some small power appliance will be left on over night. Ideally this should be an absolute minimum and lighting left on only for security, but allowing 15% of the day load, would represent actuality (see Table 8 below)

Table 8. Electrical Load Details During Term Time

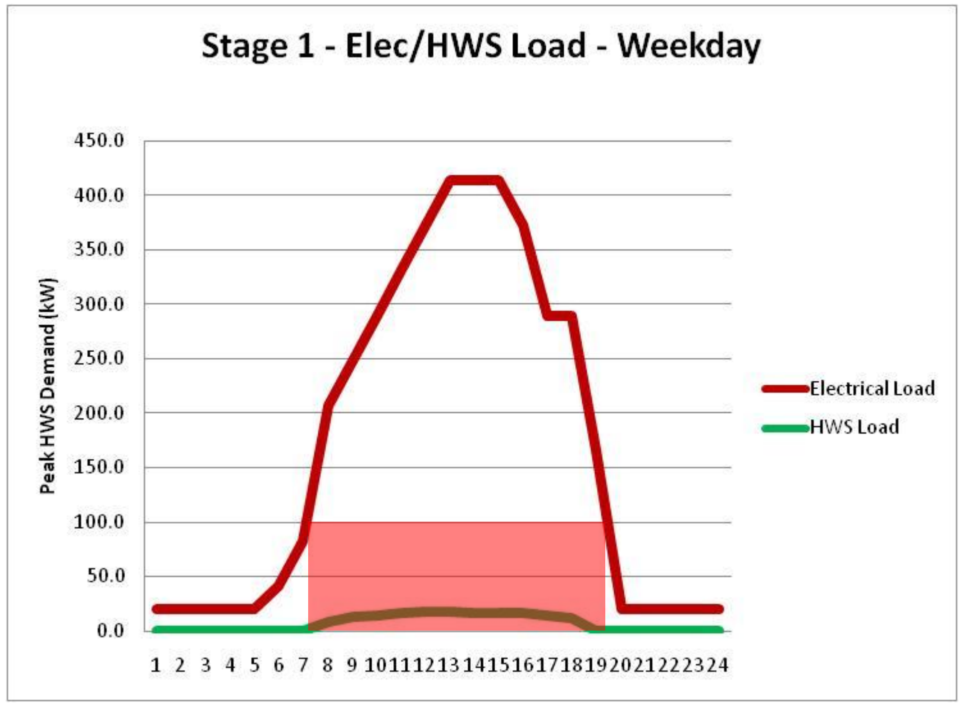
		Term Time			
		Weekdays		Weekends	
		Day	Night	Day	Night
	% of Peak Load	100%	15%	40%	15%
	Small Power	101.9	15.3	40.8	15.3
	Lighting	78.4	11.8	31.4	11.8
Seasonal Mech	Summer (kW)	391.9	0.0	156.8	0.0
	Mid-season (kW	196.0	0.0	78.4	0.0
	Winter (kW)	58.8	0.0	23.5	0.0
Total (24hrs)	Summer (kWh)	6100		2195	
	Mid-season (kW	4141		1883	
	Winter (kWh)	2769		1335	
Total (No of Days)	Summer	24.0		9.0	
	Mid-season	85.0		29.0	
	Winter	34.0		12.0	
Total (Year)	Summer (kWh)	146408		19757	
	Mid-season (kW	351969		54621	
	Winter (kWh)	94152		16018	

12.3Combined HWS and Electrical Loads

When overlaying the electrical and HWS requirement a clear discrepancy between the loads is highlighted, meaning that the electrical load exceeds the base heating load. The low HWS heat load creates an issue as typically the minimum waste heat produced by a small-cogeneration plant around 55kW (this can be lower when using micro-turbine cogeneration units), however the base HWS calculated is approximately 20kW. When considering the comparative low heat demand, integrating cogeneration to meet minimum heat load does appear feasible.

However if the cogeneration unit is sized to create the main bulk of the electrical load, then the equivalent CO_2 emissions will be reduced.

Figure 13. Electrical Profile Over Weekday



The maximum electrical base load through a weekday in term time is approx 200kW. For the weekend it's reduced to 100kW. To maintain a simple analysis, only 1no 100kWe (electrical output) cogeneration unit (Figure 15) shall operate during the whole week. The 100kWe electrical output is shown by the shaded rectangle within Figure 13 and Figure 14. Note cogeneration plant achieves maximum efficiency at full load. Cogeneration can run at part load, typically to a minimum of 50%, but the efficiency declines, so again for ease of analysis part load operation is not factored into the results.

When comparing the carbon emissions from the different energy sources, the GHG (Green House Gas) coefficient is used. The GHG for gas is 0.23kg CO_2/kWh, and for electricity (produced by coal driven power station), is 1.06kg CO_2/kWh.

The estimated numbers of hours throughout the year where the electrical building load for stage 1 exceeds 100kW is 2363hrs.

Noting this type of cogeneration considered is 35.5% electrically efficient, i.e. to produce 100kW of electricity an equivalent input energy of 282kW via gas is required. This provides a 39% reduction in CO_2 emissions, so this strategy has some merit.

When applying this to a typical weekday in term-time, with the cogeneration plant operating between 08:00hrs to 18:30hrs (total run time of 10.5hrs) the saving of CO_2 emissions is 432 kg CO_2. Annually this CO_2 saving, taking into considerations seasonal and occupancy variations is, 97214 kg CO_2.

Figure 14. Electrical Profile Over Weekend

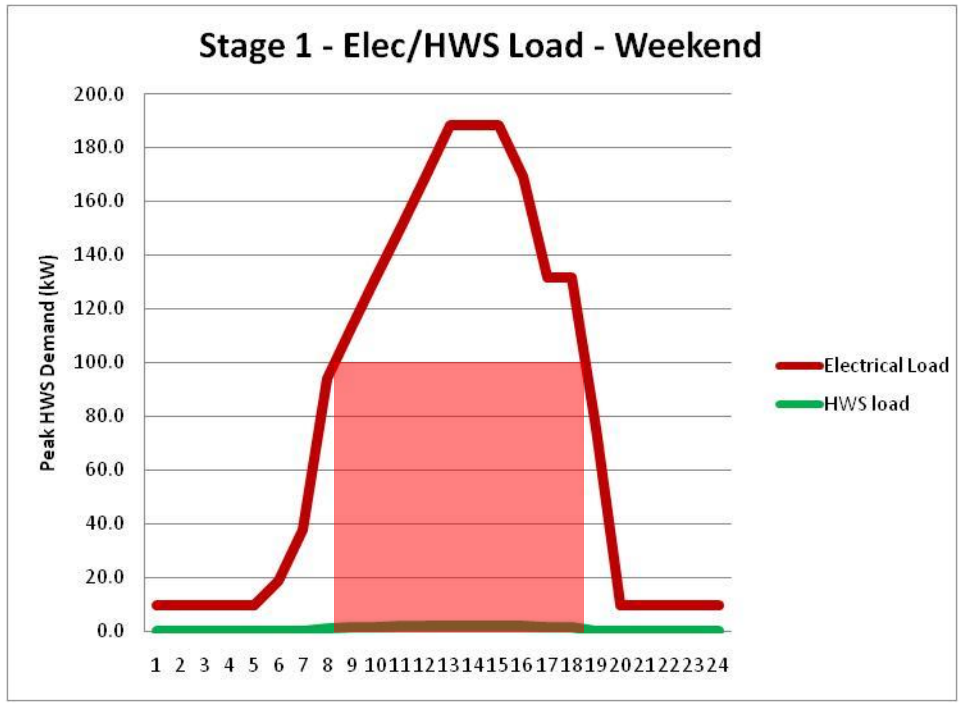


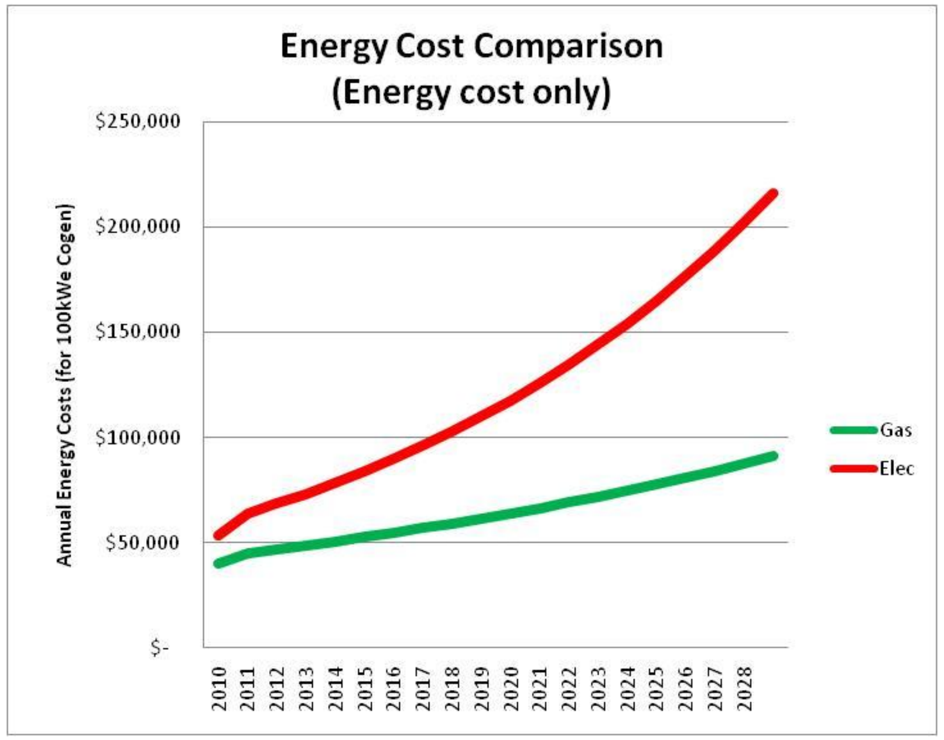
Figure 15. Picture of Cogeneration Unit.

With the next 2 to 3 years the government shall implement the Carbon Pollution Reduction Scheme (CPRS), to ensure Australia meets its expanded emissions reductions of as much as 25 per cent of 2000 levels by 2020. As a direct result of this energy prices for both gas and electricity shall rise. It is predicted for this report electricity costs shall jump by 20% next year, and thereon it has been assumed a steady inflation of 7% throughout the reminder of this development. Gas, is expected to jump by 15%, however for this report it is assumed gas incurs a slightly lower inflation rate of 4%.

Sample electricity costs are obtained from Energy Australia, Power Smart Business and Power Smart Home rates. Gas costs are taken from AGL retail gas prices. There has been no allowance for any price negotiations between Moore College and the Utility providers.

When comparing gas costs solely against electricity costs, if the inflation rate increases as predicted, see Figure 16, by 2012 when possibly the first stage is completed, electricity is approximately 50% more expensive, and by the end of stage 5 in 2028, shall be more than double. If inflation for both energy supplies remain constant to one another the cost differential remains more constant, meaning the electricity costs have less of an impact. A key issue for the feasibility of cogeneration systems and their commercial viability is the cost difference between gas and electricity. The closer the cost rates are to one another the less commercially feasible cogeneration becomes as the payback is greatly extended.

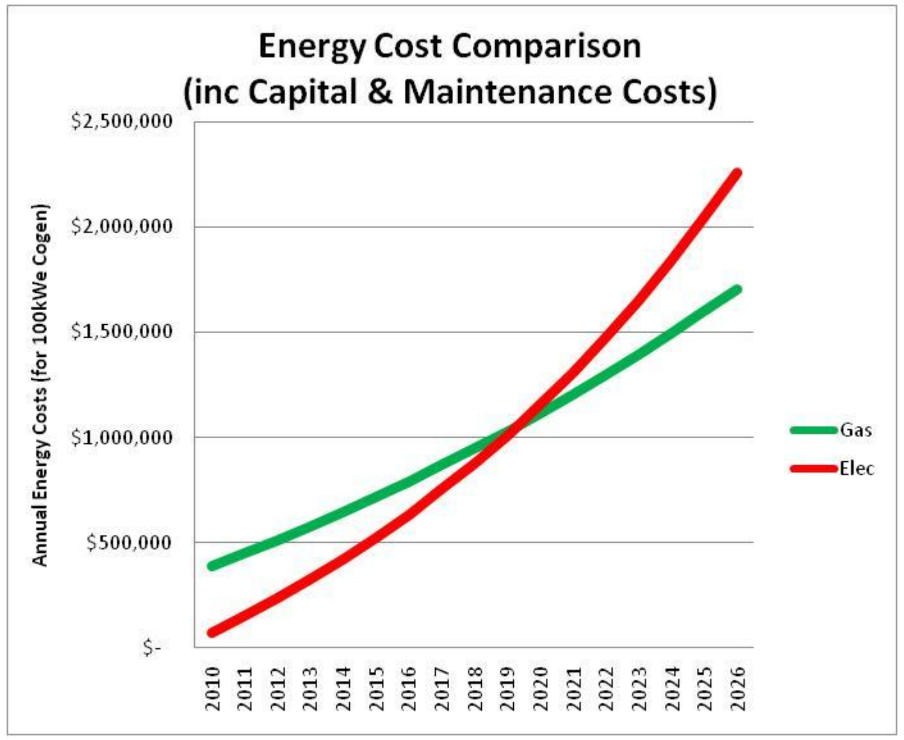
Figure 16. Predicted Increase In Gas & Electricity Energy Costs



The capital cost for a 100kWe cogeneration unit is approx $275,000, with additional $25,000 to provide the HWS interface. Maintenance costs are typically determined on $/kWh, and this example $0.04 is assumed. A 3% inflation is applied to the maintenance costs. Allowing inflation costs of 3%, the capital cost, by 2012 the installed costs is $327,818.

Assuming a commencement of plant operation in 2012, the accumulated cost for cogeneration obviously exceeds that for the cost of electricity. However, due to the predicted elevation in electricity costs, by approx 2020 the accumulated cost of installing a cogeneration unit and paying for gas used, actually start to become progressively cheaper, thus offering a payback period of around 9 years (refer to Figure 17)

Figure 17. Payback Period.



It's important to note if electricity rates rise in line with gas (i.e. at 4% after the initial price rise next year) the payback period does not occur until around 2028/29 when the final phase is completed.

13 Stage 2 Residential

This second phase is predicted to be completed by 2016, and shall provide approximately 32 apartments. The occupancy, HWS consumption and storage are defined in Table 9.

Table 9. Apartment HWS Consumption & Storage

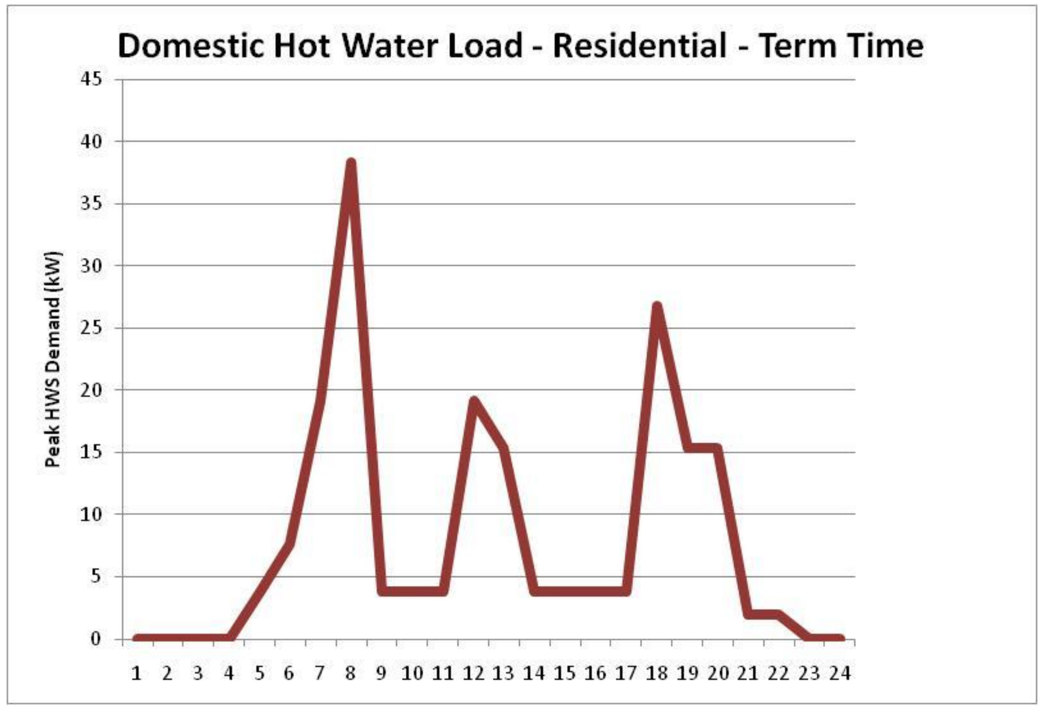
	Term Time		Holiday (& Weekends)	
NLA	3614			m2
Apartment Area	110	m2	110	m2
Occupants/apartment	2	people	2	people
Daily Consumption	50	l/person/day	50	l/person/day
Occupancy Ratio	100%		60%	
Total HWS vol (day)	3285	l	1971	l
System Efficiency	85	%	85	%
Storage Temperature	65	°C	65	°C
Water Supply Temp	15	°C	15	°C

13.1HWS Loads

The potential HWS load for the apartments aligns with the occupied periods, morning, lunch and evening. The introduction of a calorifier would smooth the spiky HWS profile, to say around 10 to 12kW, although as raised before the required HWS demand is much less than the heat dissipated from the cogeneration unit.

Therefore this steers the strategy to reducing CO_2 emissions and determining whether there is any potential payback.

Figure 18. Stage 2 HWS Peak Demand Profile – Term Time – Weekday



13.2Electrical Loads

The electrical consumption of this building is shown in

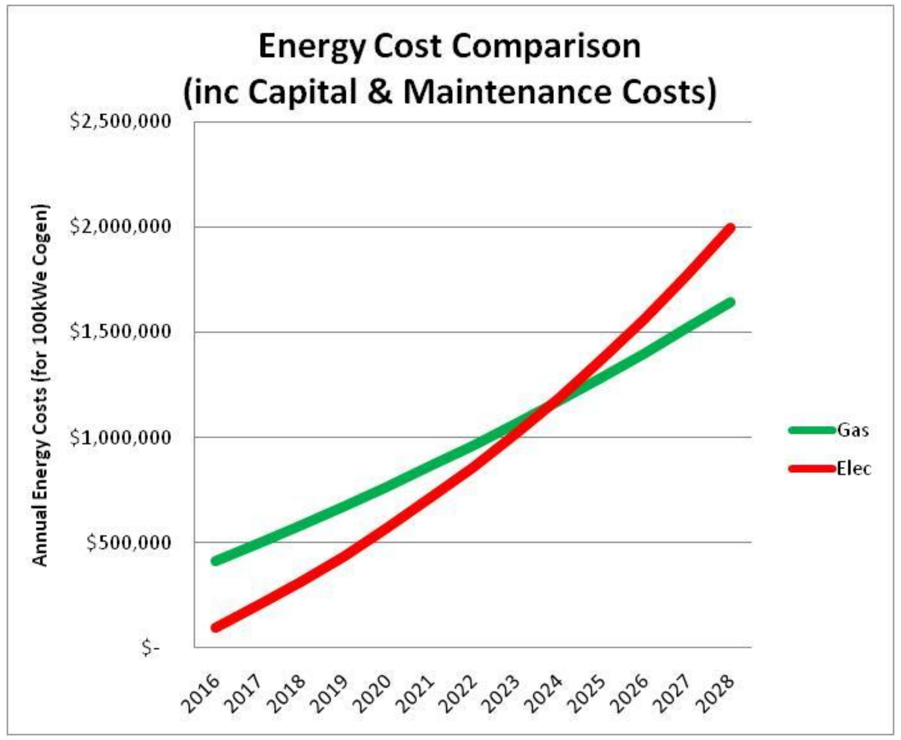
Table 7. For this stage to maximise the operating hours of the cogeneration unit, a smaller model is considered that provides 80kW of electricity.

Table 7. Electrical Load Profile

Hour	Profile	Term Time Weekday 24hrs Load (kW)	Term Time Weekend 24hrs Load (kW)	Holidays Weekday 24hrs Load (kW)	Holidays Weekend 24hrs Load (kW)	Non Semester Weekday 24hrs Load (kW)	Non Semester Weekend 24hrs Load (kW)
1:00:00 AM	0.5%	6.89	6.89	2.62	2.62	2.05	2.05
2:00:00 AM	0.5%	6.89	6.89	2.62	2.62	2.05	2.05
3:00:00 AM	0.5%	6.89	6.89	2.62	2.62	2.05	2.05
4:00:00 AM	0.5%	6.89	6.89	2.62	2.62	2.05	2.05
5:00:00 AM	0.5%	6.89	6.89	2.62	2.62	2.05	2.05
6:00:00 AM	1.0%	13.78	13.78	5.24	5.24	4.10	4.10
7:00:00 AM	2.0%	27.55	27.55	10.47	10.47	8.20	8.20
8:00:00 AM	5.0%	68.88	68.88	26.19	26.19	20.49	20.49
9:00:00 AM	6.0%	82.66	82.66	31.42	31.42	24.59	24.59
10:00:00 AM	7.0%	96.43	96.43	36.66	36.66	28.69	28.69
11:00:00 AM	8.0%	110.21	110.21	41.90	41.90	32.79	32.79
12:00:00 PM	9.0%	123.98	123.98	47.13	47.13	36.89	36.89
1:00:00 PM	10.0%	137.76	137.76	52.37	52.37	40.99	40.99
2:00:00 PM	10.0%	137.76	137.76	52.37	52.37	40.99	40.99
3:00:00 PM	10.0%	137.76	137.76	52.37	52.37	40.99	40.99
4:00:00 PM	9.0%	123.98	123.98	47.13	47.13	36.89	36.89
5:00:00 PM	7.0%	96.43	96.43	36.66	36.66	28.69	28.69
6:00:00 PM	7.0%	96.43	96.43	36.66	36.66	28.69	28.69
7:00:00 PM	4.0%	55.10	55.10	20.95	20.95	16.39	16.39
8:00:00 PM	0.5%	6.89	6.89	2.62	2.62	2.05	2.05
9:00:00 PM	0.5%	6.89	6.89	2.62	2.62	2.05	2.05
10:00:00 PM	0.5%	6.89	6.89	2.62	2.62	2.05	2.05
11:00:00 PM	0.5%	6.89	6.89	2.62	2.62	2.05	2.05
12:00:00 AM	0.5%	6.89	6.89	2.62	2.62	2.05	2.05
Total	100%	1378	1378	524	524	410	410

The completion of this stage is 2016, and therefore electricity costs would have risen significantly, such that even when including the cost of the cogeneration unit and the ongoing maintenance costs, a payback of 8 years is achieved (see Figure 19). In addition, the annual CO_2 emissions would reduce by 38484 kg CO2.

Figure 19. Predicted Increase In Gas & Electricity Energy Costs



If the gas inflation rises in line with the electricity price, then the payback period increases significantly to approx 25 years.

14 Stage 3 Residential & Academic/Teaching

The third phase encompasses mixed use of apartments and an academic/teaching building. The location of this stage overlays the current dining area, therefore it's assumed the academic building shall replace the existing dining facilities. In addition to ensure there was adequate heat load in this scenario from the cogeneration unit, the heating loads for communal showers were included.

When combining the various heat load profiles an average HWS load of 55kW is created (See Figure 20). This is sufficient to warrant connecting to a cogeneration circuit and utilising the waste heat.

Figure 20 Combined HWS load

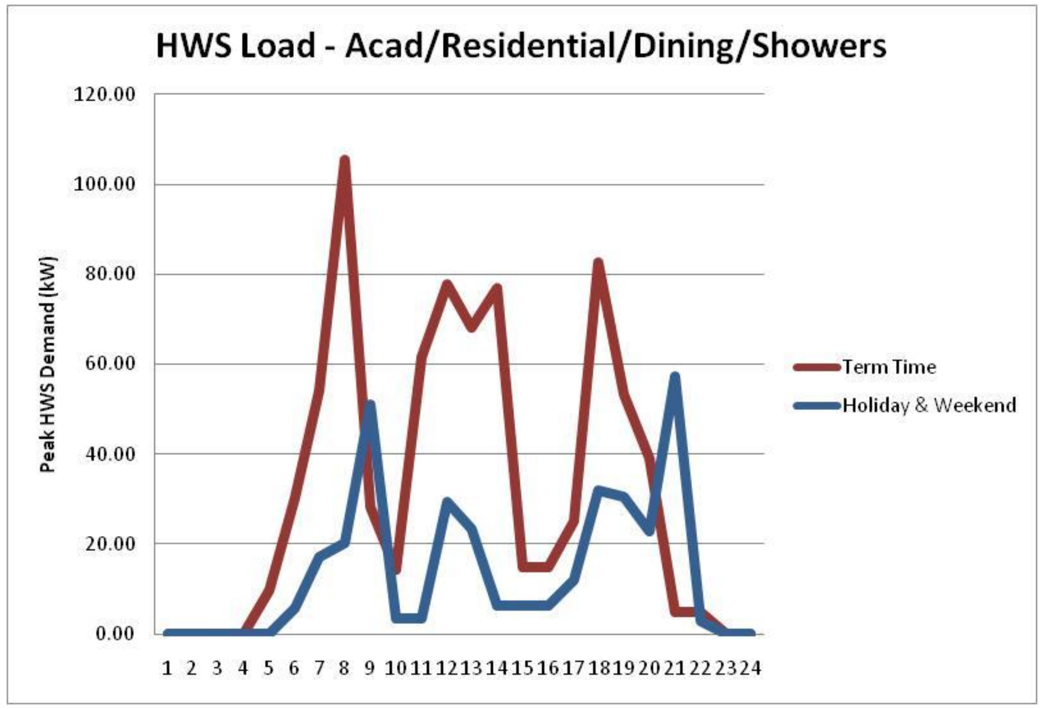
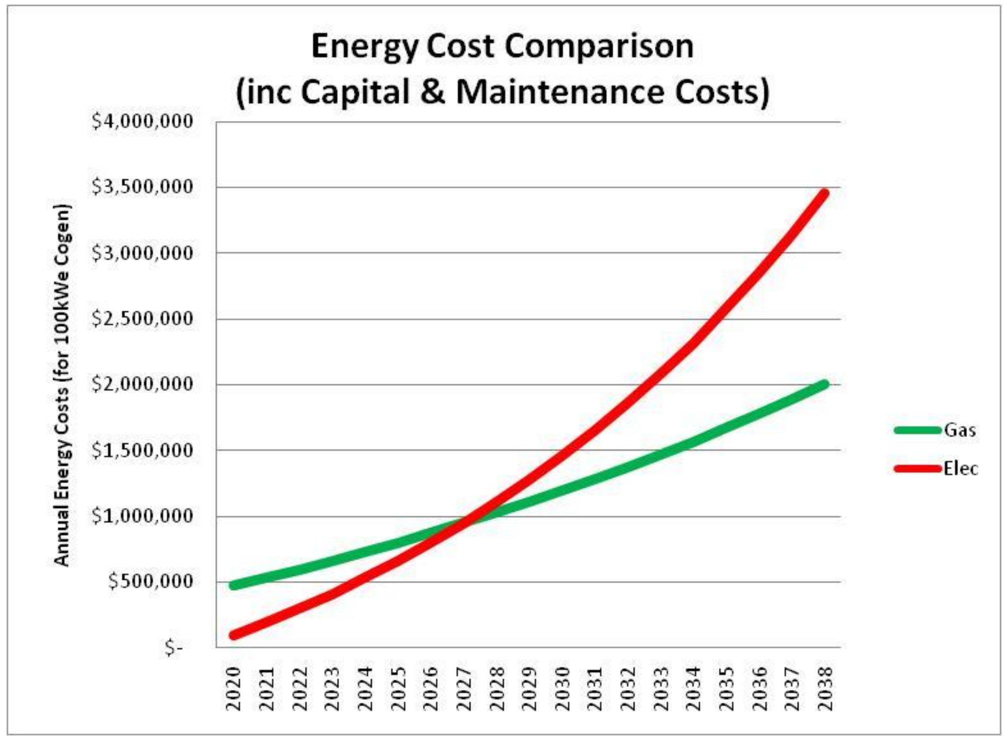
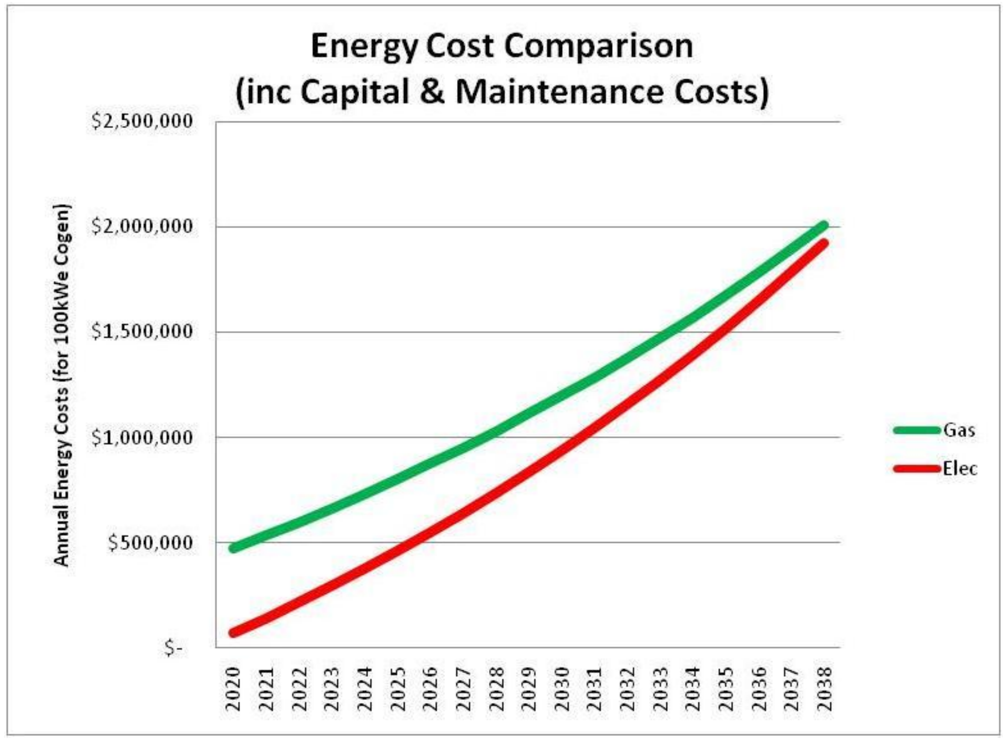


Figure 21. Predicted Increase In Gas & Electricity Energy Costs (Scenario 1)



The current supply cost for the cogeneration unit is $275,00, but allowing 3% inflation (plus $25K additional costs to providing HWS interface), the future costs by 2020 is approx $474,000. Again however, if the electrical rates increase at a higher margin then the gas, payback shall be around a reasonable 6 to 7 years.

Figure 22. Predicted Increase In Gas & Electricity Energy Costs (Scenario 2)



To emphasise how the future inflation rates of gas and electricity prices impact on cogeneration payback periods, Figure 22 shows if the gas rates remain the same as the electricity after the initial increase of next year, and the payback occurs after 18 years.

15 Stage 4 Residential & Academic/Teaching

Stage 4 is to be completed by 2024 The combined heat load for both the Residential and Academic building during this stage are very low, and would not warrant connection to the cogeneration system. Therefore the intent of including cogeneration at this stage, along with the earlier stages, is to reduce the CO_2 emissions and future running costs, should gas prices remain significantly lower.

The trend follows with Stage 4, and payback occurs around 8 years.

However when considering the other scenario on equal inflation to both energy costs, the payback period extends longer than 20 years, as shown in Figure 24.

Figure 23 Predicted Increase In Gas & Electricity Energy Costs (Scenario 1)

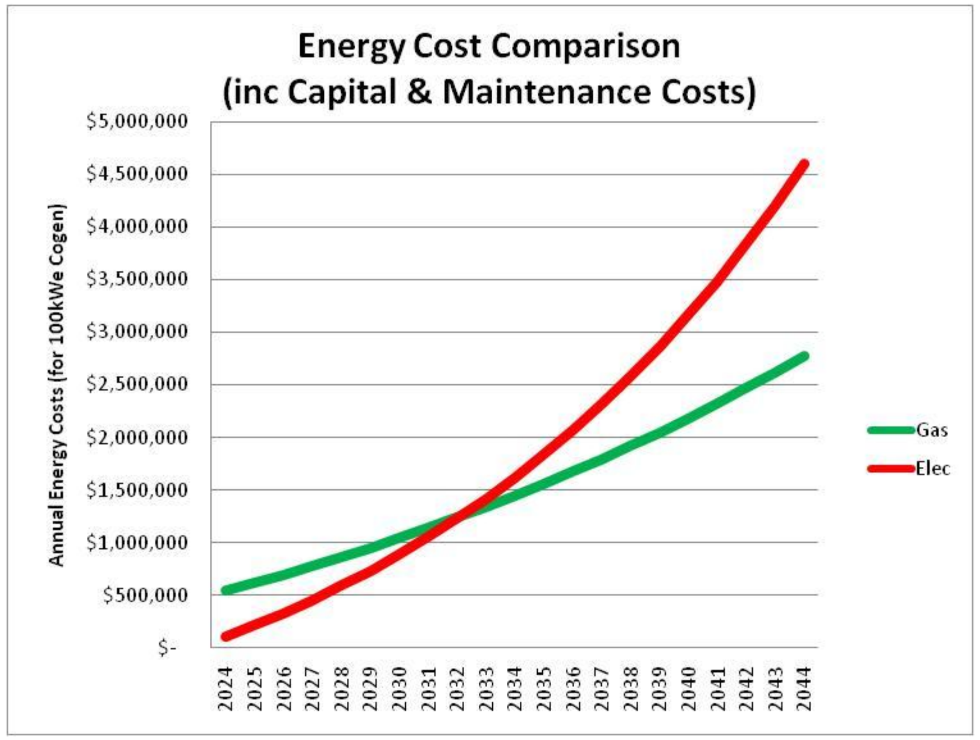
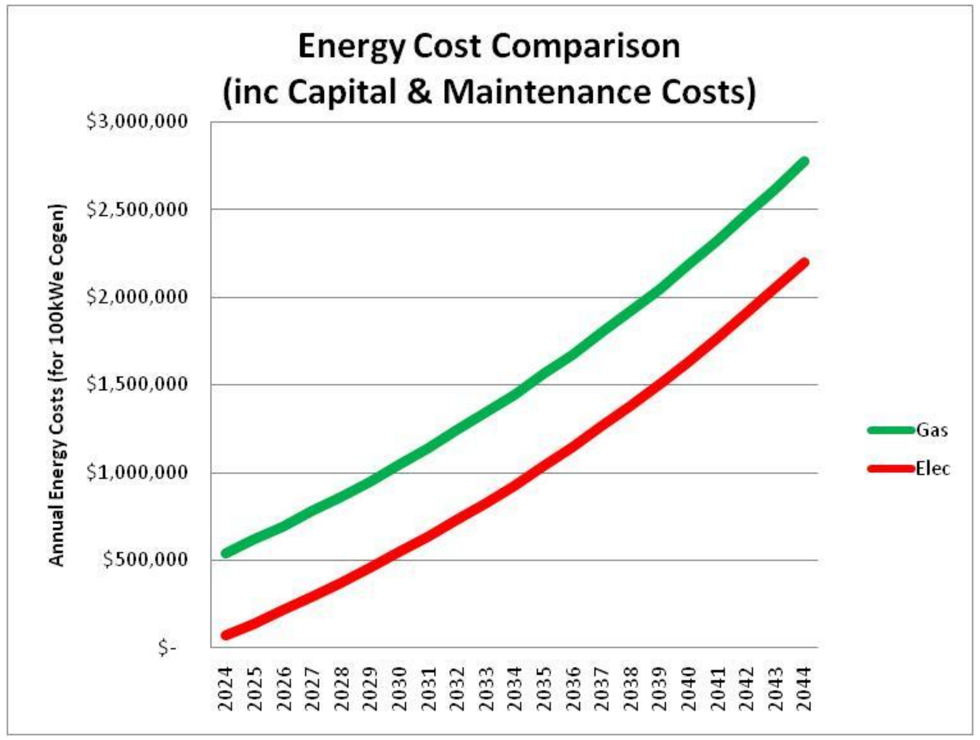


Figure 24 Predicted Increase In Gas & Electricity Energy Costs (Scenario 2)



16 Stage 5 Residential & Academic/Teaching

This final stage, due for completion by 2028, follows the pattern of previous findings based on the earlier stages. Once again, HWS loads are small, and cogeneration would only be considered for reducing C02 emissions and if the costs of electricity considered exceeded the cost of gas.

17 Beyond Stage 5

As electrical generation includes a greater proportion of 'green' alternatives, whether from solar, tidal, wind, biomass etc, the reliance of the coal driven power stations will lessen. As a direct result, the resultant electrical grid GHG emissions shall decrease.

Using a reduction in CO_2 emissions for gas over coal fired grid electricity might not be a suitable long term strategy for including cogeneration into a scheme, as consumption of natural gas to create the electricity might become the main CO_2 polluter.

18 Conclusion

The main focus and purpose of the report stemmed around cogeneration and establishing if introducing cogeneration into the future development stages was environmentally and financially feasible. What this report discovered through simulating many scenarios, is cogeneration for Moore College would not be used to its full potential, due to the low constant demand for heat from the Academic and/or Residential buildings.

Cogeneration will receive improved payback periods through longer operating periods and the higher the HWS base-load. The Moore College Campus with its semesters and holiday periods does not seem to fit this description, and will never offer the same constant energy requirements as say a swimming pool open to the public for most of the year.

Should the electrical price rise steadily higher than gas over the coming years, this inefficiency of not having a high base heating load, or not running the plant for the majority of the year is overcome simply on accumulated running cost. Alternately if these energy rates inflate identically the payback period extends a lot further, steadily increasing from approximately 16 years to 30 plus by Stage 5. This ignores any price agreements Moore College may negotiate with gas or electricity suppliers.

Until clean energy sources are created, we need to maximise the nett efficiency of a fuel source, therefore the excessive heat from the cogeneration requires a more productive use than emitting straight to atmosphere. This is where tri-generation could be considered and may have some merit for the Library. However it would be limited to non-residential buildings.