Report for Bay Pavilions

Energy Audit

Eurobodalla Shire Council

13 July 2023

→ **The Power of Commitment**

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The Power of Commitment

Executive Summary

This report outlines an energy audit conducted by GHD for the Bay Pavilions Arts and Aquatic centre at 12 Vesper St, Batemans Bay, for the Eurobodalla Shire Council (ESC).

The building has been open since June 2022, during which time the operating costs are understood to be substantially higher than initial estimates predicted. This has resulted in ESC engaging GHD to undertake an energy audit of Bay Pavilions to help understand the realistic energy requirements of the building and whether opportunities exist to reduce this without impacting the functionality of the building.

The key aims of this report are to:

1. Quantify the operating costs and energy consumption of the building.
2. Identify where energy is being consumed and how efficiently.
3. Identify potential energy conservation measures and their cost benefits, to address the currently high operational cost of the building.

Operating Costs and Energy Consumption

For the period June 22 to April 23, the time between opening and the undertaking of this energy audit, the energy consumption of the building and expenditure were as follows:

Table 1 Summary Table of Energy and Water Consumption and Costs

Electricity		Water		Total Cost
kWh	$ (incl. GST)	kL	$ (incl. GST)	$ (incl. GST)
2,574,300	$895,191	13,150	$38,639	$933,830

Key Findings

– Operating costs: Electricity consumption is the primary operating costs component (81%), followed by electrical maximum demand charges (14%) and water consumption (5%).

– Energy consumption: Pool and gym areas account for 80% of the total energy consumption, whereas theatre and centre area are 19% and external lighting is 1%. In terms of end-use, the HVAC systems (56%) and pool water treatment plant (28%) are the main energy consumers, with the remainder being general power (8%) and lighting (8%).

– Benchmarking: Bay Pavilions' pool and gym consume 24% more energy than similar aquatic centres, and the theatre and centre area consume 186% more energy than similar arts and recreational buildings.

– Reason for high energy consumption is the baseload operation of pool HVAC systems and pool water treatment plant. Other items, mainly HVAC equipment, were also noted to be operating either 24/7 or at times that do not match the usage of the area served.

– Generally, the HVAC controls were identified as a key area for improvement.

Energy Conservation Measures

This report identifies and evaluates several energy conservation measures to address the issues previously noted. Recommendations are provided which, if undertaken are expected to achieve the energy reductions and related cost savings.

Table 2 below outlines the key energy and cost saving opportunities:

Table 2 ECM Summary Table

Rank	ECM	Capital Cost ($ exc. GST)	Annual Cost Savings ($)	Simple Payback Period (yrs)
Recommended				
1	ECM1 Correct HVAC Operating Schedules	$1,200	$35,000	<1 year
2	ECM2 Correct HVAC Temperature Deadbands	$600	$28,000	<1 year
3	ECM3 Correct HVAC Controls Issues	$5,800	$54,000	<1 year
4	ECM8 Improve Operating Procedures	$1,200	$14,000	<1 year
5	ECM4 Improve HVAC Controls	$6,300	$35,000	<1 year
6	ECM6 Optimised Pool Hall Setpoints	$600	$7,000	<1 year
7	ECM9 Pool Treatment Plant Setback	$20,000	$80,000	<1 year
Not Recommended				
-	ECM5 Pool Covers	$0	-$29,000	Never
-	ECM7 Warm Pool Air Recirculation	$30,000	$10,000	3.5 years
-	ECM10 Power Factor Correction	$50,000	$5,000	12.5 years
Additional Costs				
-	Consultant design and documentation	≈$30,000	-	-
Total (Recommended Works)		**$65,700**	**$253,000**	**<1 year**

We recommend that:

- This report is distributed to key stakeholders.
- An action plan is set up to implement the energy savings recommended in this report and a target is set for energy saving.
- A member of ESC staff is given the responsibility for focussing on energy management issues and improving energy performance on site.
- Progress is reviewed in regular intervals – suggested every month initially for three months and then at three monthly intervals afterwards.
- A follow up “desktop audit” is carried out at 3 months and 6-monthly intervals afterwards, using data from the electricity sub-meters to monitor how the site is tracking to meet energy saving targets.

This report is subject to, and must be read in conjunction with, the limitations set out in section 1.2 and the assumptions and qualifications contained throughout the Report.

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1. Introduction

This report outlines the methodology and findings of the energy audit conducted by GHD for the Bay Pavilions Arts and Aquatic centre at 12 Vesper St, Batemans Bay, for the Eurobodalla Shire Council.

Bay Pavilions is a new arts and recreational centre consisting of an aquatic pavilion, a gymnasium and fitness areas, a 350-seat theatre, gallery, bar and multi-purpose rooms for public hire. The facility is owned by Eurobodalla Shire Council (ESC) and operated by Aligned Leisure.

The building has been open since June 2022, during which time the operating costs are understood to be substantially higher than initial estimates predicted. This has resulted in ESC engaging GHD to undertake an energy audit of Bay Pavilions to help understand the realistic energy requirements of the building and whether opportunities exist to reduce this without impacting the functionality of the building.

1.1 Purpose of this report

This report aims to quantify and explore opportunities to reduce Bay Pavilions operational costs, primarily through energy saving measures.

The purpose of this energy audit is to:

1. Quantify the energy consumption of the building.
2. Identify where energy is being consumed and how efficiently.
3. Identify potential energy savings measures and their cost benefits.

1.2 Scope and limitations

General

This report: has been prepared by GHD for Eurobodalla Shire Council and may only be used and relied on by Eurobodalla Shire Council for the purpose agreed between GHD and Eurobodalla Shire Council as set out in this section of the report.

GHD otherwise disclaims responsibility to any person other than Eurobodalla Shire Council arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer section 1.4 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

Accessibility of documents

If this report is required to be accessible in any other format, this can be provided by GHD upon request and at an additional cost if necessary.

Specific Items

Since Bay Pavilions has not yet been open for a full year, availability of historical data is limited, and benchmarking cannot be undertaken against previous performance. Because of this, the typical full requirements of a standard energy audit are not able to be completed. Nonetheless, this report makes use of available metering data and documentation to inform estimates where data is missing, in order to generate an understanding of the end-use breakdown and identify key energy consumers and identify opportunities for energy saving measures.

In addition to energy use, analysis of water consumption is provided in this report, and cost savings associated with reduced water consumption considered in all relevant cost-benefit analyses. Water use and savings are only considered in relation to energy use. A complete analysis of water consumption and water saving measures is not considered within this report.

As a full year of historical data was not yet available, analysis of energy use was carried out on the full period of available data. Water is billed quarterly and as such the billing does not align with the operational period of the building. Estimates were made to correct for billing periods in cost analyses. The audit periods for analysing historical data were:

– *Electricity (site utility meter): June 2022 – April 2023*

– *Electricity (sub-metering): March – April 2023*

– *Water: February 2022 – February 2023*

Cost estimates in this report are preliminary, and based on the auditor's previous experience, unless otherwise specified in the report. Actual variables may differ to those used in cost estimation and may be subject to change. No detailed quotations were obtained for the recommendations identified in this report. GHD does not represent, warrant or guarantee that the energy conservations measures (ECMs) will be undertaken at a cost that is less than or equal to the cost estimate provided. Unless otherwise specified, all costs in this report exclude GST.

If implemented, some of the recommendations outlined in the report may also result in lower maintenance costs and longer lifetime of equipment, which has not been included in costing estimates within this report.

Before proceeding with procurement of any ECMs outlined in this report, it is recommended that ESC engage the services of a professional engineer to carry out detailed design and documentation of the recommended works for pricing and installation by contractors.

1.3 Abbreviations

AHU	Air Handling Unit
BMS	Building Management System
CHW	Chilled Water
COP	Coefficient of Performance
DALI	Digitally Addressable Lighting Interface
DLP	Defect Liability Period
ECM	Energy Conservation Measure
ESC	Eurobodalla Shire Council
FCU	Fan Coil Unit
HHW	Heating Hot Water
HVAC	Heating Ventilation and Air Conditioning
kL	kilo Litre
kVA	kilo Volt Amperes
kW	kilo Watt (measure of power)
kWh	kilo Watt hour (measure of energy, typically for electricity)
LED	Light Emitting Diode
OA	Outdoor Air
O&M	Operations and Maintenance
PF	Power Factor
PFC	Power Factor Correction

PV	Photovoltaic
RA	Return Air
VAV	Variable Air Volume
VSD	Variable Speed Drive (also known as a VFD - variable frequency drive)

1.4 Qualifications and Assumptions

This report is based on the following qualifications and assumptions:

- All documentation and metering data collected for the purposes of this report are accurate and complete.
- All operations observed during site visit are typical of the ongoing operation of the building.
- All feedback from ESC and Aligned Leisure provided to be GHD on operation and history of building is accurate.

Refer throughout the report and in appendices for any specific assumptions used in calculations and conclusions drawn.

1.5 Methodology

An initial desktop review was carried out on the available historical data to analyse electricity and water consumption patterns. Available electricity interval data were used to produce graphical trends to analyse usage profiles. This analysis was overlaid with information from Operation and Maintenance (O&M) manuals, which was reviewed to identify high energy consuming systems, and determine components of after-hours loads and baseloads.

Detailed site surveys were carried out on the 26th and 27th April 2023, including an after-hours visit on the 26th. Site visits were carried out by Gerry Hackett and Rebecca Craine from GHD, with assistance provided by Aligned Leisure and ESC staff. During site visit, day and night-time walkthroughs of the building were performed, and key staff members were consulted regarding building operation. Access was provided to the BMS head-end where sub-metering data and information on the controls of HVAC and pool treatment systems were collected. Temperature/humidity loggers were placed in the pool halls for the duration of the site visit to collect data on pool conditions.

Following the site visit, further information regarding design and operation of Bay Pavilions was gathered. Analysis was carried out using the available information and used to identify energy conservation measures outlined in this report.

The analysis undertaken in this report made use of the following sources of data:

- O&M manuals for mechanical, electrical and pool systems at Bay Pavilions
- Design documentation for Bay Pavilions
- Electricity and water billing invoices provided by retailers
- Electricity interval data provided by Shell Energy and Origin Energy
- Metering data collected from the BMS
- Control systems data collected from the BMS
- Information collected from on-site observations
- Information collected from discussions with ESC and Aligned Leisure staff
- Weather and temperature data from Moruya Airport Weather Station (i.e. the closest weather station)
- Average temperature data from Carrier Hourly Analysis Program v6

The following staff members provided assistance with gathering data and site inspections for this report and their assistance is gratefully acknowledged.

– Carlyle Ginger - Divisional Manager Recreation Services, Eurobodalla Shire Council
– Brett Longstaff - Aquatic and Arts Contract Manager, Eurobodalla Shire Council
– Chris Tague - Arts and Leisure Manager, Aligned Leisure
– Alyson Whiteoak - Theatre events management, Aligned Leisure

1.6 Description of Building

The Bay Pavilions building is located at 12 Vesper St, in Batemans Bay NSW. The venue has been operational since June 2022.

Bay Pavilions is a new arts and recreational centre consisting of an aquatic pavilion, including a 25m lap pool, warm pool, splash parks and water slides, a gymnasium and fitness areas, an arts pavilion including a 350-seat theatre, gallery, bar and multi-purpose rooms for public hire, and a central area including a visitor centre, café, retail area and offices. The facility is owned by Eurobodalla Shire Council (ESC) and operated by Aligned Leisure.

The total floor area of the building is approximately 5,950m^2 with the gym area occupying 1,300m^2, the pool area 2,050m^2, the theatre area 1,950m^2, and the centre occupying 650m^2.

Bay Pavilions is open every day of the year except for Good Friday and Christmas Day. The different areas of Bay Pavilions operate across a varied operational schedule. The central and aquatic sections of the building are open for scheduled daytime operating hours. The gymnasium is open 24/7, with staff noting regular use outside of standard day time hours. Classes are regularly scheduled in the gymnasium program rooms, seeing them typically occupied between 5:40am and 7:00pm each day. Available booking records show that bookable rooms are used for both irregular and weekly recurring events, with the area in use for approximately 4 hours per day. Booking records show that use of the theatre is irregular with events typically occurring once to twice a week. Staff advised that setup time typically began the day before a show, with pack up being completed the night of the show.

Electricity and water are supplied to the building via metered connection. Electricity is supplemented by on-site generation through a 99kW rooftop solar photovoltaic (PV) system. ESC staff highlighted a requirement to not exceed 100kW of solar generation as the system would then no longer qualify as a “small-scale” system under the Renewable Energy Act (2000). As such, increased on-site electricity generation was not considered as a means to reduce electricity costs. The building is not connected to any local gas supply, with space and water heating demand being met through electrical systems. However, bottled LPG is being used on site to supply kitchen burners.

2. Operating costs and consumption patterns

2.1 Breakdown of operational costs

Water consumption, electricity consumption and electricity maximum demand are considered to be the major sources of operational costs for the Bay Pavilions Building. It was noted that bottled LPG was being used on site for kitchen appliances, but this is considered to be a minor contribution to costs with little opportunity for savings and thus not considered in this analysis. Data is based on invoices, interval data and BMS sub-metering received for the building since opening in June 2022 until the timing of the preparation of this report in April 2023.

The total operational costs of the building during this period have been $933,830. Billed water consumption accounts for $38,639 and electricity bills account for the remaining $895,191.

The electricity cost can be further broken down into electricity consumption costs, maximum demand costs and other miscellaneous costs. Electricity consumption refers to the billing that is charged per kWh of overall consumption within the billing period. Maximum demand costs refer to billing that is charged monthly for the maximum power demand placed on the network at any time during the billing period. Miscellaneous costs include fixed rate charges billed per day or per meter, as well as discounts and fees applied to the electricity bills.

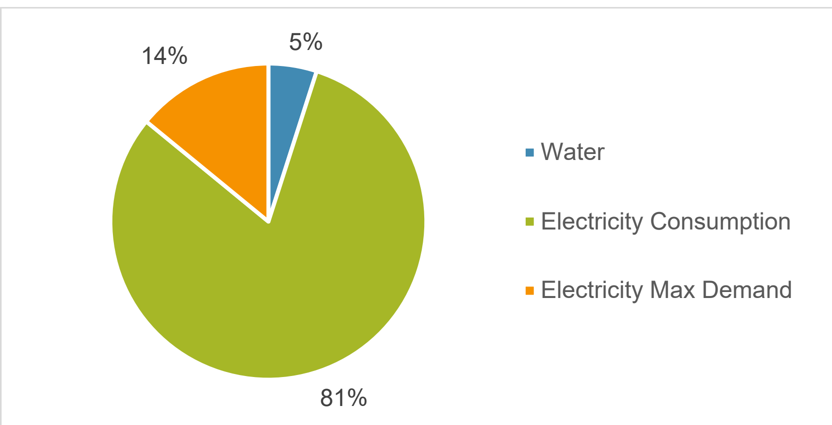

Figure 1 ***Approximated annual operational cost breakdown***

Figure 1 illustrates where operational costs of the Bay Pavilions building are being spent. During their period of operation, Bay Pavilions have engaged three different energy suppliers with differing billing rates, however the difference in percentage breakdown of costs overall, and costs for the time spent with the current supplier is less than 1%. Miscellaneous costs make up less than 1% of total operational costs and are thus not shown on the above plot.

Figure 1 shows that the largest cost in building operation is electricity consumption, making up over 80% of costs. It is therefore expected that the greatest opportunities for finding savings in operational costs will be in finding reductions in the amount of energy consumed by the building. This will also be important as electricity costs are expected to continue to rise in coming years. The majority of the remaining costs are due to electricity demand. Reducing charges relating to maximum demand will also be considered as this may also return meaningful savings.

Water costs make up a small proportion of operational costs. However, energy conservation measures identified in this report may also result in a reduction in water consumption, which may provide further savings through water costs. Specific water saving measures will not be considered as this is beyond the scope of the report.

When reviewing operational costs, it was seen that there were noticeable differences in the monthly energy costs between different electricity suppliers. Further opportunities for energy cost savings may be achieved through reviewing energy suppliers and finding the best available policy for Bay Pavilions.

2.2 Tariff Analysis

2.2.1 Electricity Tariffs

Table 3 provides a summary of the electricity tariff rates for the site. Tariff analysis is based on electricity invoices from only the current energy retailer, Shell Energy. These tariffs will be used in calculations of future energy costing and savings. Energy rates are divided into consumption, maximum demand and miscellaneous charges, and given for peak, off peak and shoulder periods.

As electricity consumption remains high at all times of day, the average cost per kWh of energy is closer to off-peak rates than peak rates. An average tariff of 25.99c/kWh will be used for all energy conservation measures that apply to full time operation, based on the weighted average consumption in peak, shoulder and off-peak periods. A demand charge of $9.2519/kVA/month will be used as the maximum demand most commonly occurs during shoulder periods. Energy costing relating to specific time periods will be used as per the values provided in Table 3.

Table 3 Electricity Tariff Analysis

Charges	Units	Peak 7:00 - 9:00 17:00 - 20:00 Business Days	Shoulder 9:00 - 17:00 20:00 - 22:00 Business Days	Off-Peak All Other Times
Energy Retail Charge	c/kWh	37.2242	18.6354	18.7585
Environmental Schemes	c/kWh	2.1567	2.1567	2.1567
Network Charge	c/kWh	5.0624	4.1956	2.7850
Market Operator Charge	c/kWh	0.1241	0.1241	0.1241
Total	**c/kWh**	**44.5674**	**25.1118**	**23.8243**
Demand Charge	$/kVA/month	10.2257	9.2519	2.3064
Total	**$/kVA/month**	**10.2257**	**9.2519**	**2.3064**
Network Supply Charge	$/day	15.8085	16.8085	17.8085
Market Operator Charge	$/day	0.0036	0.0036	0.0036
Metering Charge	$/day	0.9151	0.9151	0.9151
Total	**$/day**	**16.7272**	**17.7272**	**18.7272**

2.2.2 Water Tariff

According to Eurobodalla Shire Council, water tariffs in the region are based on consumption only, with no charges for access or availability. For the current financial year, water is billed at a rate of $3.90/kL. This value will be used in the calculation of any cost savings measures.

2.3 Electricity Consumption Analysis

This section provides further analysis on the building's electricity consumption, as this was previously identified as the major contributor of the operating costs. Site electricity consumption patterns are analysed annually, seasonally, daily and in terms of end-use breakdown. Benchmarking is also provided to determine how Bay Pavilions compares to other similar facilities.

2.3.1 Annual

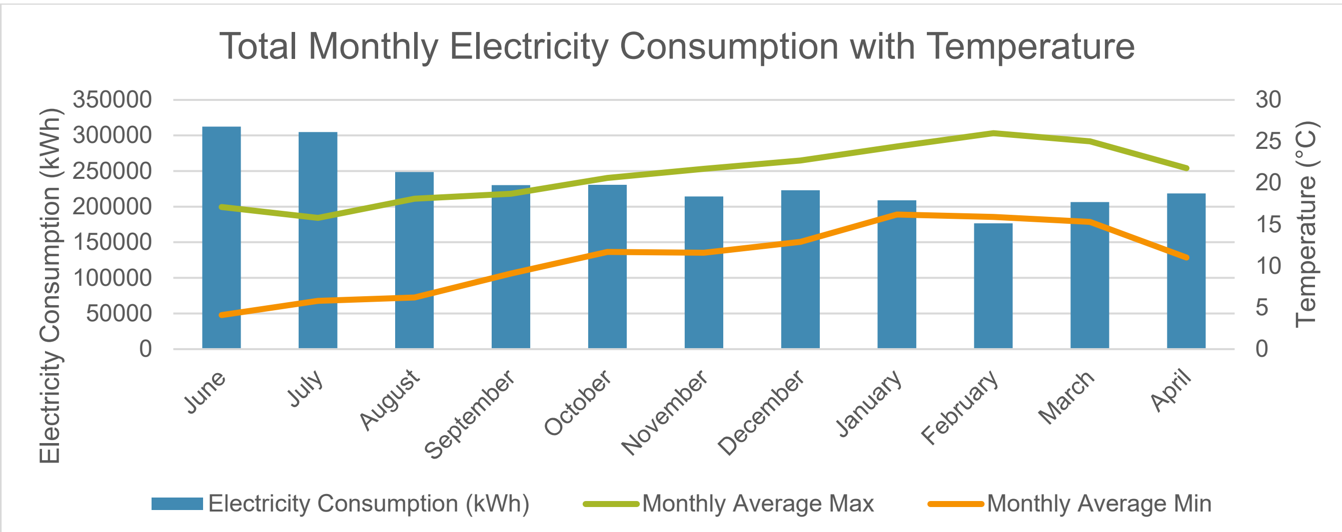

Figure 2 Total Monthly Electricity Consumption with Temperature

Figure 2 shows the total electricity consumption for each month of available data, compared with the average maximum and minimum temperatures of each month. A pattern of seasonal variation is somewhat apparent with higher electricity consumption in the winter months and lower consumption in the summer. This higher electricity consumption in colder months is likely to be associated with pool HVAC systems which constitutes a major energy consumer as it operates 24/7 to maintain warm indoor temperatures and providing heating of the incoming outdoor air ventilation.

Lower electricity consumption in summer months may also be attributed to higher solar radiation, contributing to higher on-site electricity generation from Bay Pavilions' rooftop solar photovoltaic (PV) panels.

It can however be noted that despite seasonal variation in temperature, electricity consumption remains consistently high even in warmer months, indicating that the major sources of energy consumption are not entirely dependent on external temperature.

2.3.2 Seasonal

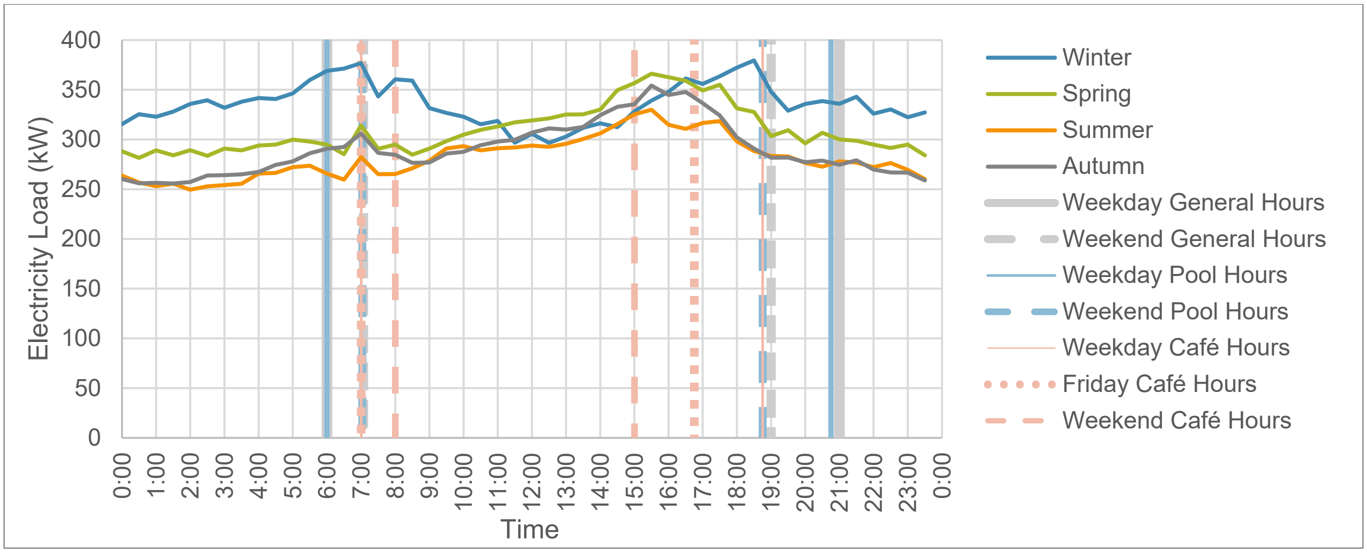

Figure 3 Average Hourly Electricity Load by Season

Figure 3 shows the average daily electricity load profiles for each season. This shows highest electricity consumption during winter days, with summer and autumn having lower electricity consumption. The profiles for each season appear to be similar during afternoon periods with the most distinct differences in morning and overnight profiles. Spring and winter show significantly higher overnight electricity consumption.

All profiles show very little decrease in electricity consumption between operational and closing hours, indicating that the majority of electricity consumption comes from an ongoing baseload of systems operating at all times. The major component of this is pool HVAC and pool treatment plant which operates at all times, however additional full-time operation of systems may also be adding to the high overnight load. Reducing the electricity demand of full-time operating systems or reducing the number of systems operating full time may therefore provide significant energy savings.

2.3.3 Daily

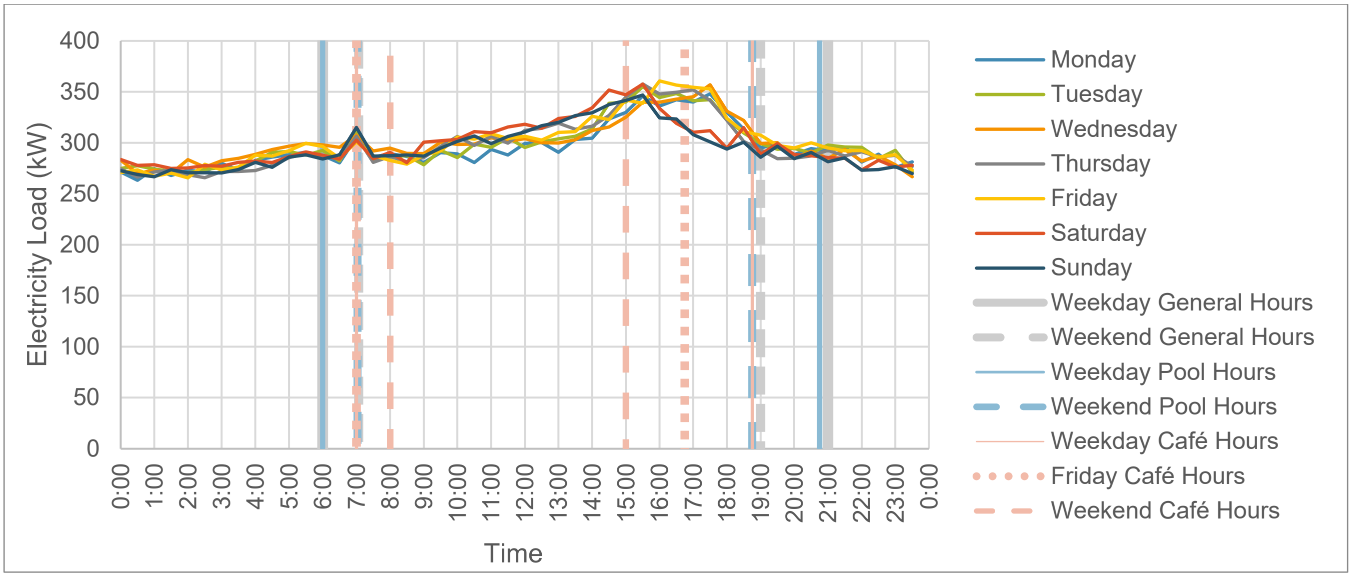

Figure 4 ***Average Hourly Electricity Load by Day of Week***

Figure 4 shows the average daily electricity load profiles for each day of the week. This illustrates a relatively consistent profile between all days of the week, with overnight consumption remaining high on all days. Consumption is highest on Fridays and Wednesdays but not largely. Weekdays show high electricity consumption later into the evening, whereas weekend electricity consumption drops earlier, likely due to differing opening hours and staff occupancy in offices.

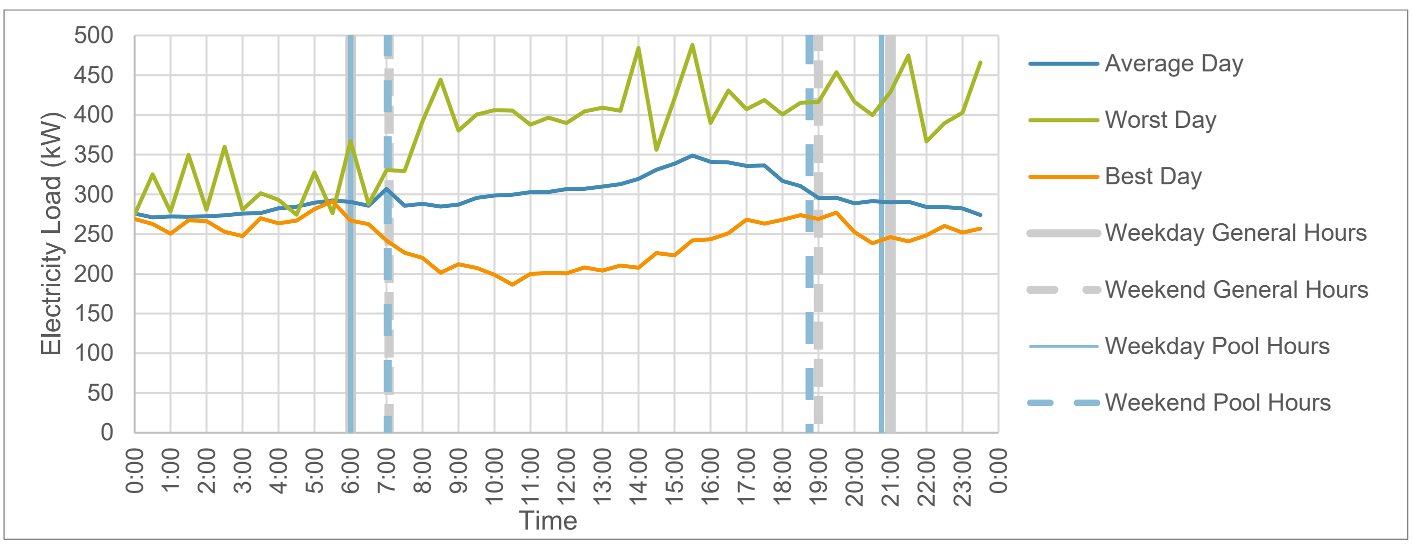

Figure 5 ***Average Hourly Electricity Load for Worst and Best Day***

Figure 5 shows the electricity load profile for the day of highest electricity consumption and lowest electricity consumption, compared to the average daily profile.

The day of highest consumption was August 23rd, which was a weekday, where an evening event was held in the dance studio and had the lowest maximum temperature of all days since the building opened, as well as one of the lowest solar exposures in this period. The day of lowest electricity consumption was December 25th, the warmer of the only two days in the year when the Bay Pavilions precinct is completely shut, which saw mild temperatures and high solar exposure. This indicates that building use, temperature and rooftop solar generation may be major contributors to the electricity demand on a given day.

A major difference between the two days is that the daytime electricity usage on the worst day increases during the daytime where the best day remains more constant. The overnight load does not show as much difference.

It can be seen that even on the day of lowest electricity consumption, the average hourly electricity load only drops below 200kW for an hour. This dip is attributed to an offset in consumption due to solar energy generation. The total electricity consumption on the highest day is 28% higher than on the lowest day, showing little variation across all days. This shows that there are no days where the overnight of equipment drops far lower than average, and further demonstrates that a high proportion of energy is being consumed by systems that do not turn off.

The increase in load profile between the worst day and the best or average day also shows the impact of the theatre and arts half of the building. The usage of these areas is based on bookings and is expected to be sporadic, and this variability is visible in the daily electricity profiles.

2.3.4 End Use Breakdown

Electricity metering data collected from the BMS and from on-site electricity meters was used to determine the breakdown of energy use at Bay Pavilions. As BMS data was only able to be collected for the two months prior to site visit, a sample period of 7 weeks in March and April was used to estimate end use breakdown. Temperature data was then used to model and correct for the seasonal variability in HVAC systems demand.

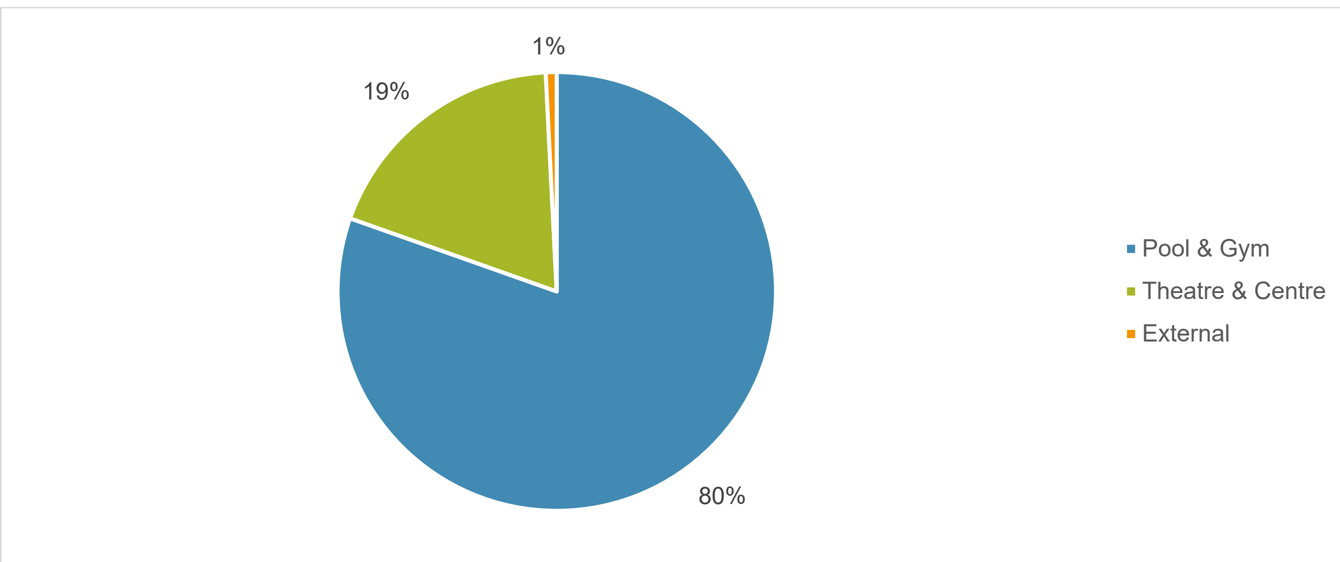

Figure 6 Breakdown of electricity consumption by area

Figure 6 illustrates the end use breakdown of electricity consumption by location in the building. Due to data availability, the building has been grouped into regions, dividing the pool and gym area from the centre and theatre area, as well as any external areas. It can be seen that the large majority of electricity is consumed in the pool and gym section of the building. The theatre and centre also makes up a significant amount of electricity use. These locations will therefore be investigated further for opportunities to identify electricity savings. External use accounts for a small amount of energy use as this consists only of external lighting which is only on at night time.

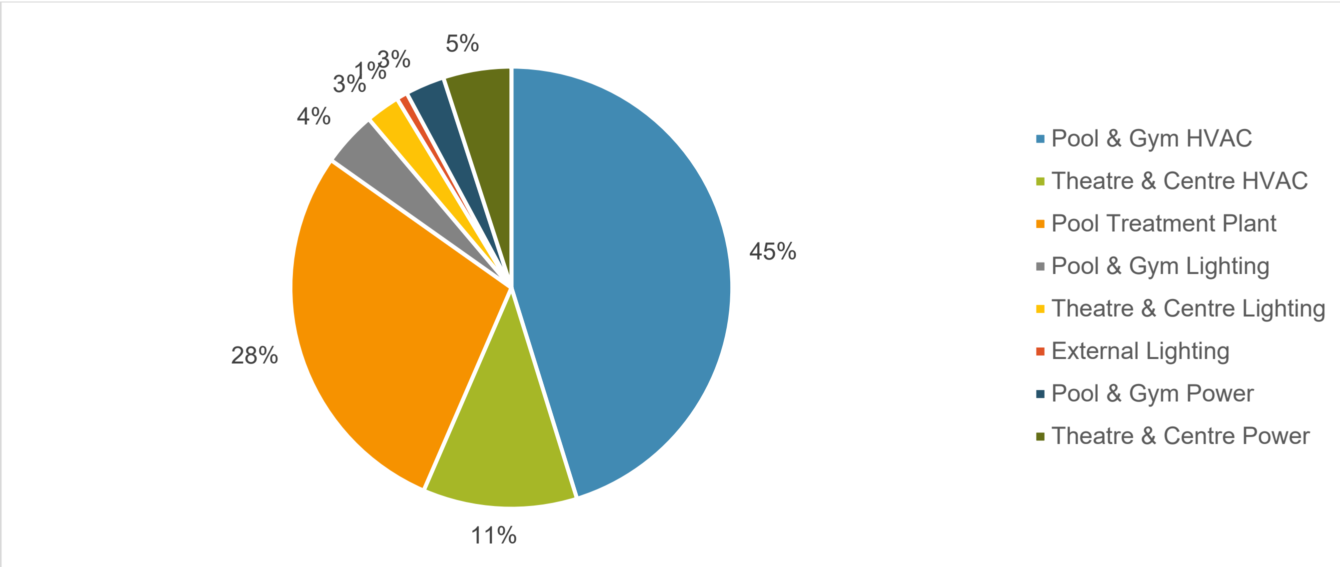

Figure 7 Breakdown of electricity consumption by application

Figure 7 provides a detailed breakdown of electricity use in Bay Pavilions by application. Power use consists of any applications that are neither HVAC or lighting, including AV equipment and items plugged into general power outlets. This figure shows that the major consumer of electricity is Pool and Gym HVAC. This is expected to be primarily pool HVAC, as the pool HVAC systems operate 24/7 to provide space heating and heating of ventilation air. Pool treatment plant also makes up a significant proportion of electricity consumption, which is attributed to the 24/7 operation of pumping and treatment systems to circulate clean water into the pools. The other major component of electricity consumption is theatre and centre HVAC. This is attributed to the heating and cooling of a large floor area of spaces, which were found upon site visit to be operating during unoccupied times and not controlling in response to the intermittent usage of these areas. Energy conservation measures will focus on these areas to identify opportunities to reduce energy costs on site, as these have the largest potential to deliver savings.

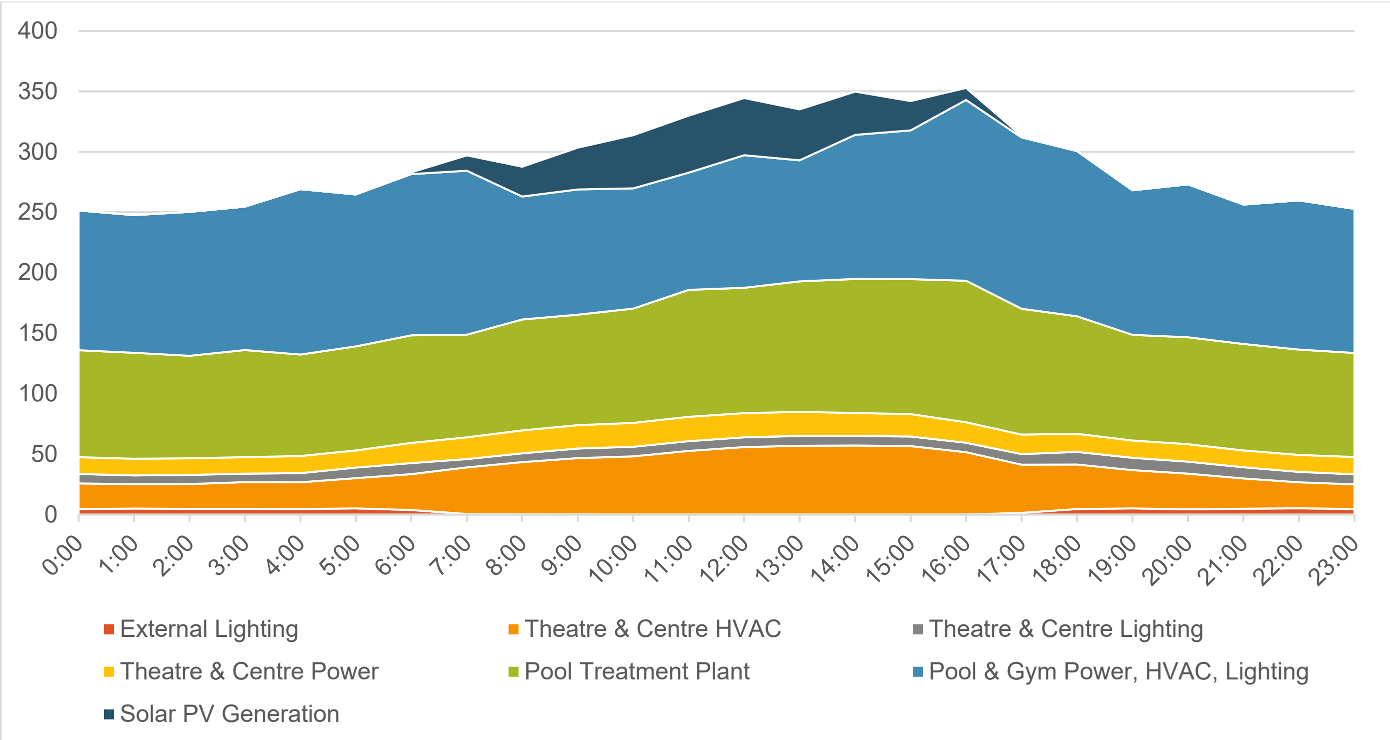

Figure 8 Average daily electricity profile March-April

Figure 8 shows the average daily electricity profile for the period of March-April where detailed BMS data was available. An estimate of solar generation is also included on this plot. As this generation reduces the electricity metered by the pool distribution board, the solar PV generation combined with pool & gym power, HVAC and lighting can be considered the actual power demand of the pool and gym section. Due to limited data availability, pool and gym HVAC, power and lighting are shown as one dataset, however, based on the energy breakdown provided in Figure 7, this is anticipated to be mostly HVAC.

This plot shows that pool HVAC has the largest demand at all times, with higher electricity consumption during the day when the pool is open, and traffic is higher in pool and gym areas. Despite the variation, the pool HVAC demand is relatively consistent with an ongoing baseload of approximately 120kW and a daytime increase of approximately 50kW.

Pool treatment plant has the second highest level of energy use, remaining relatively consistent at all times. The pool treatment plant has an ongoing baseload of approximately 85kW during closing hours, increasing to 105kW during the day.

The consistently high usage of pool treatment and HVAC systems is shown to be the major source of high baseload electricity use. This is to be expected as these systems are expected to be operating at all times. There may however be opportunities to reduce electricity consumption overnight by investigating reduced operational states and conditions in the pool and pool hall may not need to be held to the same standard when the area is unoccupied.

Theatre & Centre Power, Lighting and HVAC all contribute to smaller portions of electricity consumption, however it can be seen that their electricity consumption remains relatively constant throughout the night. This indicates that there are energy consuming systems being left in operation when the building is not is use, which are contributing to unnecessary power consumption in the building. Reducing the overnight consumption of systems which do not need to be in operation outside of opening hours may also return meaningful energy saving opportunities.

2.3.5 Benchmarking

The energy usage intensity, calculated as kWh per m^2 of gross floor area, has been calculated for Bay Pavilions for the purposes of benchmarking against similar facilities in Australia.

Table 4 indicates that Bay Pavilions consume moderately more energy than other indoor aquatic centres (+24%), and substantially more energy than other entertainment and recreational buildings (+186%). Potential explanations could be the high baseload HVAC energy consumption identified previously, notably in the theatre and centre area where other facilities of this type would typically ensure system operation matches the usage. Further reasons for this comparatively high energy consumption are identified later in this report.

Table 4 ***Benchmarking***

Measure	Bay Pavilions (MJ/m^2/year)	Benchmark Figure (MJ/m^2/year)	% Difference
Electricity – Pool & Gym	2,227	1,795	+24%
Electricity – Theatre & Centre	695	243	+186%

Sources:

1. Pool and gym benchmark figure based on '*A guide for Benchmarking Energy and the Indoor Environmental Quality of Aquatic Centres in Victoria*'. Source: **https://cdn.revolutionise.com.au/cups/arv/files/ylk9rgo6qclhxqsk.pdf** (note, benchmark figures included separate values for electricity and gas. To provide a representative comparison to Bay Pavilions, the gas figure was converted to the equivalent consumption with an electric heat pump, assuming an average gas boiler efficiency 80% and average heat pump COP of 3).
2. Theatre & Centre benchmark figure based on '*Commercial Buildings Energy Consumption Baseline Study 2022' – NSW Illawarra data – 'Entertainment and recreation buildings'*. Source: **Commercial Buildings Energy Consumption Baseline Study 2022 | energy.gov.au**

2.4 Electricity Maximum Demand Analysis

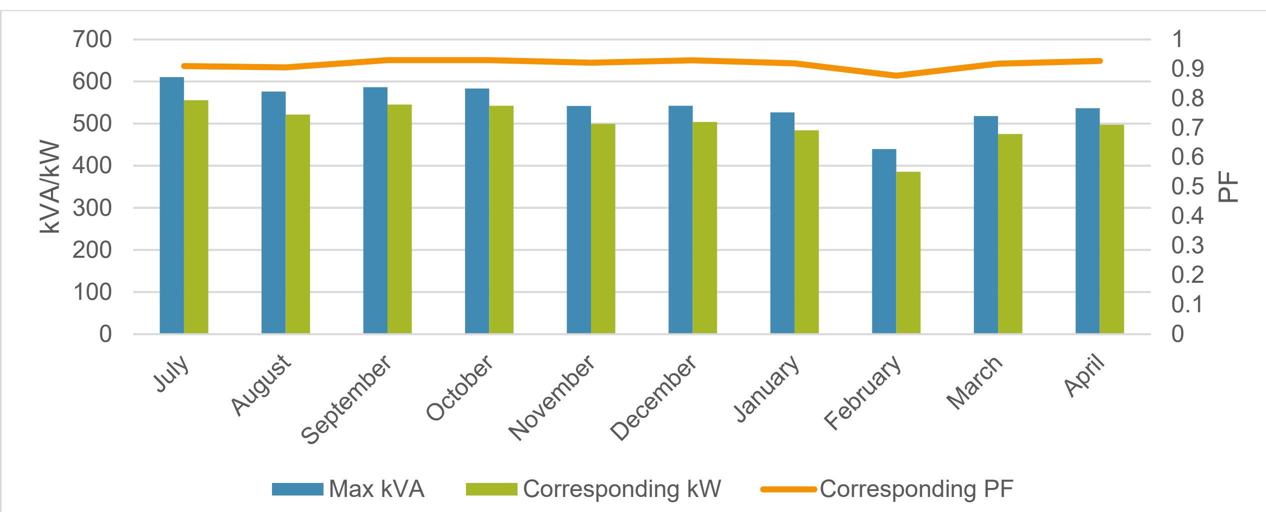

Figure 9 ***Monthly Max kVA and corresponding kW and PF***

Figure 9 shows the maximum kVA per month, with the corresponding kW and power factor. Maximum demand appears to show a similar trend to electricity consumption, being higher in winter than summer. The corresponding power factor for each month's maximum demand remains high, with values ranging from 0.87 to 0.93. A power factor over 0.99 is considered ideal as it means electricity bills will only charge for the true power drawn by the building. Power factor correction systems can ensure high power factor, which will provide some reduction in energy costs through reducing maximum demand charges.

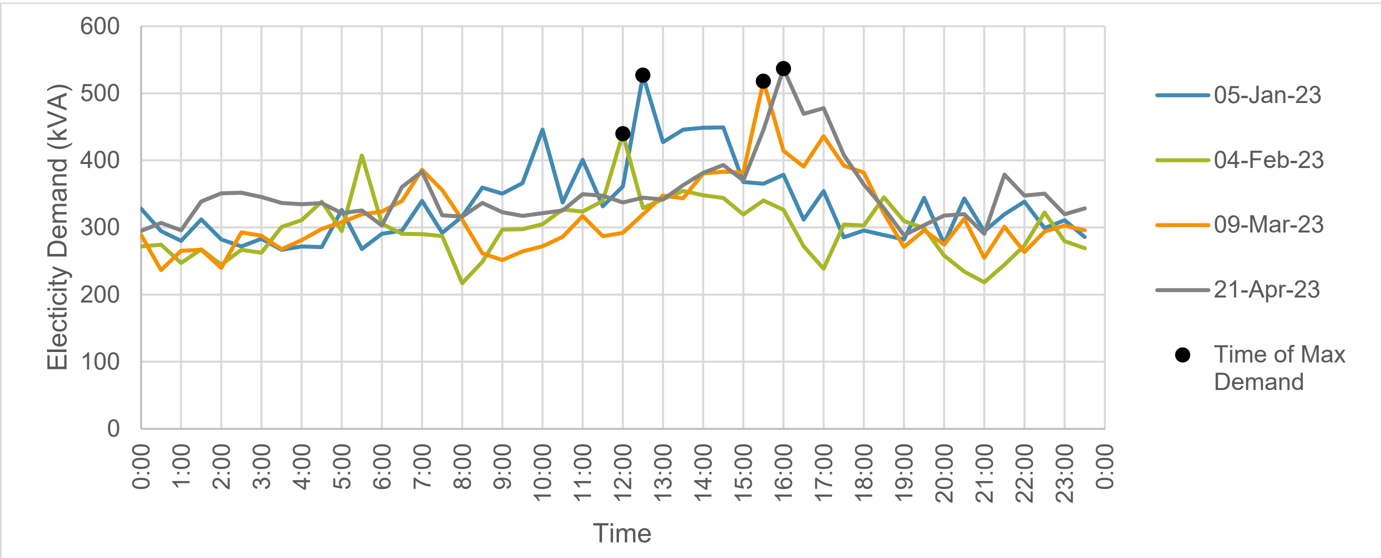

Figure 10 Electricity Profiles for Days of maximum demand

Figure 10 shows the electricity consumption profile for each of the days in which the maximum demand for the month occurs. Only months billed by the current energy supplier are shown, as previous company's half hourly data does not align with values on bills. This plot shows no apparent pattern as to when maximum demand occurs. Periods of high demand tend to occur in short bursts with the electricity demand for the next interval returning to a lower state. The resolution of the utility and sub-metering data is insufficient to identify likely causes of these spikes.

2.5 Water Consumption Analysis

2.5.1 Annual

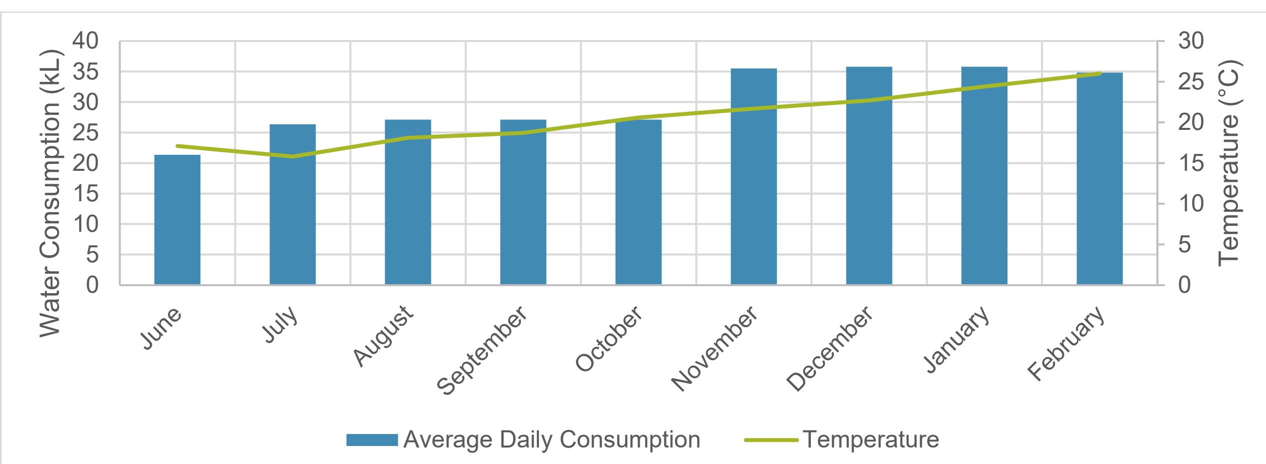

Figure 11 Total Monthly Water Consumption with Monthly Average Temperature

Figure 11 illustrates the water consumption of each month for which water billing has been made available. As water is billed approximately quarterly, water consumption is approximated to be split across each period evenly. This shows that water consumption has increased over the operational period of the building. This is attributed to outdoor pool use being higher in warmer months and evaporation in pool and irrigation applications being higher when temperatures are warmer. Improving upon energy efficiency at Bay Pavilions may also result in reducing water demand which may result in further savings.

2.5.2 End Use Breakdown

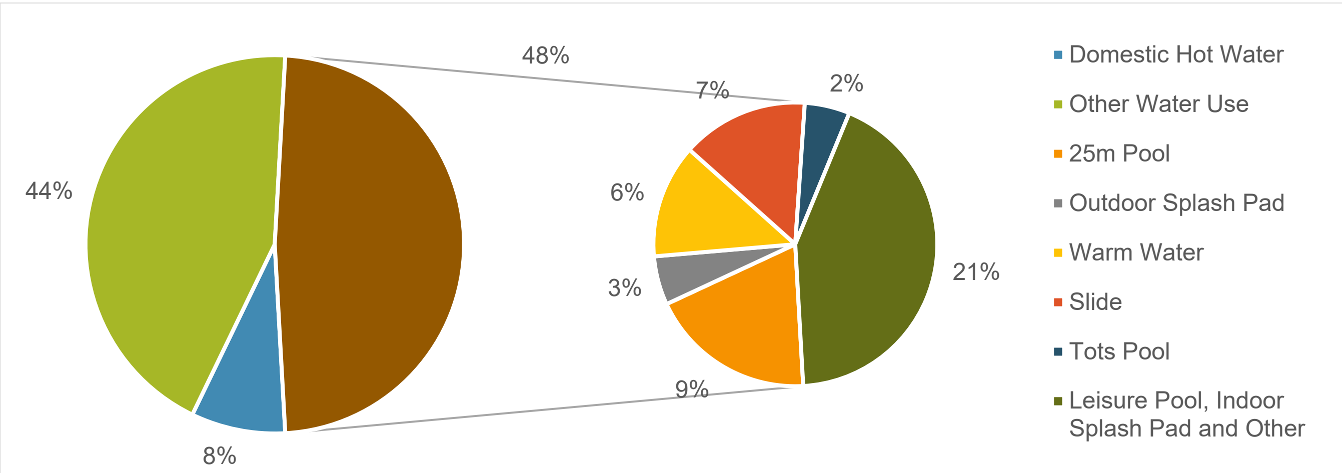

Figure 12 End use breakdown of water consumption

Figure 12 provides the estimated end use breakdown of water consumption at Bay Pavilions. Water consumption has been estimated based on site water meter readings and water bills. Due to limitations in the available data, a breakdown of water uses outside of pool water provision and domestic hot water could not be provided. “Other Water Use” is attributed to irrigation, domestic cold water, HVAC make-up, heat recovery make-up, and non-potable backup water. Figure 12 shows that pool plant provision makes up almost half of the sites water consumption. Measures implemented to reduce energy demand in pool plant and HVAC may also return water savings via minimising pool evaporation losses, which will have potential to return some savings on water use costs.

3. HVAC

3.1 Description of Systems

The heating, ventilation and air conditioning (HVAC) systems at Bay Pavilions are summarised as follows:

Thermal Plant

Heating and cooling to the building is generally provided by two central heating hot water (HHW) and chilled water (CHW) systems, one serving the pool and gym area and the other serving the theatre and centre management area. These plant are located in external rooftop plant areas at separate ends of the building.

Each system consists of multiple hydronic air-source heat pumps, which are typically 4-pipe type that can provide both heating water and chilled water independently of each other and simultaneously using heat recovery (i.e. heat rejected from rooms being cooled provide a heat source for rooms being heated). The pool thermal plant also contains a third 2-pipe heat pump that provides heating-only to account for the increased heating demands of the pool heating and HVAC systems. The chilled and heating water is then circulated throughout the building via insulated copper pipework to the various air handling units, fan coil units and heat exchangers.

Each thermal plant system contains ancillary plant associated with the heat pumps, such as circulating pumps, buffer tanks, expansion tanks, mains water make-up, and chemical dosing.

Pool Heating

The pools are heated from the central heating hot water system. HHW is supplied to plate heat exchangers, one for each of the seven pool systems, which provide a heating to the pool water via the water treatment recirculation loop. Refer to Figure 15 which shows the typical heating configuration from the pool treatment plant perspective.

Air Handling Plant

The various types of air handling plant in the building are described below. Refer to Figure 13 which shows the configuration and areas served for each type of plant:

- Main pool hall – Served by a heating-only air handling unit located on the rooftop. The AHU recirculates air from the pool hall and mixes with outdoor air prior to being heated and supplied back into the pool hall. The unit contains a run-around coil heat recovery system, which preconditions the incoming outdoor air via recovering heat from the exhaust air. Air is supplied to the hall via linear diffusers around the perimeter directed onto glazing. The unit is generally controlled to maintain warm conditions (25-29°C) in the pool hall with sufficient outdoor air ventilation to maintain indoor air quality, control relative humidity below 60%, and prevent condensation on glazing and other surfaces.
- Warm-water pool hall – Served by a heating-only AHU located on the rooftop. This AHU is similar to that supplying the main pool hall, except that it operates on full outdoor air rather than recirculating air from the space. It maintains warmer conditions (30°C).
- Gym – Served by a variable-volume AHU located on the rooftop. The AHU contains CHW and HHW coils and a variable-speed supply fan which provides conditioned air to the gym via six zones, each served by a VAV box.
- Theatre – Served by a constant-volume AHU located in the upper storey plant room. The AHU contains CHW and HHW coils and serves multiple zones including the seating area and the stage, with zone reheat provided for the stage zones.
- Other areas – Served by chilled and heating water fan coil units and air handling units. These are typically constant-volume units which are either ceiling-cassette type, or ducted type located in plant rooms or ceiling spaces.
- Comms rooms – Served by single wall-mount split systems to provide cooling to ICT or AV equipment.

Ventilation Systems

Outdoor air ventilation is generally supplied to the building via the air conditioning systems, where it is introduced at the AHU or FCU and mixed with return air prior to be conditioned.

Exhaust air ventilation is generally provided via the following:

– Amenities (i.e. toilets, change rooms).
– Kitchen exhaust hood, including make-up air supply fan.
– Plant rooms and pool treatment chemical storage.

Automatic Controls

A Building Management System (BMS) provides control and monitoring of the HVAC systems, along with monitoring of energy and water meters. The system is a Synchronous Building Automation system and contains a head-end display via remote login. The system provides various control features that aim to reduce energy consumption, including:

– Economy cycle (i.e. when ambient conditions suit, outdoor air is used for ‘free cooling’).
– Demand controlled ventilation, to reduce volume of outdoor air that needs conditioning by monitoring CO_2.
– Setpoint reset strategies for fan speed control and heat pump flow water temperatures.

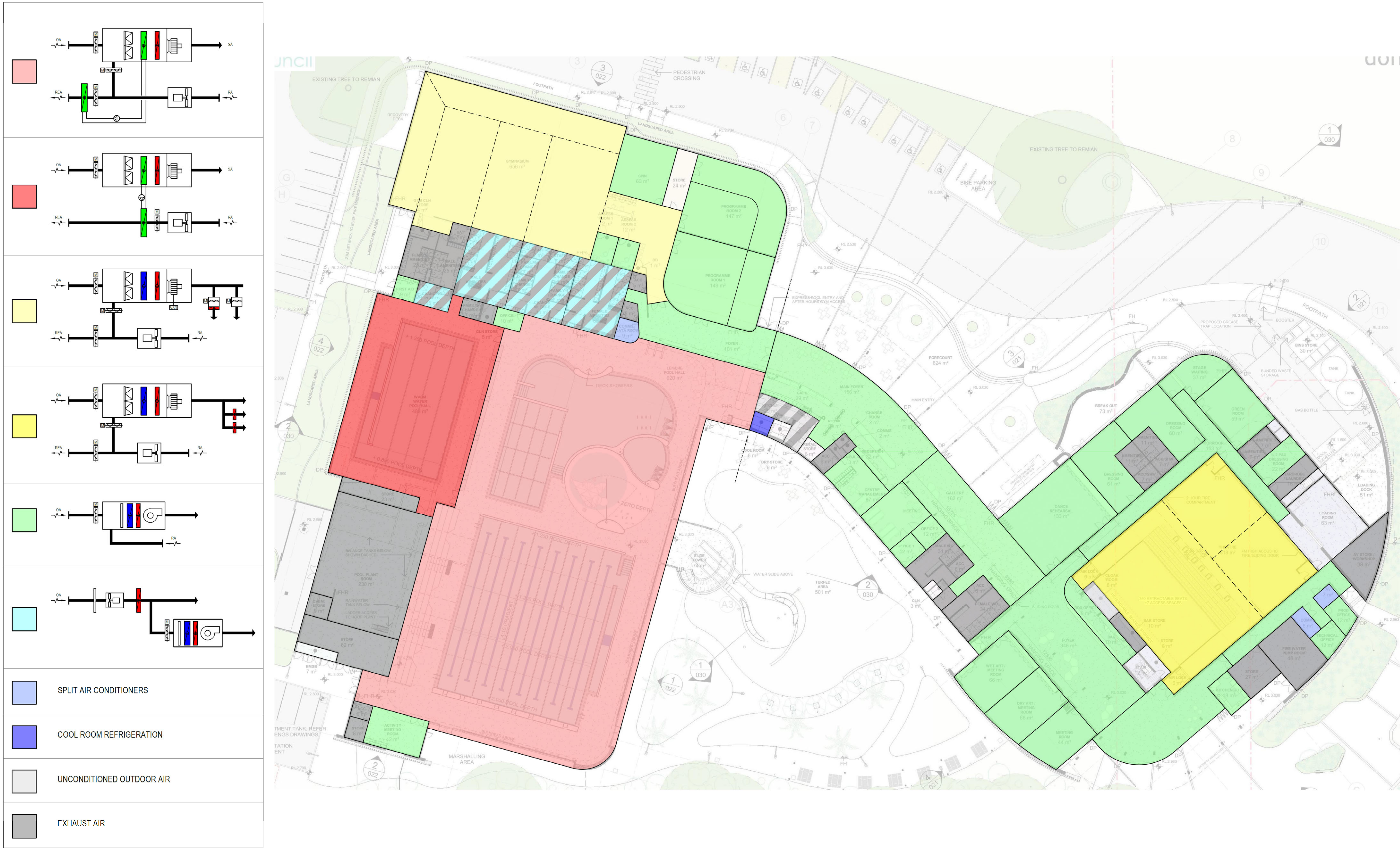

Figure 13 HVAC zoning and unit types

3.2 Commentary

HVAC systems are the major contributor to energy consumption at Bay Pavilions. As illustrated in Figure 7, HVAC makes up 56% of total electricity consumption and thus 45% of operational costs. The majority of this energy is consumed in the pool and gym region if the building, with the largest consumers identified to be the heating and ventilation of the two pool halls. It is common that HVAC makes up most electricity consumption in pool facilities, however this large energy consumption indicates potential opportunities to identify meaningful cost savings in HVAC operation.

Generally, the types of HVAC systems in use at Bay Pavilions are modern and utilise components that have the potential to operate with high energy efficiency, if controlled well. This high efficiency operation is supported by use of components such as:

– Heat recovery on heating and cooling systems (i.e. the installed heat pumps recovery heat rejected from the cooling system and provides as a heat source to the heating system).
– Heat recovery on pool ventilation (i.e. the incoming outdoor air is preconditioned from heat recovered from the exhaust air, reducing the outdoor heating energy by 60%).
– Variable speed pumping.
– Suitable zoning.
– BMS with various smart controls features (CO2 demand control ventilation, economy cycle, etc).

Despite this, we have noted several aspects which are contributing to higher energy consumption than necessary. These are mostly associated with the BMS and controls.

1. Occupancy time schedules setup for air conditioning units in many cases do not suit the occupant usage of the rooms. This results in HVAC energy consumption at unnecessary times. We have noted the following scenarios:
   - 24/7 operation of units serving areas which are not continuously occupied. This includes the gym spin, program and access rooms, centre gallery areas, and staff office areas.
   - Daily operation of units serving areas which are typically unoccupied unless an event is scheduled. This includes theatre back-of-house rooms, meeting rooms, art studios, etc. This also included the theatre, although this unit had its time scheduled altered a few months ago.
2. Fine-tuning adjustments and alterations to HVAC controls have been made in the 10 months since building has opened. These have aimed to address comfort complaints but have impacted energy consumption. These include:
   - Narrow deadbands of temperature control around setpoint. Controls description typically specifies deadbands of 3°C however observed values are typically smaller in the range of 1°C. This would mean for a setpoint of 22.5°C, instead of heating to 21°C and cooling to 24°C the system is heating to 22°C and cooling to 23°C. This active heating or cooling close to setpoint has a significant impact on energy consumption and in some cases results in overshoots which cause fluctuations from heating to cooling. This is the case for majority of AHUs and FCUs.
   - Mismatched temperature setpoints in rooms or open areas which are served by multiple units. This results in the lower-setpoint unit providing cooling against the higher-setpoint unit which is heating. Apart from the energy wastage of this, a knock-on effect is it prevents the CHW and HHW thermal plant from triggering some energy-saving setpoint reset strategies. This is currently occurring for centre gallery corridor, gym program rooms and theatre, however is susceptible to occur to any other room or area served by multiple units.
   - Manual adjustment of temperature setpoints. Setpoints were noted to vary throughout the facility, some being relatively low for cooling (i.e. 18-21°C). Acknowledging this may have been done to suit the activity of the space or the type of events in the theatre, however the impact on energy efficient can be significant.

3. The BMS controls are not allowing the HVAC systems to turndown in response to the variable and intermittent usage of some areas of the building. This is both due to the designed strategies not maximising opportunities for demand control, and the strategies that are employed are not working as intended. Examples include:
   a. Time schedules setup for some units do not suit room usage (as previously described).
   b. Constant air volume AHUs and FCUs are generally used throughout the building (except the Gym), rather than variable volume systems that reduce airflows when demand for heating and cooling is lower.
   c. No temperature setback modes are provided to rooms that are infrequently occupied. A setback provides a wider tolerance for temperatures to drift when room is unoccupied to minimise tight control of heating and cooling. It provides energy savings although maintains room temperatures close enough to the required setpoint in order to restore comfort conditions quickly once room becomes occupied.
   d. Outdoor air ventilation introduced to the building is generally higher than necessary and likely more than is required for maintaining indoor air quality and AS1668.2 compliance. This includes:
      – Where demand-controlled ventilation via CO_2 monitoring is provided to AHUs, the outdoor air dampers were introducing large quantities of outdoor air whilst CO_2 readings were relatively low (600-650 ppm).
      – Where economy cycle is provided to AHUs, this was activated despite the outdoor air conditions at the time being warmer than the room that needed cooling.
      – FCUs typically have open/close outdoor air dampers, which are always open when unit is activated regardless of the occupant numbers.
      – Where outdoor air dampers were at a minimum position, this seemed arbitrarily set to 30%. Dampers are inherently non-linear, a damper position of 30% could be introducing up to 60% of the damper flow rate.
      – Main pool hall AHU outdoor air damper was noted to be introducing more outdoor air than needed to maintain relative humidity or condensation conditions. Furthermore, the run-around heat recovery coil was inactive during the site visit, meaning full heating of outdoor air needs to be provided by the heat pumps (if this occurred for 12 months, the additional energy costs are approx. $30,000).
      – Warm water pool AHU operates on full outdoor air as there is no recirculation of return air. This means that all air supplied to the room must be heated from ambient temperatures when full outdoor air may not always be necessary to maintain relative humidity setpoints.
   e. Setpoint reset strategies are limited. In some cases, these do not appear to be provided (e.g. CHW and HHW pump speed control) and where these are provided, they are not achieving the desired setbacks during low demand times (e.g. CHW and HHW flow temperature setpoints are not being relaxed during low demand times due to presence of one or two rogue zones, often due to the heating and cooling 'fighting' each other).
4. Staff operational issues were noted that would impact energy efficiency, including:
   - Staff leaving external and internal doors open from conditioned spaces. This was observed to occur in the following areas during the site visit:
      – Main pool hall. Staff reported they leave doors open on mild and warm days to improve comfort in the hall. During these times, the HVAC system AHU-0R-P01 remains operational and continues to provide heating with little impact on room conditions.
      – Theatre foyer doors. These were noted to be open during a night-time event.
      – Pool office door. During these times the AC unit serving this office AC-0G-P02 remained operational, cooling at maximum capacity to offset pool room heat with little impact on room conditions.
   - Pool covers are installed but not used by staff. This impacts amount of evaporation and heat loss occurring from the pool surfaces and hence increases make-up water required, make-up water that requires heating, and amount of outdoor air that needs to be introduced to offset the increased humidity from pool evaporation.
   - Temperature setpoint ad-hoc adjustments, as noted previously.

5. BMS sensor readings were noted to be inaccurate, unrealistic, and providing conflicting readings in many instances. Some of these sensor values are used in control strategies and therefore could have implications for comfort, air quality, condensation control and energy consumption. Typical and significant instances:
   - Pool hall temperature and relative humidity values. These inaccuracies could be resulting in higher outdoor air rates than necessary to maintain humidity setpoints, or more heating than necessary to maintain temperature setpoints. More concerning, it could create air quality issues with condensation risks which could have serious consequences to occupant health and building longevity.
   - Mixed air temperature readings are generally all unrealistically high.

Other observations on the HVAC systems that may not be contributing to high energy consumption but may impact aspects of building performance such as condensation, air quality and comfort, are listed in in Section 9.

Refer to Appendix A which notes which of the noted issues are applicable to each unit.

4. Pool Water Treatment

4.1 Description of Systems

Bay Pavilions contains seven water treatment plants that service each of the following systems independently:

- 25m Lap Pool
- Indoor Leisure Pool
- Warm Water Pool
- Toddlers Pool
- Indoor Splash Pad
- Water Slides (4-off)
- Outdoor Splash Pad

A summary of each pool system is provided in Table 5 and the area served by each system is shown in Figure 14.

Table 5 Pools Summary

Pool	Surface Area m^2	Average Depth m	Volume m^3	Max. Bather Load Qty/day	Peak Bather Load Qty	Turnover Rate hrs	Recirc Rate m^3/hr	Pool Water Temp °C
25m Pool	551	1.55	900	1000	165	2.5	342	28
Leisure Pool	290	0.75	247	640	132	1.2	181	32
Warm Water Pool	228	1.2	254	850	104	1.1	238	34
Toddler's Pool	30	0.15	9	-	15	0.33	14.5	32
Indoor Splash Pad	120	0	19	-	60	0.49	19	28
Water Slides	32	0.25	50	1200	4	0.75	67	28
Outdoor Splash Pad	460	0	64	-	161	0.49	142	28

Figure 14 Pool water systems

Each system generally consists of pre-pump strainers, recirculating pumps, regenerative-media ultra-fine filters, water chemistry control, chemical dosing, ultra-violet sterilisation, heating, and automatic mains make-up water. The general configuration of the pool water treatment plant is shown in Figure 15.

Systems such as the indoor and outdoor splash pads, slides, etc differ to the general configuration as they resupply the treated water back to the balance tanks, and from there separate pumps will supply the features and slides when these are operational.

All pool water treatment plant is located within a dedicated plant room, as shown in Figure 14.

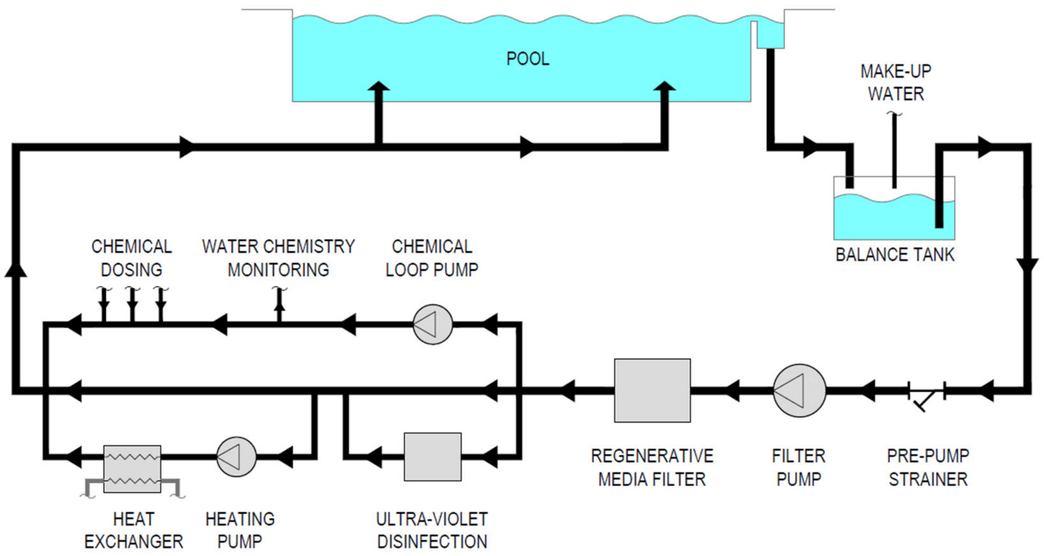

Figure 15 Pool water treatment plant - General configuration

4.2 Commentary

As shown in Figure 7 the pool treatment plant accounts for 28% of the facility's energy consumption. Within this, the most significant consumers are the filter pumps (approx. 57%) and the UV lights (approx. 25%). These appear to be constant and responsible for majority of the 85kW base load from the pool treatment plant. The remaining 18% of energy consumption are pumps that cycle on/off as needed (i.e. heating, water slides, water features, backwash) and ancillary plant and controls.

Potential areas of energy wastage in the pool treatment plant are noted as follows:

1. Filter pumps operate at near-constant flow rates to achieve the recirculation rate nominated in Table 5. This recirculation rate is a design parameter which is calculated based on the peak bather load and a corresponding water turnover rate for the pool's water volume. However, this peak bather rate rarely occurs at Bay Pavilions, for majority of the building's opening hours the pool is substantially below this peak. Hence there are less contaminants generated in the pool water and the required turnover rate may be less. Furthermore, when the pool is closed, there is no contaminants being added to the pool. Operating the filter pumps to maintain the design flow rates at all times is potentially unnecessary and consuming significant energy, noting these pumps account for 16% of the facility's energy consumption.
2. The UV sterilisation lights also appear to operate at a relatively constant output continuously (i.e. 24/7). Again, this is potentially unnecessary considering the reduced contaminants generated in the pool due to low utilisation. These UV lights appear to account for approximately 7% of the building energy consumption, so has the potential to provide some savings if this operation can be reduced.
3. Heating pumps cycle on and off to meet the pool heating requirement. Providing variable speed drives to these pumps would allow lower speeds and hence less power draw, even if operating for longer durations. However, as these pumps are small and appear to contribute minimally to the overall energy consumption, these works are not likely to provide short payback.

4. Pumps serving the water slides and features are operated at reduced hours, i.e. slides operate 4pm-7pm weekdays and 10am-4pm weekends, and outdoor splash pad pumps operate on a timer based on manual activation of a push button. However, the energy metering trends show that these items do cause relatively high spikes in power draw of 30 kW. Considering the low utilisation of the facility in general, a further reduction in hours or closure of the outdoor splash pad and water slides during low-attendance days or out-of-season periods may be worth consideration.
5. Pool water temperatures generally appear higher than typical industry recommendations. These are shown in Table 6. For example, if pool water for the 25m pool and leisure pool were each reduced by 2°C (i.e. 26°C and 30°C respectively), the annual energy cost savings for the Main Pool Hall are estimated to be in the order of $6,000-$10,000. If possible GHD recommend Bay Pavilions consider lowering these setpoints to achieve further energy savings.

Table 6 Pool water temperatures

Pool Type	Water Temperature °C (Industry Recommendations)	Water Temperature °C (Bay Pavilions)
Active swimming, training, water sports	25-27	28
Passive swimming, learning to swim classes	27-29	32

Source: ***Sydney Water - Best practice guidelines for water management in aquatic leisure centres***

5. Lighting

5.1 Description of Systems

Internal lighting throughout the building is LED, with various fitting types to suit each space served, as follows:

– High-bays – in high ceiling areas such as Main Pool Hall and gym.
– Downlights – amenities, corridors, dressing rooms, theatre and Warm Water Pool Hall.
– Linear extrusions – offices, program rooms, meeting rooms and gym.
– Troffers – kitchen and offices
– Wall up-lights – gallery corridors
– Track lighting – for gallery displays.
– Battens – in back-of-house, plant rooms, loading dock and slide tower.
– Specialist lighting for theatre.

External lighting for the building is also LED, via a combination of post-mount, surface wall-mount, bollard-mount and inground fittings.

Lighting control methods are varied:

– A Dynalite automatic lighting control system serves most internal and external lighting in the building. It is understood the lights operate on a consistent time schedule of 6am–9pm, although can be manually overridden via a user interface panel in the Centre Management offices. The lighting control system provides a combination of motion control, dimmable/non-dimmable, addressable/non-addressable (i.e. DALI) and specific control features to suit the area served (i.e. colour changes for signage and theatre, 24-hour control of 25% lights in gym, etc).
– Motion sensor activation in amenities, change rooms and staff offices.
– Manual switching in back-of-house areas, storerooms, plant rooms and loading dock.

Lighting is powered and metered from dedicated chassis in the electrical distribution boards throughout the building.

5.2 Commentary

As shown in Figure 7, lighting accounts for 8% of the building’s total electricity consumption. Almost 90% of this is attributed to indoor lighting, with Pool & Gym lighting making up the largest component. Due to the small contribution of lighting to overall power consumption and a limited data availability, a further breakdown of lighting energy consumption is not provided.

Generally, the types of lighting systems used at Bay Pavilions appear to be operating efficiently. Lighting systems make use of modern technologies such as LEDs, dimmers and motions sensors to support energy efficiency.

Some inefficiencies were identified that could be unnecessarily contributing to lighting electricity consumption:

1. Electricity metering data indicates that power is consumed at all hours by lighting. This includes in the Theatre & Centre region of the building where there is no known requirement for after-hours lighting beyond safety and emergency lighting. Rooms relying on manual switching may operate unnecessarily if left on. This was noted in the gym and theatre storerooms during the site visit.
2. Handover documentation for the lighting systems do not provide description for how the automatic controls are programmed. It is unclear what the operating time schedules, however these could be activating lighting to control unnecessarily. Furthermore, the duration of time delays before lights switch off after being activated by motion sensor is unclear. Meeting rooms were observed to remain lit long after the space became unoccupied. Long time delays on sensor lighting may be causing unnecessary energy use in lighting.

6. Power

6.1 Description of Systems

Bay Pavilions is fed power from the Vesper St side, where the main switchboard is located externally to the building. From this main switchboard, power is supplied to sub distribution boards and mechanical services switchboards, to provide power to the appliances and services locate throughout the building. Electric vehicle charging bays are also provided on site, however these have a separate utility meter which is not accounted for in the building's electricity consumption.

The main switchboard contains chassis each for Normal Services and Safety Services. Safety Services are understood to be limited to smoke exhaust in the theatre and fire pump room ventilation, whereas all other services are powered from the Normal Services Chassis.

No back-up power generation is provided to the site, however there is future provision to connect a generator if required. There is also no Power Factor Correction (PFC) unit for the site.

The building contains 99kW of solar photovoltaic cells along with inverters and grid protection unit, installed on the rooftop above the pool halls. These provide a renewable supply to assist in meeting the electricity demand of the building when weather conditions suit.

Electricity metering is provided at each switchboard. This includes the utility meter connected upstream of the main switchboard for site billing purposes, and sub-meters for each distribution board (both lighting and power) and mechanical services switchboards. Sub-metering is connected and viewable via the site BMS for energy management purposes.

Throughout the building, various appliances and equipment are connected to the distribution boards and switchboards. These items generally appear typical for the types of spaces served.

6.2 Commentary

As shown in Figure 7, general power accounts for 8% of the building's total electricity consumption.

- Metering data indicates that over half of power consuming systems remain active overnight. Although there are known sources of overnight consumption such as fridges and the kitchen cool room, additional systems may be unnecessarily active contributing to energy consumption.
- Rooftop solar electricity generation is estimated to make up approximately 4% of electricity consumed in the building, offsetting a portion of electricity cost.
- General power consumption makes up a small portion of energy demand and appears to be operating efficiently. The following instances have been identified, which may be contributing to unnecessary energy costs.
  - Projectors in gym program rooms were observed to be left on after closing hours when the rooms were unoccupied.
  - The theatre winch appears to be consuming electricity at all times.
- There is no PFC unit for the site. Power Factor (PF) is generally high, but improved PF may reduce the charges applied to maximum electricity demands.
- Electricity metering issues have also been identified that may not be contributing to high energy consumption but may impact building operators to monitor energy consumption and maintenance needs effectively:
  - Meters displaying zero values or errors.
  - No metering data visible on BMS where meter is shown on electrical single line diagram to be connected to BMS, including for the solar array.

7. Energy Conservation Measures

This section outlines energy conservation measures (ECMs) that GHD have assessed for Bay Pavilions. These have been developed to address issues previously identified that are contributing to the high energy consumption and operating costs. For each instance, an estimate is provided for the expected capital and ongoing cost of implementation as well as the resulting water and energy cost savings. If implemented, some ECMs may also result in lower maintenance costs and longer lifetime of equipment, although this has not been factored into this assessment.

Noting the building age is only 12 months old, the aim was to develop ECMs that minimise physical on-site replacement or significant modifications of services. Such works cannot be justified considering the equipment is new and generally in good condition. Therefore, ECMs are generally targeting controls programming modifications and changes in staff operational procedures. Where physically on-site works are considered, these are typically minor in nature and associated with addition of new equipment or features rather than replacement of existing.

The values contained in this section are based on simplified calculations and should only be considered as preliminary estimates. The impact of some recommendations could not be quantified without detailed thermal energy modelling or on-site trial and error (i.e. adjusting and monitoring). As such, ESC may wish to carry out additional investigations before implementing some ECMs if more confidence on capital costs and savings is required. Refer to Appendix C for detailed calculations and assumptions for each ECM.

Except for where otherwise specified, each ECM is calculated independently of any other ECM. Implementation of multiple ECMs may see diminishing returns on the savings predicted for any individual ECM. The ECMs also assume that all modifications are new works that will be priced and implemented by an installation contractor, although in practice some might constitute as defects that could be rectified free of charge as part of the Defects Liability Period.

7.1 ECM1 Correct HVAC Operating Schedules

Capital Expenditure ($)	Operational/ Maintenance Cost ($)	Annual Utility Savings	Annual Cost Savings ($)	Simple Payback Period (years)
$1,200	$0	146600 kWh	$35,000	<1 year

Several HVAC systems at Bay Pavilions have been found to be in operation 24/7 where it is not necessary for them to do so. Further, it was noted that the HVAC operation in the theatre had been recently changed to only be on when events were scheduled in the theatre, however the theatre back of house rooms were not set to this schedule. These rooms are expected to only be in use when the theatre is in use.

This ECM explores the recommendation to modify the time schedules for each item of HVAC equipment to suit the actual usage of the area served. This would include placing units that are unnecessarily operating at all times onto an appropriate ‘opening hours’ based operation schedule, and placing all units supplying rooms in the theatre back of house on an appropriate ‘events’ based schedule.

As part of the planning and documentation for this, Aligned Leisure would be consulted to gain an understanding of the specific usage of each area in the building to ensure the allocated time schedule in the BMS suits.

The implementation costs for this ECM requires only the reprogramming of the HVAC system controls in the BMS, so capital expenditure includes only the time taken to perform this change.

The savings for this ECM are based on the reduced amount of operation time for relevant units. A theatre schedule was based on the frequency of previous theatre use (as advised by Aligned Leisure), and it was assumed that for each event, areas would be in use for the day before and the day of any event.

The low upfront cost and high return rate of this ECM means that this quickly recovers the cost of this work, with high potential to return meaningful energy savings.

The following recommendations are made regarding this ECM:

1. Consult with Aligned Leisure to confirm usage of each area.
2. Develop time schedules for each area to suit the actual usage.
3. Reprogram BMS to assign time schedules to each corresponding HVAC equipment.

7.2 ECM2 Correct HVAC Temperature Deadbands

Capital Expenditure ($)	Operational/ Maintenance Cost ($)	Annual Utility Savings	Annual Cost Savings ($)	Simple Payback Period (years)
$600	$0	104700 kWh	$28,000	<1 year

Several HVAC systems were found to be heating and cooling near their temperature setpoint. The BMS Functional Description in the mechanical O&M manuals detail for most general use areas that active heating and cooling should not begin until room temperature exceeds 1.5°C above or below specified temperature setpoint. Numerous systems have been identified to have lower deadbands (within ±0.5°C of setpoint), resulting in more frequent heating and cooling.

This ECM explores the reinstatement of the temperature deadbands back to the specified range of 3°C. Energy savings are informed by typical energy savings associated with deadband adjustment, as per *Bannister, P (2014) What Simulation Can tell us about building tuning*.

The implementation costs for this ECM requires only the changing of BMS programming, so capital expenditure includes only the time taken to perform this change. The low upfront cost and high return rate of this ECM means that this change quickly recovers the cost of this work.

It was noted by ADCO that tuning of deadbands was undertaken to address complaints regarding occupant comfort. Whether this was the case for the entire building or only select areas needs to be confirmed, as making a wholesale change based on potentially isolated instances may not be appropriate. Furthermore, comfort issues can often be caused by factors other than air temperature (e.g. drafts, radiant heat from windows) or perhaps only one person had a comfort complaint. Understanding the actual cause is important rather than resorting to adjusting setpoints as a quick fix. The impact on energy consumption should be considered when making these changes.

The following recommendations are made regarding this ECM:

1. Consult with Aligned Leisure about history of comfort-related complaints in building and seek their feedback on reverting back to a wider temperature deadband. Investigate any areas where comfort complaints have been reported for drafts, radiant heat, etc.
2. Reprogram BMS to return temperature deadband to design values (i.e. 3°C).

7.3 ECM3 Correct HVAC Controls Issues

Capital Expenditure ($)	Operational/ Maintenance Cost ($)	Annual Utility Savings	Annual Cost Savings ($)	Simple Payback Period (years)
$5,800	$0	220400 kWh	$54,000	<1 year

As discussed in the HVAC commentary in Section 3.2, several operating issues were identified with the existing HVAC controls on the BMS. Incorrect control operation is considered to be contributing to unnecessary electricity consumption.

This ECM explores the correction of the following controls operation issues:

- Determine an appropriate minimum outdoor air damper position. This is applicable for AHUs with modulating outdoor air. Calculate an appropriate minimum outdoor air flow rate based on AS1668.2 (i.e. 0.35 L/s.m^2). Engage commissioning contractor to determine the OA damper position that achieves this minimum flow and set this as the minimum damper position for each AHU in the BMS.
- Modify CO2 demand-controlled ventilation damper throttling range. Adjust such that when CO2 is below 700ppm the OA damper position is minimum position and when CO2 increases to 800ppm the damper position increases to the design OA damper position.
- Modify economy cycle controls operation, to ensure that outdoor air is only introduced if it provides cooling when required.
- Fix operation of AHU-0R-P01 heat recovery run-around coil. This is currently inactive.
- Fix operation of AHU-0R-P01 outdoor air damper control. This is currently not operating as described.
- Recalibrate BMS sensors.
- Setup controls to prevent multiple units within same area from ‘fighting’ between heating and cooling. This involves linking the temperature setpoints so that each unit within an area has the same setpoint, and if one unit’s setpoint is adjusted then all other units automatically change too.

Note, the above may constitute as addressing defects with the installation rather than new works, and therefore may not incur the estimated capital costs.

This ECM will require time on site for a commissioning technician to carry out airflow measurements, and time on site for the BMS technician to check and calibrate sensors. Otherwise, the remainder of implementation works associated with this ECM is anticipated to be reprogramming of the HVAC system controls in the BMS.

The following recommendations are made regarding this ECM:

1. Calculate appropriate minimum outdoor airflow rates.
2. Commissioning contractor to measure outdoor airflows and determine min. and max. damper positions.
3. BMS technician to inspect on site faulty heat recovery system for AHU-0R-P01, recalibrate sensors.
4. BMS contractor to reprogram BMS to address the above items.

7.4 ECM4 Improve HVAC Controls

Capital Expenditure ($)	Operational/ Maintenance Cost ($)	Annual Utility Savings	Annual Cost Savings ($)	Simple Payback Period (years)
$6,300	$0	146900 kWh	$35,000	<1 year

As discussed in the HVAC commentary in Section 3.2, the BMS controls are not allowing the HVAC systems to turndown in response to the variable usage of some areas of the building.

This ECM explores the addition of control strategies in the BMS to enhance the HVAC systems ability to respond better to low demand. It includes the following:

– Convert all AHUs (except pool and gym units) into variable volume systems. Each AHU already has variable speed drives to accommodate this, so therefore it is envisaged this is limited to BMS reprogramming to allow supply fan to reduce speeds when temperature is within deadband. Design checks are necessary to ensure to what extent the existing air diffusion equipment can accommodate reduce airflow rates.
– Implement 'setback' modes to FCUs serving rooms that are intermittently used throughout the day (i.e. gym spin, program and access rooms, meeting rooms, dance studio). This includes widening the deadband to 6-7°C during daytime unoccupied times, but once a room wall controller is pressed the deadband tightens to 3°C for 1 hour (adjustable) for the corresponding unit. During the setback mode, the supply fan will switch off when temperatures are within the deadband and the outdoor air damper closes.
– Modify toilet exhaust fan control to be via motion sensor rather than time schedule, to only operate when people enter the bathrooms. Fans to switch off after with a run-on timer.
– Modify setpoint reset strategies to be BMS to a trim-and-respond approach, which generally perform better at providing better energy savings and less influenced by 'rogue' zones. Furthermore, implement setpoint reset strategies for pump speed control.

This ECM, along with ECM3, include several complex and interconnected control strategies that will require fine-tuning to optimise the energy savings. This could be done via trial and error, although instead we recommend carrying out a thermal energy simulation of the building and its HVAC systems to model and fine-tune these strategies during the planning and design stage. This approach will reduce the on-site fine-tuning time to help arrive at a quicker solution.

The ECM will also require time on site for a BMS technician to install additional BMS field devices, notably motion sensors in bathrooms. The remaining implementation works associated with this ECM is anticipated to be reprogramming of the HVAC system controls in the BMS.

The following recommendations are made regarding this ECM:

1. Carry out thermal simulation of building and HVAC systems to test and optimise strategies.
2. BMS technician to install additional BMS field devices for these strategies.
3. BMS contractor to reprogram BMS to implement the above controls.

7.5 ECM5 Pool Covers

Capital Expenditure ($)	Operational/ Maintenance Cost ($)	Annual Utility Savings	Annual Cost Savings ($)	Simple Payback Period (years)
$0	$38,000	27,000 kWh 550 kL	$9000	never

Applying covers over the pool when not in use during closed hours will reduce the amount of evaporation from the pool surface. This will reduce the water consumption that needs to be made up to offset this evaporation, reduce the energy necessary to heat this make-up water, and reduce the amount of outdoor air and associated heating energy that is needed to dehumidify this moisture. It is also expected to reduce the cost of water treatment.

The pool currently has pool covers installed next to each pool, and so the introduction of pool covers will come at no additional capital cost. Discussions with Bay Pavilions staff indicated that the reason for currently not utilising the pool covers was the cost and difficulty of staffing the time taken to remove lane ropes and set up pool covers.

This ECM evaluates the cost and benefit trade-offs of placing pool covers over the pools when not in use.

Under advice of Bay Pavilions staff, set up and removal of pool covers across all pools was estimated to take two staff members two hours per day. The hourly rate for staff was advised to be $26/h. Internal pool hall and outdoor ambient temperatures were modelled to understand the impact of pool covers on pool evaporation, ventilation and heating.

This analysis has shown that the cost of staffing this activity outweighs the savings provided by pool covers.

Additional scenarios were considered to understand if any conditions would enable pool covers to provide cost savings. This included:

– Reducing time spent through means such as leaving lane ropes in place.
– Reducing time spent by targeting individual pools with higher impact.
– Covering pools in conjunction with other pool related ECMs.

In all scenarios, even if pool covering and removal took two staff members 30 minutes per day, the cost of staffing this activity is not recovered through energy or water savings.

Therefore, the covering of pools is not recommended when the cost of staffing the activity is considered.

7.6 ECM6 Optimised Pool Hall Setpoints

Capital Expenditure ($)	Operational/ Maintenance Cost ($)	Annual Utility Savings	Annual Cost Savings ($)	Simple Payback Period (years)
$600	$0	25700 kWh -2 kL (increased use)	$7,000	<1 year

This ECM evaluates the potential adjustment of air temperature setpoints in the pool halls to reduce the operating costs. Changing the air temperature in the pool hall is expected to impact various factors. For example, reducing the pool hall air temperature, whilst controlling outdoor air rates to maintain 60% relative humidity, results in:

– Increased pool evaporation and the associated make-up water consumption to offset this.
– Increased energy to heat the make-up water.
– Increased outdoor air supplied, and the associated heating energy of that outdoor air.
– Reduced energy to provide space heating to the pool hall.

This ECM adjusted various air temperatures for both pool halls to determine if an optimal point existed for reducing operating costs. The key findings were:

1. For the main pool hall, where the amount of outdoor air is variable to control humidity, the increase in outdoor air heating offset the reduction in space heating, resulting in minimal cost savings from altering the air temperature.
2. For the warm water pool, where the amount of outdoor air remains fixed, the reduction in space heating is the dominant factor and results in operating cost savings if air temperature setpoint was reduced. However, overly cool air temperatures may be undesirable in the pool hall as it may cause discomfort for swimmers coming out of the warmer water, thus limiting the application of this during occupied times.

Therefore, this ECM considers lowering the Warm Water Pool Hall air temperature setpoint to 28°C during opening hours, and then allowing temperature to reduce after hours and providing only enough heating to maintain relative humidity at 60%.

Analysis of this scenario shows minimal increase in pool water evaporation with meaningful decreases in outdoor air heating and space heating. When implementing these ECMs it is recommended that trial runs and potential tuning be performed to verify that modelled system operation performs as expected, and comfort is not impacted. The time taken to reprogram the BMS, as well as time taken for reviewing Pool Hall operation is considered in the capital cost of this ECM.

The following recommendations are made regarding this ECM:

3. Reprogram BMS to have a variable setpoint schedule for 28°C during opening hours and allowing temperature to drop after-hours potentially down to 20°C whilst controlling to maintain 60% relative humidity.
4. Perform test run of this program to verify the outcomes of altered setpoints.
5. Tune BMS programming accordingly based on outcomes.

7.7 ECM7 Warm Pool Air Recirculation

Capital Expenditure ($)	Operational/ Maintenance Cost ($)	Annual Utility Savings	Annual Cost Savings ($)	Simple Payback Period (years)
$30,000	$0	37600 kWh 100 kL	$10,000	3.5 years

In the Main Pool Hall, the air handling plant includes a return air provision that allows a portion of air from the pool hall to be recirculated and mixed with outdoor air prior to be reheated and resupplied back to the pool hall. The proportion of outdoor air introduced is controlled to the minimum amount necessary to maintain humidity conditions and indoor air quality.

In the warm water pool hall, no such recirculation provision is provided. Full outdoor air is always supplied to the pool hall, which increases heating energy consumption.

This ECM explores the viability of modifying the exhaust air ductwork to allow the recirculation of air in the warm water pool hall back to the air handling unit AHU-0R-P02, thus replicating the main pool hall system in an attempt to save energy.

Outdoor air and indoor air temperatures were used to model supply airflow rates into the pool hall, and the difference in heat demand for when pool air recirculation is and is not in use. This ECM requires the modification and construction of new ductwork, as well as relocation of some existing components. Capital costs account for new ductwork and water pipework, labour for construction and relocation of electronics, and programming new controls in the BMS. Initial inspection of site and as-built drawings has confirmed the physical viability of these modifications on site.

Due to the cost of construction and corrosion resistant ductwork, the capital cost for this ECM is high. This does however return a large reduction in pool energy consumption and relatively short payback.

As discussed in ECM6, pool air recirculation reduces the efficacy of changing pool temperature setpoints, and as such introducing air recirculation to the Warm Water Pool may negate savings produced through temperature setpoint optimisation and setback modes. Changing pool hall temperatures has a much lower capital cost whilst still providing comparable cost savings.

As such it is recommended that ECM6 be implemented instead of this ECM. If implementation of this ECM is considered, it is recommended that more detailed modelling be completed to understand the impact of operating in conjunction with low air temperatures and confirm the viability of this measure.

7.8 ECM8 Improve Operating Procedures

Capital Expenditure ($)	Operational/ Maintenance Cost ($)	Annual Utility Savings	Annual Cost Savings ($)	Simple Payback Period (years)
$1,200	$0	47300 kWh	$14,000	<1 year

During the site visit, several operational practices were noted that were contributing to unnecessary electricity consumption. This ECM investigates addressing energy wastage due to building operational procedures.

This ECM explores the impact of the following activities:

- Providing manual override on the BMS to shutdown units when staff wish to open external and internal doors to conditioned spaces, to prevent wasteful heating and cooling during these times and preventing units struggling to maintain conditions (which can impact the thermal plant controls). This includes for the following:
  - Main pool hall (doors to outside).
  - Theatre foyer (door to outside).
  - Pool office door (internal door into main pool hall).
- Projectors in the gymnasium program turned off whenever not in use.
- All manual light switches turned off when not in use.
- Develop user guide for staff to inform of energy impacts on adjusting temperature setpoints on energy consumption, and a troubleshoot guide in the event of comfort complaints that they could consider before resorting to adjusting temperature setpoint.
- Setup metering displays on BMS to provide monthly reports summaries on energy and water consumption, compared to previous months, years, etc. If staff can see the impact that their actions make on energy efficiency, they might make more effort to adjust their practices to provide improvements.

The success of this ECM is dependent on staff adhering to the procedures. Alternatively automated control solutions can be provided to remove the reliance on staff following procedures. This may include door switches connected to the BMS to automatically shut-off the AHUs when the doors are open for more than 1 minute, or motion sensors in rooms to switch on/off lights. The manual command option is the simplest and thus will be considered in the ECM. If it is noticed that this procedure is not being followed, it may be desirable to install sensors to perform the task. Introduction of a sensor system is expected to require an additional $20,000 capital cost.

Recommendations:

1. Develop user guide for staff with list of procedures to follow and troubleshooting assistance.
2. Reprogram BMS to provide a “Door Open” manual override button for shutting off AHUs or FCUs when doors are open.
3. Reprogram BMS to provide energy and water monitoring summaries.
4. Brief staff and other program room users to ensure projectors are turned off at the end of each day.
5. Brief staff to ensure all manual light switches are turned off.

7.9 ECM9 Pool Treatment Plant Setback

Capital Expenditure ($)	Operational/ Maintenance Cost ($)	Annual Utility Savings	Annual Cost Savings ($)	Simple Payback Period (years)
$20,000	$10,000	390900 kWh	$90,000	<1 year

This ECM considers reducing the default operation of the pool water treatment plant to suit the current low utilisation of the pools relative to design assumptions. This includes:

– Reducing the filter pumps speed to lower the recirculation rates. It is envisaged that the pumps speeds can be reduce by 60-80% of the current operating speeds (based on maintaining flow rate through the filters to be 50% higher than minimum nominated filter flow rates).
– Reduce output of UV lights.

The resulting savings of this are significant (9% of total building operating costs), and therefore GHD believe is worth further consideration. However, we acknowledge there are potential water quality and swimmer health risks associated with reducing the recirculation rates and operation of the UV lights. As these could potentially impact the water quality and have potential implications on swimmer's health. If ESC or Aligned Leisure wish to consider this further detail, GHD recommend approaching in a staged cautious manner as follows:

1. Prior to making any changes, carry out baseline water quality tests in the pool and throughout the recirculation loop. Recommend these are carried out at 6am, 12pm, 9pm of the same day (i.e. start-middle-end of day).
2. Reduce pump speeds incrementally (e.g. in 6 Hz increments). After each adjustment, carry out water quality testing in the same locations as previously tested for comparison to baseline readings and confirm whether water quality is within acceptable limits. It is envisaged that the changes would be carried out over the course of a one week. The number of pool occupants during this adjust-and-test period is also to be monitored and recorded.
3. If the measures have not caused any issues with water quality or plant operation, proceed with engaging the pool plant contractor to update the pool plant controls with a boost override mode that will allow staff to activate and revert the pool plant back to higher design flow rates (for peak periods).

The estimate of capital expenditure includes costs of the above adjust-and-monitor approach and also the controls modifications by the pool contractor.

GHD recommend the original design engineers and the pool plant equipment suppliers are consulted prior to implementation, to confirm basis of design calculations and advise on potential impacts with making these changes.

7.10 ECM10 Power Factor Correction

Capital Expenditure ($)	Operational/ Maintenance Cost ($)	Annual Utility Savings	Annual Cost Savings ($)	Simple Payback Period (years)
$50,000	$240	19 kVA/mth	$5000	12.5 years

This ECM explores the impact of installing a Power Factor Correction unit on site to increase the power factor of electricity demand. The current power factor for maximum demand values is high, averaging at 0.91, however power factor correction has the potential to increase this to over 0.95, thus reducing maximum demand charges.

Installation of a PFC unit requires a location for the unit to be placed. The storage room in the pool area near the main switchboard cupboard has been identified as a potential location for this. The capital cost of this measure includes the cost of a PFC unit and its installation. Recommended maintenance tasks for a PFC have been used to estimate maintenance costs. Cost savings have been calculated assuming a corrected PF of 0.95, although higher average PF may be achievable.

Given that power factor is already high, and the capital cost of installing a PFC unit is high, the rate of return on this measure is low, taking over 12 years to pay off.

As such, installation of a PFC unit is not recommended.

8. Summary and Ranking of ECMs

The ECMs from the previous section have been summarised in Table 7, ranked in order of priority to be implemented. The ranking is a judgement based on capital costs, ease of implementation and return on investment.

Additional costs, such as consultant fees for the design and documentation of these works, have also been included in the table below.

Table 7 ECM Summary

Rank	ECM	Capital Cost ($ exc. GST)	Annual Cost Savings ($)	Simple Payback Period (yrs)
Recommended				
1	ECM1 Correct HVAC Operating Schedules	$1,200	$35,000	<1 year
2	ECM2 Correct HVAC Temperature Deadbands	$600	$28,000	<1 year
3	ECM3 Correct HVAC Controls Issues	$5,800	$54,000	<1 year
4	ECM8 Improve Operating Procedures	$1,200	$14,000	<1 year
5	ECM4 Improve HVAC Controls	$6,300	$35,000	<1 year
6	ECM6 Optimised Pool Hall Setpoints	$600	$7,000	<1 year
7	ECM9 Pool Treatment Plant Setback	$20,000	$80,000	<1 year
Not Recommended				
-	ECM5 Pool Covers	$0	-$29,000	Never
-	ECM7 Warm Pool Air Recirculation	$30,000	$10,000	3.5 years
-	ECM10 Power Factor Correction	$50,000	$5,000	12.5 years
Additional Costs				
-	Consultant design and documentation (incl. thermal energy model for controls tuning).	$30,000	-	-
Total (Recommended Works)		**$65,700**	**$253,000**	**<1 year**

We recommend that:

– This report is distributed to key stakeholders.

– An action plan is set up to implement the energy savings recommended in this report and a target is set for energy saving.

– A member of ESC staff is given the responsibility for focussing on energy management issues and improving energy performance on site.

– Progress is reviewed in regular intervals – suggested every month initially for three months and then at three monthly intervals afterwards.

– A follow up “desktop audit” is carried out at 3 months and 6-monthly intervals afterwards, using data from the electricity sub-meters to monitor how the site is tracking to meet energy saving targets.

9. Other Observations

During investigations carried out for this energy audit, some observations have been made that may not relate directly to energy consumption or operating cost savings, but have impacted investigations or presented notable issues in operation. GHD noted these identified installation issues in a letter to ESC on 22 May 2023. This is attached in Appendix B.

9.1 Handover Documentation

As discussed throughout the report, several inconsistencies between handover documentation provided and the operation noted in the building have been identified. Further, no handover documentation could be identified describing the lighting controls functional description. Complete and up to date documentation on building design and operation may be valuable for any future maintenance or upgrading activities.

9.2 Energy and Water Metering

The sub-metering for electricity and water appear to have not been setup properly, both in terms of physical installation and interfacing with the BMS. The types of issues noted include:

– Error messages on physical meter, saying… “No data available! No response from device.”
– Zero-value readings on physical meters.
– Zero-value readings on BMS electricity and water meter summary pages.
– No meter visible on BMS where meter is shown on as-installed electrical single line diagram to be connected to BMS.
– Water metering data on BMS generally does not match with physical meter readings and billing water meter.
– Water meters physically damaged or not installed as documented.

9.3 BMS Setup

The BMS graphic displays have instances where they are poorly setup or inaccurate with the actual installation, including the following:

– Graphics are inaccurate to actual system configurations.
– Inconsistent display of trend log legend. Legend / key is generally missing from trends.
– Incomplete graphics – pages not setup for items of equipment.
– Dynamic animations for fans, coils, dampers, etc do not match corresponding numerical values.

9.4 Other Items

The following other items were noted with the HVAC systems:

– Stainless steel finishes in the pool treatment plant room are experiencing corrosion after only 12 months of building operation. A potential contributor to this is the warm humid corrosive air from the adjacent warm water pool hall appears to be migrating through this plant room, condensing on the colder surfaces, and causing corrosion. This migration of air is likely due to the HVAC control of the supply and exhaust fans for AHU-0R-P02 which was noted on site to be over-pressurising the pool hall. The control of these fans needs to be reassessed to ensure the pool hall remains at a negative pressure of at least 15 Pa relative to its surrounds and prevent migration of warm humid corrosive air to other areas of the building.
– The main pool hall is currently struggling to reach setpoint temperature of 29°C (currently only 25°C is achievable). This appears to be caused by a lack of supply air volume from the AHU-0R-P01, since the AHU

itself is currently modulating the heat output to meet a supply air temperature setpoint even though the hall is not up to temperature.

– The Pool Office Unit AC-0G-P02 cannot currently maintain comfortable conditions in the room. Due to occupant discomfort, the door is left open whenever the office is in use, which creates other issues previously noted. To improve occupant comfort, it may be desirable to upgrade the unit to be able to effectively reduce heat load.

Appendix A

Summary of HVAC Issues

Legend:	
x	Issue Identified
	Issue suspected but could not be confirmed due to limited information or improper operation
	Not applicable to system

Unit	Area Served	Issues Identified										
		Full Time Operation (where relevant)	Non-event Based Operation (where relevant)	Narrow Dead-band	Return Fan Speed not as Described	Temperature Control not as Described	Airflow Not Meeting Setpoint	Incorrect/ Conflicting Sensor Readings	Off when should be on	Fighting Adjacent System	Inconsistent Damper Control	HHW/ CHW Coil Active with Inactive Fan
Pool AC												
AC 0G P01	Pool First Aid Room			x								
AC 0G P02	Pool Office									x		
Pool OAU												
OAU 0G P01	Pool Mens Changeroom	x				x						
OAU 0G P02	Pool Women’s Changeroom	x				x						
OAU 0G P03	Pool Change Village	x				x						
OAU 0G P04	Pool Change Place	x				x						
Pool/Gym FCUs												
FCU 0G 01	Gym Spin Room	x		x		x						
FCU 0G 02	Gym Program Room 2 - Centre	x		x		x				x		
FCU 0G 03	Gym Program Room 2 - Perimeter	x				x				x		
FCU 0G 04	Gym Program Room 1 - Centre	x		x		x						
FCU 0G 05	Gym Program Room 1 - Perimeter	x		x		x						
FCU 0G 06	Pool Foyer	x		x		x						
FCU 0G P01	Pool Activity Meeting Room			x		x					x	
Pool/Gym AHUs												
AHU 0R P01	Main Pool Hall				x	x		x			x	
AHU 0R P02	Warm Water Pool				x	x		x				
AHU 0R P03	Gym							x			x	
Gym ACs												
AC 0G G01	Gym Access Room 1	x		x								
AC 0G G02	Gym Access Room 2	x		x								
Gym VAVs												
VAV 0G 01	Gym											
VAV 0G 02	Gym								x			
VAV 0G 03	Gym						x					
VAV 0G 04	Gym								x			
VAV 0G 05	Gym						x					
VAV 0G 06	Gym								x			
Theatre FCUs												
FCU 0G T01	Dance Rehearsal Room	x	x	x		x						
FCU 0G T02	Dressing Room 1		x	x		x						
FCU 0G T03	PAX Dressing Room		x	x		x					x	
FCU 0G T04	Stage Waiting Area		x	x		x						
FCU 0G T05	Green Room		x	x		x						

Legend:	
x	Issue Identified
(blue shading)	Issue suspected but could not be confirmed due to limited information or improper operation
(grey shading)	Not applicable to system

Unit	Area Served	Issues Identified										
		Full Time Operation (where relevant)	Non-event Based Operation (where relevant)	Narrow Dead-band	Return Fan Speed not as Described	Temperature Control not as Described	Airflow Not Meeting Setpoint	Incorrect/ Conflicting Sensor Readings	Off when should be on	Fighting Adjacent System	Inconsistent Damper Control	HHW/ CHW Coil Active with Inactive Fan
FCU 0G T06	Dressing Room 2		x	x		x						
FCU 0G T07	Theatre Corridor 1		x	x		x						
FCU 0G T08	Theatre Corridor 2		x	x		x						
FCU 0G T10	Box and Bar		x			x				x	x	
FCU 0G T11	Theatre Meeting Room			x		x						
FCU 0G T12	Dry Art Meeting Room			x		x						
FCU 0G T13	Wet Art Meeting Room			x		x						
FCU 0G T14	Box Office Perimeter		x	x		x					x	
Theatre/Centre ACs												
AC 0G C01	Centre Management Office 1	x										x
AC 0G C02	Centre Management Office 2			x								
AC 0G T03	Theatre Production Room		x									
AC 0G T04	Theatre Technical Office	x	x									x
AC 0G T05	Theatre Kitchenette		x									
Theatre/Centre AHUs												
AHU 0G T01	Box Office Foyer			x				x		x		
AHU 01 T01	Theatre							x			x	
AHU 0G C01	Main Foyer	x			x			x		x	x	
AHU 0G C02	Gallery	x		x				x		x	x	
Centre FCUs												
FCU 0G C01	Centre Management 1			x		x						
FCU 0G C02	Centre Management 2	x		x		x						
Total number of instances		**18**	**13**	**26**	**3**	**28**	**2**	**7**	**3**	**7**	**9**	**2**

Appendix B

Identified Installation Issues Letter

16 Marcus Clarke Street, Level 7
Canberra, Australian Capital Territory 2601
Australia
www.ghd.com

Our ref: 12607958

22 May 2023

Carlyle Ginger
Eurobodalla Shire Council
Vulcan St
Moruya NSW 2537

Bay Pavilions Energy Audit – Identified Installation Issues

Dear Carl

This letter provides a list of installation issues that GHD noted at Bay Pavilions while carrying out recent investigations for the energy audit which Eurobodalla Shire Council (ESC) engaged us for. We recommend that ESC follow these items up with ADCO Constructions while the building is still within its Defects Liability Period to be resolved.

These items are based on observations from GHD's site visit on 26-27 April 2023. It is not intended to be a comprehensive review of all defects for the building and is primarily focused on items that have impacted the energy audit investigations (e.g. BMS controls, energy metering, etc). GHD have not reviewed the installation against the contract documentation that ADCO Constructions were to comply with, but rather have noted issues that relate to:

– Inconsistencies between the installation and the handover documentation.
– Apparent setup, commissioning, or maintenance issues.
– Aspects where the result is not fit-for-purpose and have led to other issues.

This list will form part of GHD's energy audit report, however is being provided early to allow ESC to raise these issues with ADCO Constructions prior to Defects Liability Period ending.

Please contact the undersigned if you have any further questions or comments.

Regards

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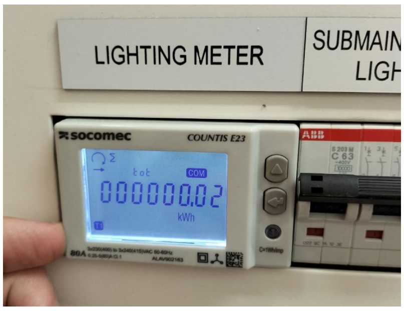
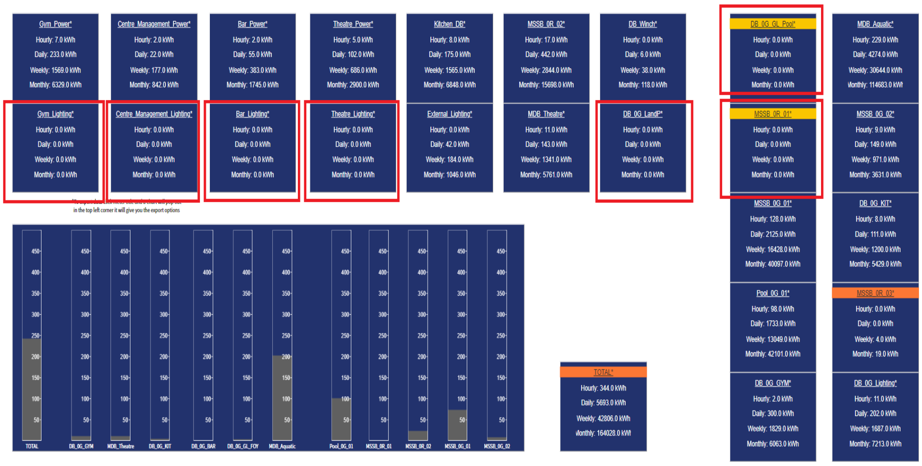
Copy to: Brett Longstaff

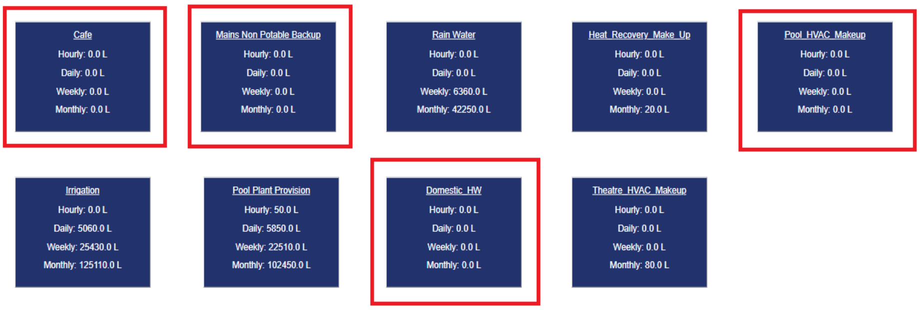
#	Description
1	**BMS and HVAC controls**
-	The below describes the issues noted with the Building Management System (BMS) and HVAC controls, and is to be read in conjunction with: – Attachment A – List of typical issues applicable to each unit. – Attachment B – Sample screenshots with further comments on issues.
1.1	Controls operation of HVAC systems is not as described in the BMS Functional Description, provided in the O&M manuals. Typical discrepancies are listed below, and further specific discrepancies are noted in Attachment B screenshots. Some of these items will impact energy consumption and may contribute to other issues noted: – 24/7 operation for units that should be on an opening hour schedule. E.g. gym program rooms FCUs, centre management AHUs and ACs. Units also were operating when BMS Time Schedule said “Inactive”. – Narrower deadband of temperature control around setpoint than described in controls description, resulting in active heating or cooling close to setpoint and in some cases overshoots and fluctuations in heating and cooling. – AHU supply and return air fan speed controls are tracking (i.e. exactly matching) in generally all instances, whereas for some systems this was described as controlling to maintain space differential pressures (e.g. pool halls). For AHU-0R-P02 which serves the warm-water pool hall, this appears to be causing over-pressurisation of the hall which could be contributing to the corrosion of stainless steel surfaces in the adjacent pool treatment plant room. – Temperature control is generally noted to be based on modulating CHW and HHW valves to meet a supply air temperature setpoint which resets based on room temperature, rather than the described CHW and HHW valves directly controlling to maintain room temperature setpoint. For AHU-0R-P01, this approach combined with perhaps low supply airflow appears to contribute to main pool hall never reaching room temperature setpoint. – Motorised damper control appears inconsistent, including instances where: • Outdoor Air (OA) dampers were 100% open yet conditions for economy cycle or CO2 demand-control ventilation were not met. • FCUs had their OA damper closed while the FCUs were still operating based on time schedules (occurring at 4.40pm). • Pool Hall AHU-0R-P01 OA damper was modulating open but not based on any of the criteria described. • Relief air dampers did not match the corresponding OA dampers. • OA dampers were open whilst FCU or AHU were off. – Instances where motorised CHW or HHW valves were open during times when the FCU or AHU were off.
1.2	BMS sensor readings were noted to be inaccurate, unrealistic and providing conflicting readings in many instances. Some of these sensor values are used in control strategies and therefore could have implications with comfort, air quality, condensation control and energy consumption. Typical and significant instances: – Pool hall temperature and relative humidity values. Temperature and humidity logging carried out by GHD in pool halls provide conflicting results. Main hall relative humidity was reading 0%. – Mixed air temperature readings are generally all unrealistically high.
1.3	BMS graphic displays are inaccurate or poorly setup, as follows: – Dynamic animations for fans, coils, dampers, etc do not match corresponding numerical values. E.g. damper animations do not match position %, HHW/CHW coil animations do not match valve position %, rotating fan animations do not match fan status, etc. – Graphics are inaccurate to actual system configurations. E.g. AHU-0R-P01 run-around coil position, VAV boxes in gym not showing the reheat coils for the perimeter units, AHU-01-T01 not showing the seating zone, FCUs indicate they are 100% outdoor air and do not show the return air, etc. – Inconsistent display of trend log legend. Legend / key is generally missing from trends, and can only indicate what each colour line is representing upon hovering over line. – Incomplete graphics – pages not setup for outdoor air and exhaust air ventilation fans, heating coil for OAF-0G-G01.
2	**Metering**
-	Energy and water metering not setup properly, as outlined throughout this section.
2.1	Zero-value readings on physical meters: – DB.0G GL&P.THT – DB.0G GL.BAR

<table>
<tr><th>#</th><th>Description</th></tr>
<tr><td></td><td>

</td></tr>
<tr><td>2.2</td><td>
Error reading on physical meter: “No data available! No response from device.”
– MSSB-0R.01
– DB-0G.GL.POOL
– DB-0G EXT
– GPU


</td></tr>
<tr><td>2.3</td><td>
Zero-value readings on BMS electricity meter summary page:
– Gym Lighting
– Centre Management Lighting
– Bar Lighting
– Theatre Lighting
– DB_0G_L&P
– DB_0G_GL_Pool
– MSSB-0R.01

</td></tr>
<tr><td>2.4</td><td>
Zero-value readings on BMS water meter summary page:
– Café
– Mains non-Potable backup
– Pool HVAC Makeup
– Domestic HW
</td></tr>
</table>

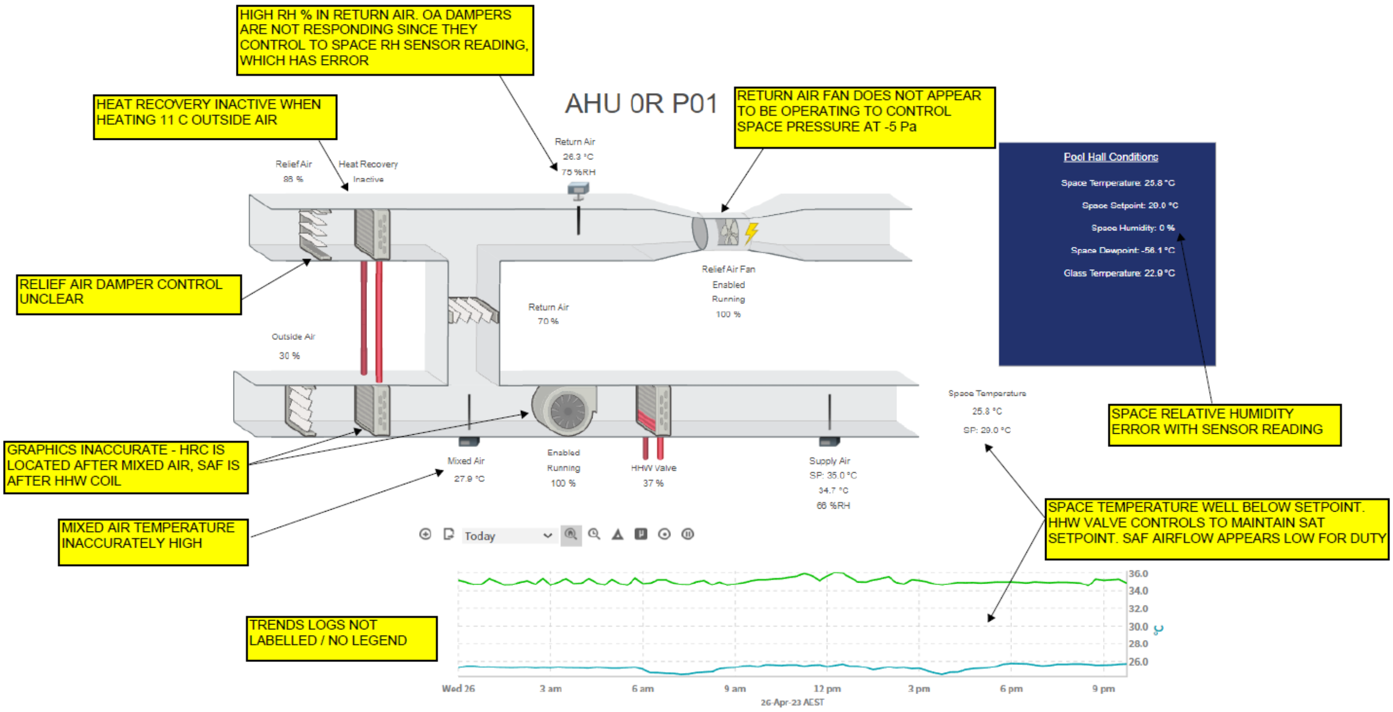
#	Description
	
2.5	No meter visible on BMS where meter is shown on electrical single line diagram to be connected to BMS. – DB-0G GL&P.THT – DB-0G.BAR – DB-0G GL&P.FOYER – DB-0G.EXT – GPU – Site Main Switch Board
2.6	Water metering data on BMS generally does not match with physical meter readings and billing water meter.
2.7	Water meters physically damaged or not installed. – Slides water meter (WM-816) is cracked and leaking. – Indoor splash pad water meter (WM-815) has been removed and currently sitting on floor.  
3	**Miscellaneous**
3.1	No handover documentation provided for: – Lighting control system – functional description

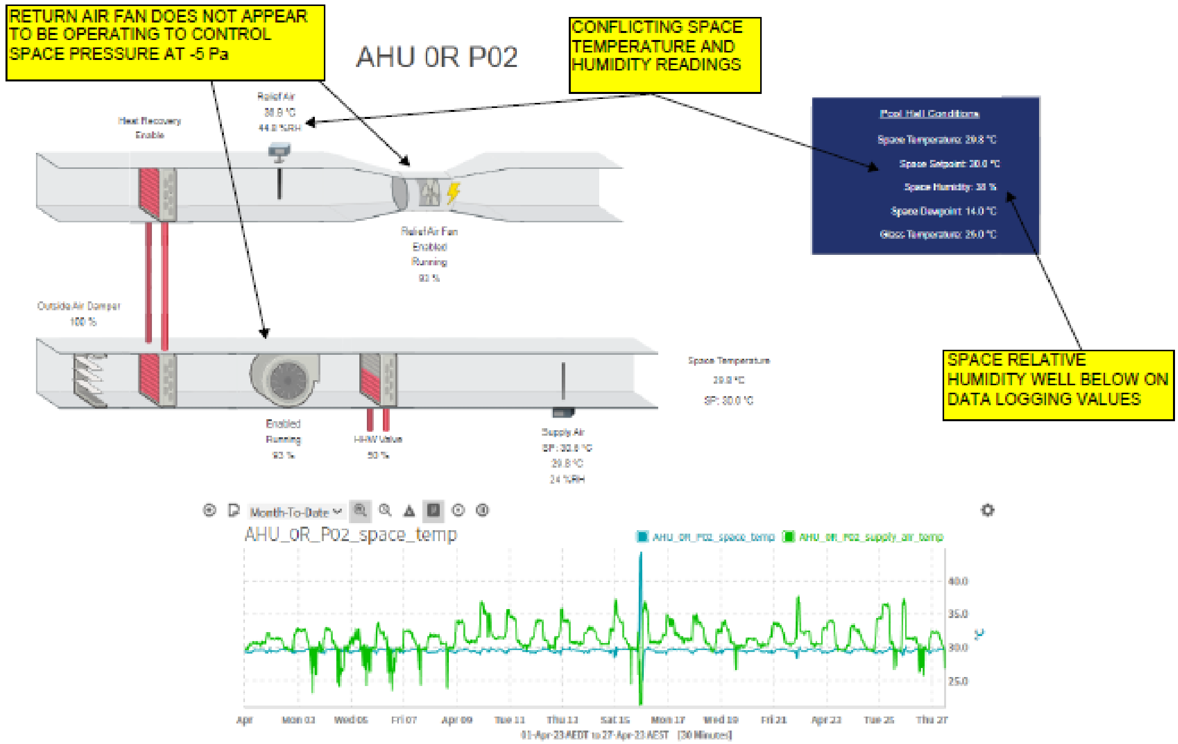
Attachment A - List of typical issues applicable to each unit

Legend:	
x	Issue identified
	Issue suspected but could not be determined due to limited information or improper operation
	Not applicable to system

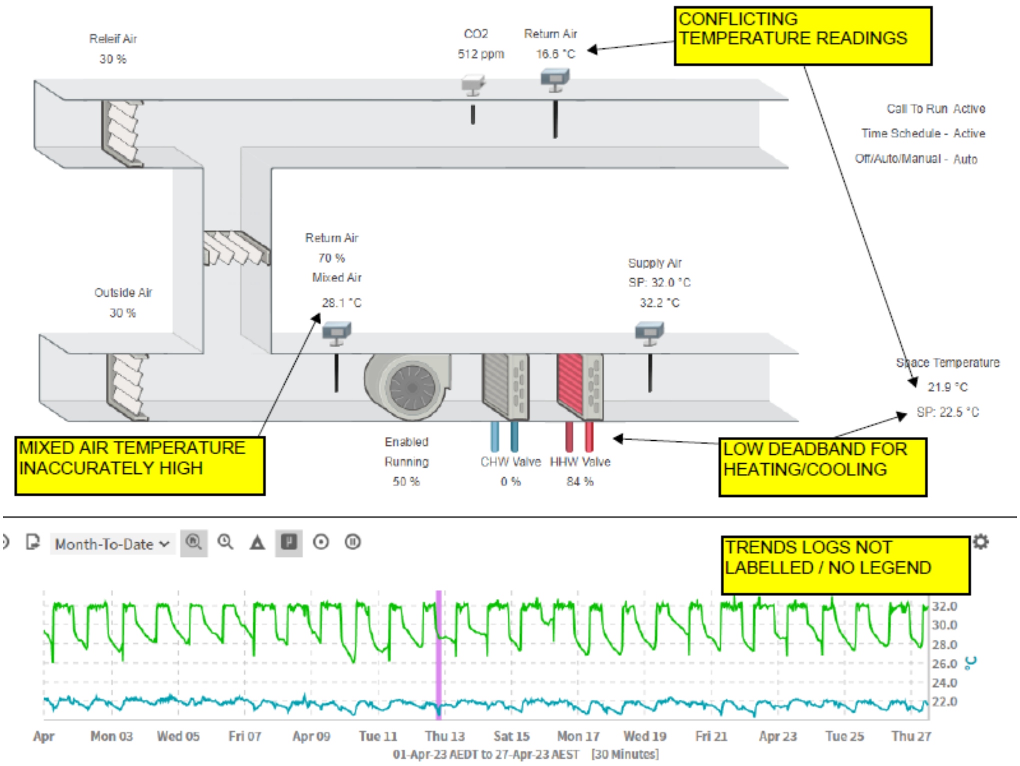
		Issues Identified						
Unit	**Area Served**	**24/7 Operation**	**No or Narrow Deadband**	**Return Fan Speed not as described**	**Temperature Control not as described**	**Incorrect / Conflicting Sensor Readings**	**Inconsistent Damper Control**	**HHW/CHW Coil Active with Inactive Fan**
Pool AC								
AC 0G P01	Pool First Aid Room		x					
AC 0G P02	Pool Office							
Pool OAU								
OAU 0G P01	Pool Mens Changerooms	x			x			
OAU 0G P02	Pool Women's Changerooms	x			x			
OAU 0G P03	Pool Change Village	x			x			
OAU 0G P04	Pool Change Place	x			x			
Pool/Gym FCUs								
FCU 0G 01	Gym Spin Room	x	x		x			
FCU 0G 02	Gym Program Room 2 - Centre	x	x		x			
FCU 0G 03	Gym Program Room 2 - Perimeter	x			x			
FCU 0G 04	Gym Program Room 1 - Centre	x	x		x			
FCU 0G 05	Gym Program Room 1 - Perimeter	x	x		x			
FCU 0G 06	Pool Foyer	x	x		x			
FCU 0G P01	Pool Activity Meeting Room		x		x		x	
Pool/Gym AHUs								
AHU 0R P01	Main Pool Hall			x	x	x	x	
AHU 0R P02	Warm Water Pool			x	x	x		
AHU 0R P03	Gym					x	x	
Gym ACs								
AC 0G G01	Gym Access Room 1	x	x					
AC 0G G02	Gym Access Room 2	x	x					
Theatre FCUs								
FCU 0G T01	Dance Rehearsal Room	x	x		x			
FCU 0G T02	Dressing Room 1		x		x			
FCU 0G T03	PAX Dressing Room		x		x		x	
FCU 0G T04	Stage Waiting Area		x		x			
FCU 0G T05	Green Room		x		x			
FCU 0G T06	Dressing Room 2		x		x			
FCU 0G T07	Theatre Corridor 1		x		x			
FCU 0G T08	Theatre Corridor 2		x		x			
FCU 0G T10	Box and Bar				x		x	
FCU 0G T11	Theatre Meeting Room		x		x			
FCU 0G T12	Dry Art Meeting Room		x		x			
FCU 0G T13	Wet Art Meeting Room		x		x			
FCU 0G T14	Box Office Perimeter		x		x		x	
Theatre/Centre ACs								
AG 0G C01	Centre Management Office 1	x						X
AG 0G C02	Centre Management Office 2		x					
AC 0G T03	Theatre Production Room							
AC 0G T04	Theatre Technical Office	x						X
AC 0G T05	Theatre Kitchenette							
Theatre/Centre AHUs								
AHU 0G T01	Box Office Foyer		x			x		
AHU 01 T01	Theatre					x	x	
AHU 0G C01	Main Foyer	x				x	x	
AHU 0G C02	Gallery	x	x			x	x	
Centre FCUs								
FCU 0G C01	Centre Management 1		x		x			
FCU 0G C02	Centre Management 2	x	x		x			
	Total number of instances	**18**	**26**	**2**	**28**	**7**	**9**	**2**

Attachment B – Sample screenshots with further comments on issues

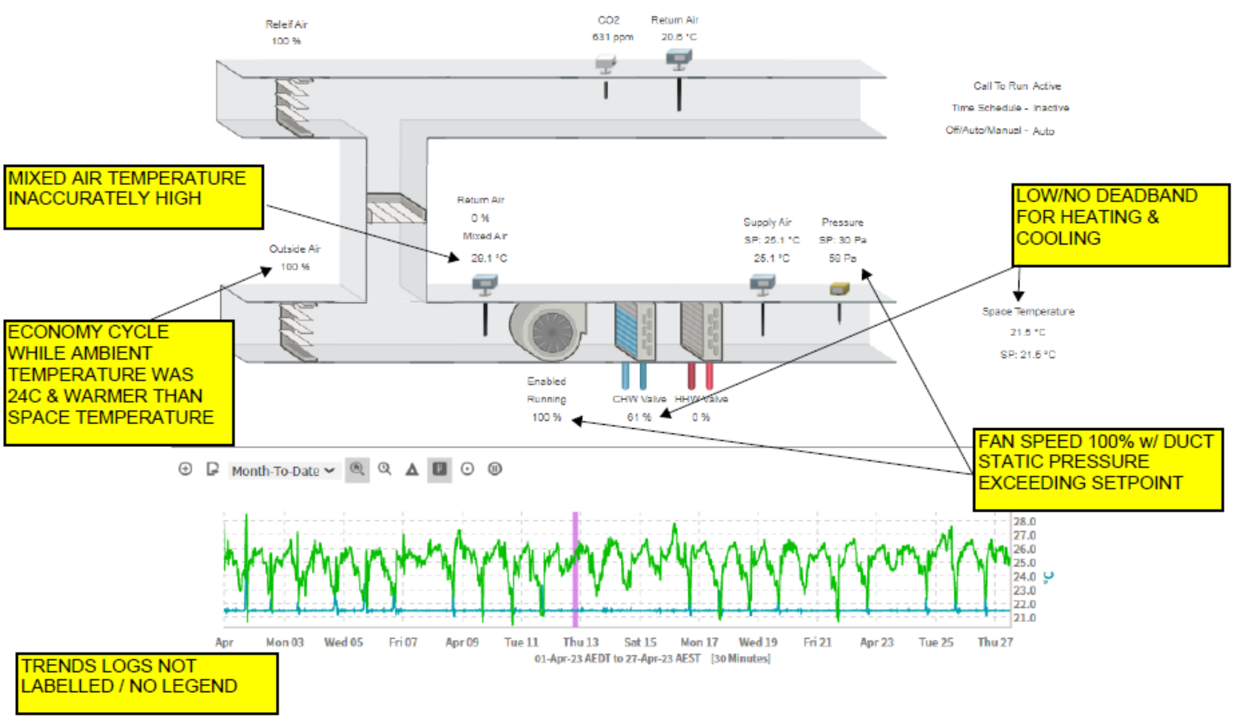


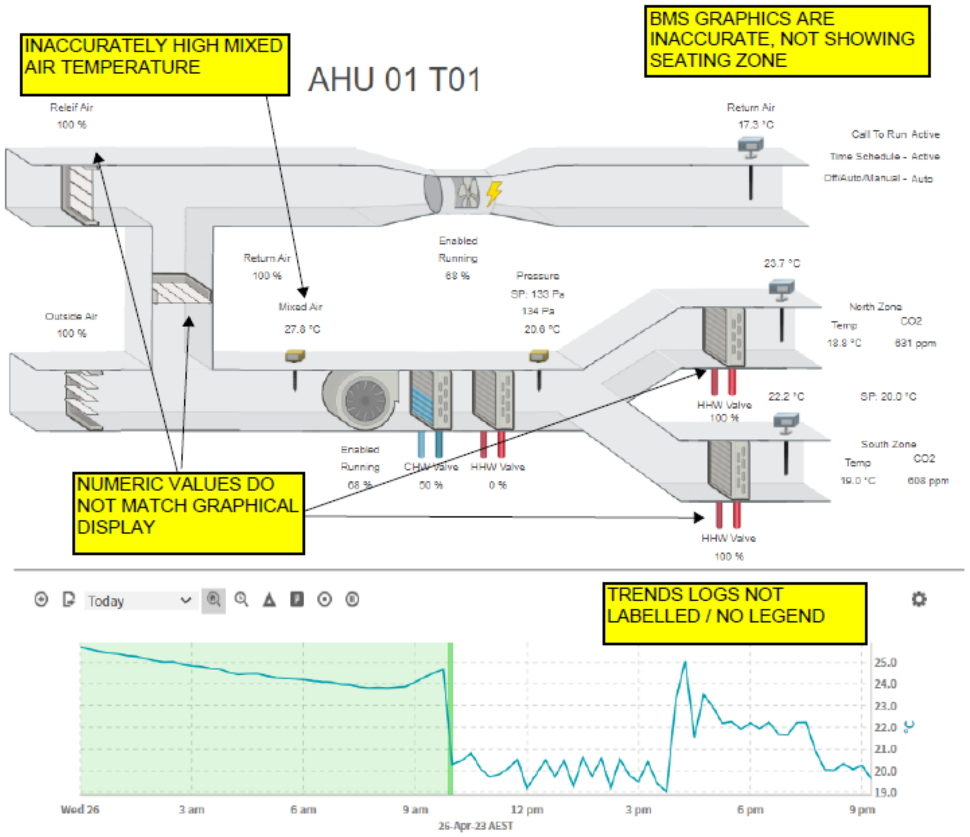


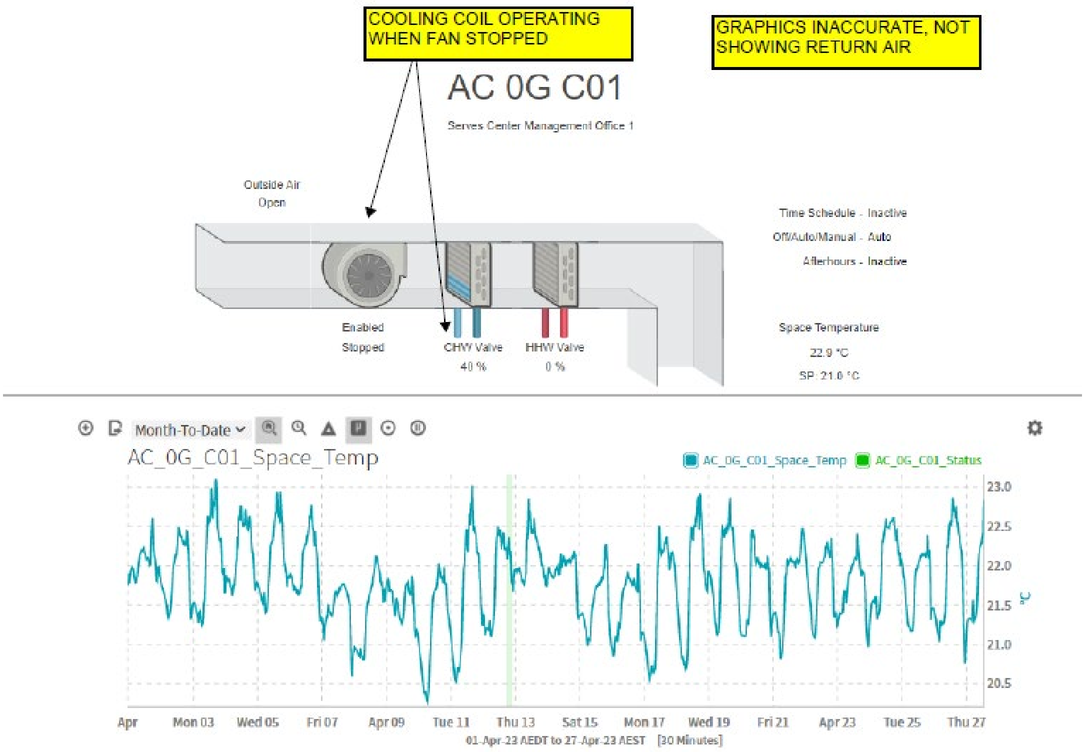
AHU 0G T01

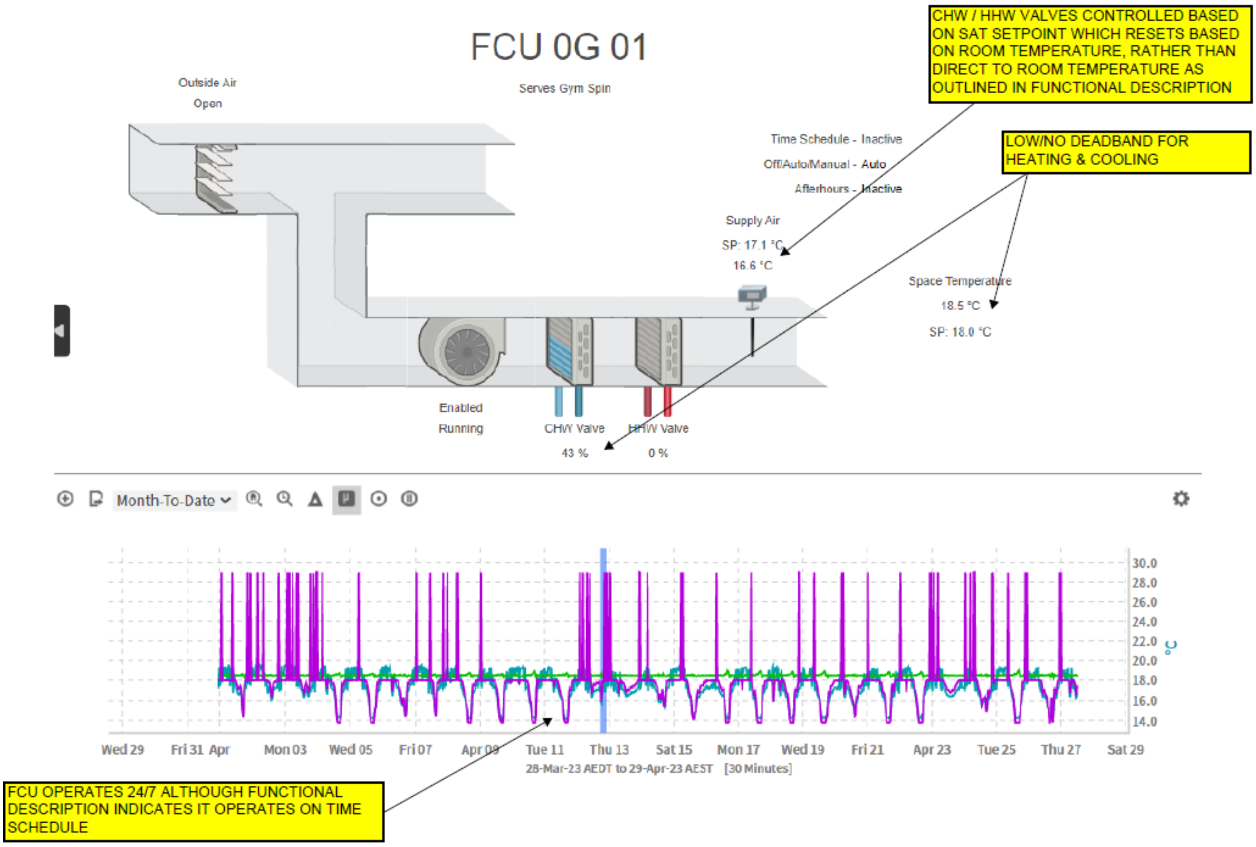


AHU 0G C01




INACCURATELY HIGH MIXED AIR TEMPERATURE
AHU 01 T01
BMS GRAPHICS ARE INACCURATE, NOT SHOWING SEATING ZONE
Releif Air
100 %
Return Air
17.3 °C
Call To Run Active
Time Schedule - Active
Off/Auto/Manual - Auto
Enabled
Running
68 %
Return Air
100 %
Pressure
SP: 133 Pa
134 Pa
20.6 °C
Outside Air
100 %
Mixed Air
27.8 °C
23.7 °C
North Zone
Temp
18.8 °C
CO2
631 ppm
22.2 °C
SP: 20.0 °C
HHW Valve
100 %
South Zone
Temp
19.0 °C
CO2
608 ppm
Enabled
Running
68 %
CHW Valve
50 %
HHW Valve
0 %
NUMERIC VALUES DO NOT MATCH GRAPHICAL DISPLAY
HHW Valve
100 %
Today
TRENDS LOGS NOT LABELLED / NO LEGEND
25.0
24.0
23.0
22.0
21.0
20.0
19.0
Wed 26
3 am
6 am
9 am
12 pm
3 pm
6 pm
9 pm
26-Apr-23 AEST


COOLING COIL OPERATING WHEN FAN STOPPED
GRAPHICS INACCURATE, NOT SHOWING RETURN AIR
AC 0G C01
Serves Center Management Office 1
Outside Air
Open
Time Schedule - Inactive
Off/Auto/Manual - Auto
Afterhours - Inactive
Enabled
Stopped
CHW Valve
40 %
HHW Valve
0 %
Space Temperature
22.9 °C
SP: 21.0 °C
Month-To-Date
AC_0G_C01_Space_Temp
AC_0G_C01_Space_Temp
AC_0G_C01_Status
23.0
22.5
22.0
21.5
21.0
20.5
Apr
Mon 03
Wed 05
Fri 07
Apr 09
Tue 11
Thu 13
Sat 15
Mon 17
Wed 19
Fri 21
Apr 23
Tue 25
Thu 27
01-Apr-23 AEDT to 27-Apr-23 AEST [30 Minutes]


FCU 0G 01
Serves Gym Spin
Outside Air
Open
Time Schedule - Inactive
Off/Auto/Manual - Auto
Afterhours - Inactive
Supply Air
SP: 17.1 °C
16.6 °C
Space Temperature
18.5 °C
SP: 18.0 °C
Enabled
Running
CHW Valve
43 %
HHW Valve
0 %
Month-To-Date
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
°C
Wed 29
Fri 31
Apr
Mon 03
Wed 05
Fri 07
Apr 09
Tue 11
Thu 13
Sat 15
Mon 17
Wed 19
Fri 21
Apr 23
Tue 25
Thu 27
Sat 29
28-Mar-23 AEDT to 29-Apr-23 AEST [30 Minutes]
CHW / HHW VALVES CONTROLLED BASED ON SAT SETPOINT WHICH RESETS BASED ON ROOM TEMPERATURE, RATHER THAN DIRECT TO ROOM TEMPERATURE AS OUTLINED IN FUNCTIONAL DESCRIPTION
LOW/NO DEADBAND FOR HEATING & COOLING
FCU OPERATES 24/7 ALTHOUGH FUNCTIONAL DESCRIPTION INDICATES IT OPERATES ON TIME SCHEDULE

Appendix C

Detailed Calculations and Assumptions

This section outlines the steps taken and resources used in the calculation of energy and costs for each ECM.

Two main models were created to simulate the operation and energy consumption of HVAC systems at Bay Pavilions, one for general HVAC systems and one providing detailed modelling of temperature, humidity, evaporation, and heat loads in the pool halls.

General HVAC Model

– Hourly average temperature data from Carrier Hourly Analysis Program v6 (HAP) for Moruya Airport (i.e. which is the location closest to Batemans Bay with the most representative weather data) was used to provide an estimate for outside air temperatures and humidity for each hour of an average year.
– Equipment schedules from the Mechanical O&M manuals were used to collect data on the input power draw and maximum heating and cooling capacities of each piece of equipment.
– Electrical single line diagrams from Mechanical as-built drawings and asset registers from the Mechanical O&Ms were used to determine which pieces of equipment sat on each Mechanical Services Switchboard (MSSB).
– Operation schedules were created to define times when equipment would be in operation. Each unit was placed on a schedule of operation based on location and actual observations made during site visit. Scheduled times for HVAC operation were assumed to be:

Schedule	Times
Gym, Pool Hall, other 24/7 areas	Always on
General, Pool Offices, Centre, Theatre Area (non-events based)	On 5am-8pm everyday. Off otherwise
Theatre Area (events based)	On 35% of days (see Note 1) between hours of 7am-12am. Off otherwise.

Note 1: Theatre schedule is based on frequency of previously scheduled events assuming each event results in two days of use from 7am-12am, to account for bump-in and bump out, additional setup and multi-day shows.

– Outdoor temperature data were used to estimate the Coefficient of Performance (COP) during heating and cooling for an average hydronic heat pump for each hour of the year, according to the following data (based on equipment selections from Aermec heat pumps):

Amb. Temp. (°C) Heating	COP Heating	Amb. Temp. (°C) Cooling	COP Cooling
-2.6	2.68	14	5.3
5	3.24	20	4.6
10	3.87	25	4.1
15	4.13	35	3.1
20	4.3	-	-
30	4.5	-	-

– Outdoor temperature data were used to estimate the percentage of maximum heating or cooling provided by each unit for each hour of the year. Relevant units were limited to only heat or only cool where specified in Mechanical O&M manual functional description. Heating and cooling were assumed to operate based on the following outdoor temperature conditions:

	Heat Max	Heat Zero	Cool Zero	Cool Max
General Areas (°C)	1	16	18	37
Pool Hall (°C)	1	25	-	-

– Percentage of maximum heating/cooling was multiplied by COP and modulated based on operating schedule to calculate average power for heating/cooling for each piece of equipment for each hour of the year. Fan power was modulated by operating schedule to calculate fan average power for each piece of equipment for each hour of the year.

- Average power was totalled for each MSSB to determine annual kWh totals. All heating/cooling power provided by the HHW/CHW system was attributed to the board where the heat pump for that system was connected.
- Scaling factors were applied for each MSSB and each heat pump to normalise the simulated annual power consumption to the estimated annual breakdown of power consumption for each board based on metering data.
- A baseline scenario was created based on the operation controls observed during site visit. Scenarios were generated for each ECM, as described in the section for each ECM below, and then compared to the baseline to calculate differences in annual electricity consumption and costs.

Pool HVAC model

- Hourly average temperature data from HAP for Moruya Airport was used to provide an estimate for outside air temperatures and humidity for each hour of an average year.
- The following equation was used to model evaporation and humidity in the pool hall for each given hour, from *ASHRAE (2015) Applications:*

$$w_p = 4 \times 10^{-5} A(p_w - p_a)F_a$$

where

$\mathrm{w_p}$ = evaporation of water, kg/s

$\mathrm{A_p}$ = area of pool surface, m^2

$\mathrm{p_w}$ = saturation vapor pressure taken at surface water temperature, kPa

$\mathrm{p_a}$ = saturation pressure at room air dew point, kPa

$\mathrm{F_a}$ = activity factor

- The average hourly evaporation was used to calculate:
  - Annual pool make-up water consumption and costs. The make-up water consumption is assumed to equal the amount evaporated. Based on a tariff of $3.9 per kL from the utility bills, the water consumption costs were estimated.
  - Annual heating energy for heating the pool water make-up water. This assumes mains water is 10°C and is heated to the pool setpoints temperature (i.e. 28°C for the 25m pool, 32°C for the leisure pool, and 34°C for the warm water pool). Based on heat pump COP, the average hourly input power to the heat pumps were determined, and total this for the year provided the total kWh electricity consumption. Using a tariff of $0.2382 per kWh from utility bills determined the electricity costs.
  - The amount of outdoor air heating energy. This calculation converted the evaporation rate to a latent kW load in the space, for which the quantity of outdoor air (at conditions matching the hourly Moruya Airport weather data) was determined to maintain 60% RH. Using this outdoor air rate, the heating capacity necessary to heat up from ambient conditions to pool hall temperatures was determined (assuming main pool hall is at setpoint of 29°C and warm water pool hall is 30°C) and applying a runaround coil effectiveness of 0.6. Based on heat pump COP, the average hourly input power to the heat pumps were determined, and total this for the year provided the total kWh electricity consumption. Using a tariff of $0.2382 per kWh from utility bills determined the electricity costs.
  - GHD have excluded estimating impact of evaporation on water treatment costs.
- A baseline scenario was created based on the operation controls described in the functional description. Scenarios were generated for each ECM, as described in the section for each ECM below, and then compared to the baseline to calculate differences in HVAC loads, makeup water demand, and water heating loads. These values were used to calculate annual electricity and water consumption and their related costs.

These models were then utilised in the calculations as described under each ECM.

ECM1 Correct HVAC Operating Schedules

– Using General HVAC model, all units on 24/7 schedules that were not required to be based on the Mechanical O&M Functional Description were placed on the 'General' schedule (refer to previous table).
– All units in the theatre back of house area were placed on the 'Theatre Area (events based)' schedule.

ECM2 Correct HVAC Temperature Deadbands

– The deadband programmed for each unit was estimated based on BMS trends.
– For each unit in the general HVAC model, the percentage reduction in energy consumption from increasing each unit deadband from its current value to 3°C was estimated as per *Bannister, P (2014) What Simulation Can tell us about building tuning.*

ECM3 Correct HVAC Controls Issues

– The following could not be estimated with the limited BMS data available. Thermal energy simulation would be required to determine this.
  - Damper position
  - CO2 demand control
  - Economy cycle
  - AHU-0R-P01 OA damper control issues
  - BMS sensor calibration issues
– Repairing AHU-0R-P01 heat recovery coil - outdoor airflow rates were estimated using the pool HVAC calculator. The energy required to heat outdoor air to pool temperature was calculated based on airflow and HAP outdoor air temperature data and was compared to that required when outdoor air was preheated by the heat recovery system with exhaust air at 25°C and a heat exchanger effectiveness of 0.6 based on Mechanical O&M manual.
– Adjacent systems fighting – Using the general HVAC model, for each pair of systems fighting each other, the maximum heating/cooling load provided by the weaker system was added as a constant load to stronger system and the additional energy consumed in meeting that load was considered as the energy that could be saved by repairing this operation. As the competing systems are served by the same heat pumps which have heat recovery, factoring in the total heating/cooling power of each unit operating on full would have overestimated the additional energy consumption, so this was not done.

ECM4 Improve HVAC Controls

– Convert AHUs into variable volume systems – Using the general HVAC model, for all AHUs (except pool and gym units), when the percentage of heating/cooling was below 50%, fan speed was reduced to 50% and fan power estimated to consume 12.5% of its maximum power, based on fan affinity laws.
– Setback' modes to FCUs – This was calculated based on a simplified thermal model for an air conditioned room using HAP V6, to determine a % scaling applied to the baseline figures.
– For the remaining following items, without a detailed thermal simulation these were difficult to quantity. Based on previous experience with fine-tuning buildings, this was estimated to provide a 10% saving on HVAC energy consumption.
  - Motion sensor for toilet exhaust
  - Modify setpoint reset strategies to be BMS to a trim-and-respond approach

ECM5 Pool Covers

– Using the pool HVAC model, covering of the pool during closing hours was estimated by altering the unoccupied activity factor to 0.025 (previously 0.5, noting pool covers are reported to reduce pool water evaporation by 95%).

– Based on advice from Aligned Leisure staff, time taken to apply and remove pool covers was assumed to take 2 staff members 1 hour in the morning and 1 hour in the evening, and staff wages were assumed to be $26/hour. Using these values, the annual cost of paying staff to use pool covers was calculated. Sensitivity analysis was performed for the scenario where staff could apply/remove pool covers in 15 minutes.

ECM6 Optimised Pool Hall Setpoints

– Using the pool HVAC model, a variety of scenarios were tested by changing the indoor air temperature and compared to baseline. The best results for values that remained reasonable for the application were chosen for recommendation.

ECM7 Warm Pool Air Recirculation

– Using the pool HVAC model, applied a similar model to the main pool hall where the outdoor air varies to achieve a RH of 60%. This was compared to the adjusted pool HVAC model where the outdoor air flow rates was set to a fixed 4,000L/s.

ECM8 Improve Operating Procedures

– Manual shutdown for open doors:
  - Main pool – Using the general HVAC model, when outdoor temperature was between 18-24°C, pool doors were assumed to be open, and thus AHU-0R-P01 heating was assumed to be off, fans remained operational.
  - Theatre Foyer – Due to lack of information on frequency and duration of occurrence, savings were not estimated.
  - Pool Office – Based on office advice from Aligned Leisure, the pool office door was understood to be left open whenever occupied. It was therefore considered ineffective, and calculations assumed that the unit was off at all times.

– Gymnasium Projectors – AV as-built documentation was used to find the model of projectors in use and their operating power. The annual power savings were calculated by comparing consumption if projectors were on at all times with consumption if only on during general opening hours.

– Manual light switches turned off – Electrical as-built documentation was used to find the power consumption of light fittings in the rooms where manual switches left on were observed. The annual power savings were calculated by comparing consumption if lights were on at all times with consumption if only on during general opening hours.

– Staff user guide – could not be estimated, and hence not quantified.

– BMS metering reports - could not be estimated, and hence not quantified.

ECM9 Pool Treatment Plant Setback

– High design bather rates indicated that occupancy would not be the limiting factor to pump turndown. Turndown was conservatively limited to be 50% higher than the minimum nominated filter flow rate to ensure correct operation was maintained. Pumps were assumed to be turned down by varying amounts to achieve this flow rate. Overall pump power consumption was thus reduced by 70% (based on affinity laws) and UV lights by 50%. Values were multiplied by existing estimated cost breakdown to calculate cost savings.

ECM10 Power Factor Correction

– The cost savings achieved by installing PFC were estimated by comparing maximum demands charges from electricity invoices to what they would have been if PFC had enabled PF to be 0.95 at that given time. Cost savings were then scaled up to an annual rate.

– A maximum demand value of 485 kVAr was determined from electricity interval data. Based on this value a XX size PFC unit was assumed with an estimated installed cost of XX.

– The ongoing maintenance costs for the installation were based on a maintenance manual for a PowerLogic™ PFC Low Voltage Capacitor Bank, with estimated times for task completed as follows:

	Period Every	Time Taken (minutes/year)
Network information & operation condition verification		
Network loads changes	1 year	10
Temperature, Voltage and Hormonic level	1 year	15
Operation verification & measures		
Power factor controller settings and alarm history	1 year	10
SD/MX coil operation	1 year	15
Capacitance Measure	1 year	15
Electrical connection check		
power cables tightening check	Initial after 1 month and then 1 year	10
Visual Inspections		
Envelope integrity	1 year	
Cleanliness	1 year	
Thermal sensors check	1 year	
Incoming & steps CB tripping	1 year	
Detuned reactor integrity	1 year	
Earthing connection integrity	1 year	20 total for all
Components replacement		
Capacitors + Contactor ≈ 35°C		
(annual average temperature)	7 years	
Capacitors + Contactor ≈ 25°C		
(annual average temperature)	10 years	10 total for all
Components replacement		
Inlet filters	2 years	
Fan filters outlet	2 years	15 total for all
Total		**2 hours**

– The hourly cost for an electrician to perform these tasks was assumed to be $120/hr.

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→ The Power of Commitment