



Ministry of Environment

ENERGY AUDIT REPORT

Maldives Meteorological
Services' Gan Office



Promoting Energy Efficient Buildings through
Strengthening Low Carbon Energy
Island Strategies (LCEI) Project





Ministry of Environment

Strengthening Low Carbon
Energy Island Strategies (LCEI)
Project



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Table of Contents

EXECUTIVE SUMMARY	1
1 SITE DESCRIPTION	2
2 PRE-VISIT ANALYSIS.....	5
2.1 DATA LOGGING – OFFICE	6
2.2 DATA LOGGING – ACCOMMODATION	9
3 SITE VISIT OBSERVATIONS.....	11
3.1 AIR CONDITIONING	11
3.2 BUILDING FABRIC	12
3.3 GLAZING	13
3.4 BUILDING ORIENTATION	13
3.5 BUILDING SEALING.....	14
3.6 VERTICAL TRANSPORT	14
3.7 EXTERNAL LIGHTING.....	14
3.8 INTERNAL LIGHTING	14
3.9 EQUIPMENT.....	16
3.10 ON SITE GENERATION	17
3.11 POWER SUPPLY	17
3.12 OCCUPANT COMFORT	18
3.13 AFTER HOURS CONSUMPTION	18
3.14 OCCUPANT SURVEY.....	18
3.15 BUILDING CONTROL	19
4 ENERGY BUDGET	20
4.1 ACCOMMODATION BLOCK	20
4.2 OFFICE BLOCK.....	21
5 RECOMMENDATIONS.....	23
5.1 EXPECTED SAVINGS.....	24

Executive Summary

The Ministry of Environment is developing energy efficiency improvements for the built sector of the Maldives in line with the Maldives Climate Change Policy Framework (2015), the Maldives Energy Policy & Strategy (2015) and the Maldives commitments to the Montreal Protocol on Substances that Deplete the Ozone Layer. This initiative forms part of the Strengthening Low Carbon Energy Island Strategies Project (LCEI) which is implemented by the Ministry of Environment (MoE) with support from UNEP and funded by the Government of Maldives and the Global Environmental Facility (GEF). The aim of the LCEI project is to achieve market transformation for energy efficiency and low carbon technologies.

The purpose of this project is to support the implementation of energy efficiency and carbon improvements in the built environment in the Maldives. The project comprised the assessment and design of cost effective energy efficiency improvements in selected buildings. One of the objectives is to apply similar improvement measures to future comparative facilities. These buildings are Velaanaage Office Building, Hulhumale' Flat 110 (a residential building), K. Guraidhoo Mosque (Masjid-ul Sidheeq) and Maldives Meteorological Service's (MET) Gan Office. For each building, the scope of works included an energy audit, identification of energy efficiency improvement opportunities, development of a monitoring and a verification plan to assess the effectiveness of the proposed energy efficiency improvements, cost estimation and prioritisation of energy efficiency improvements. In addition, an energy efficiency policy and energy management plan were prepared for Velaanaage Office Building.

This report includes deliverables completed for Maldives Meteorological Service's Gan Office as part of the cost effective energy efficiency design project for selected buildings. The scope of works includes an energy audit of the MET Office and its adjacent storage shed and hydrogen generator shed as well as the accommodation block. One of the objectives is to assess the energy consumption usage and to identify areas of significant energy consumption.

The scope was delivered by Utilico Pvt Ltd in partnership with an Australian consulting company Anser Group Pty Ltd. Project works commenced in February 2018 by gathering facility information including utility bills, building services drawings, architectural drawings and operational schedule. The Consulting Team ("the Team") visited the site in March 2018 for a detailed assessment of existing assets and building including construction method, building envelope, occupied space and surrounding environment, interview of building users, and measurement of site energy usage. Following on the site visit and collection of preliminary data, a detailed energy audit report was prepared. The energy audit results and findings from the site visit were used to inform recommendations for energy efficiency and carbon improvements.

The office block had an energy density of ~127kWhrs per m² over calendar year 2017 and the accommodation block had an energy density of ~3kWhrs per m² over calendar year 2017.

Energy usage for the MET Office building was found to be on average 3000 kWhrs a month (30.54MWhrs CY (Calendar Year) 2017.) and consistent throughout the year reflective of the consistent climatic conditions. Similarly, the accommodation block's energy usage averaged consistently at 22 kWhrs (266kWhrs CY 2017) per month, though there were significant increases in consumption when the building was occupied. The major energy consumer for both sites was the air conditioning which contributed to 66% of total energy budget for the MET Office building and 85% for the accommodation block respectively.

The major opportunities to reduce energy includes upgrade of air conditioning system and regular maintenance of the units. Lighting system upgrade would further contribute to energy savings. It should also be noted that occupant engagement is critical for energy reduction. The occupants should

be provided with general education on energy usage and operational performance tracking should be regularly conducted to sustain energy consumption.

1 Site Description

The Maldives Meteorological Service's (MET) Addu City office is located on the Gan Island in the south of the Maldives. The area under consideration is comprised of a number of different buildings, across two main locations and energy meters.

The MET office accommodation is a room and adjacent ensuite to provide temporary accommodation for office workers required to remain at or nearby to the met office overnight. The room is part of a block of similar accommodation units and contains very simple lighting, air conditioning and ablution facilities.



Figure 1: Accommodation block

The office area includes three main office rooms, a small accommodation area and associated tea prep, ensuite, and locker area, as well as two adjacent buildings comprising a storage shed (permanently conditioned and including two work stations) and a hydrogen generation shed.

Both buildings have very little in terms of common areas or external services, with lighting controlled as part of a block.

The three portions of the MET Office area are shown below.



Figure 2: Aerial image showing location of MET office buildings



Figure 3: Office building

2 Pre-Visit Analysis

Prior to visiting the site, the Team reviewed historical electrical consumption data for both the main office and the accommodation block, based on both electric utility bills and data logging undertaken on site. The plot below shows consumption data for each meter, from January 2010 to December 2017.

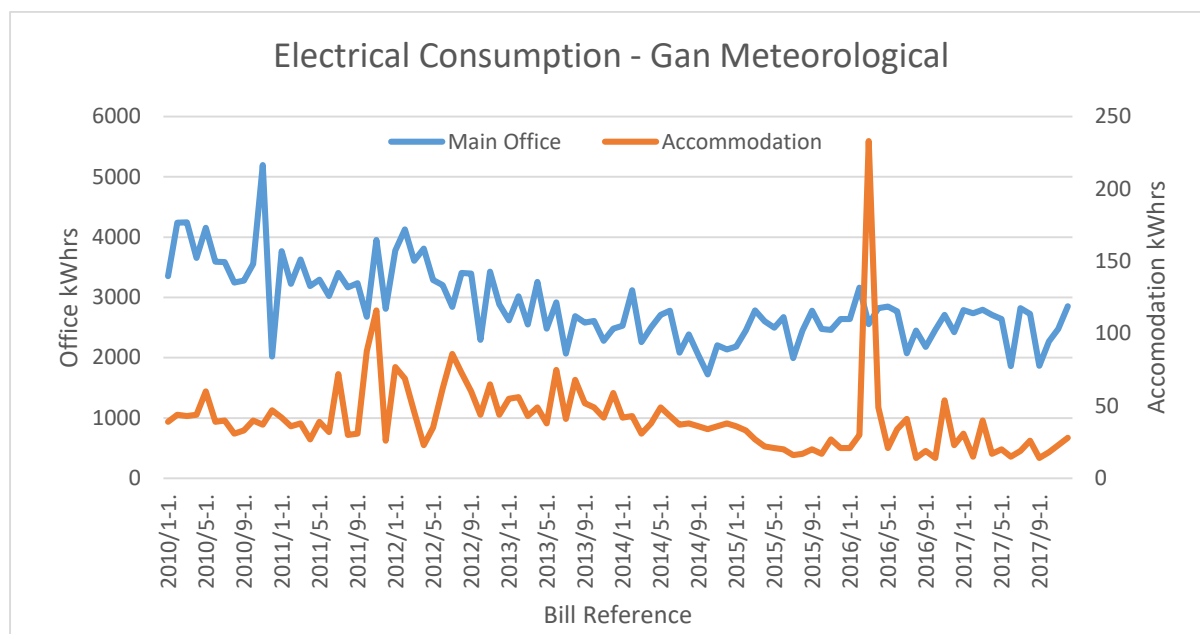


Figure 4: Energy consumption for each meter from January 2010 to December 2017 – as taken from electricity bills

Both meters show a consistent downward trend in monthly usage over the period. It is not clear what has driven the reduction in the office consumption, however, the accommodation block has seen reduced occupancy in recent times as occupants have increasingly used the area in the office block. In addition, increased occupant awareness of energy consumption and government initiatives to improve energy efficiency are expected to have contributed.

The reason for the unusually high consumption in May 2016 is unknown, however, based on the connected systems, the Team expect it is due to air conditioning and lighting being left on for the majority of the month.

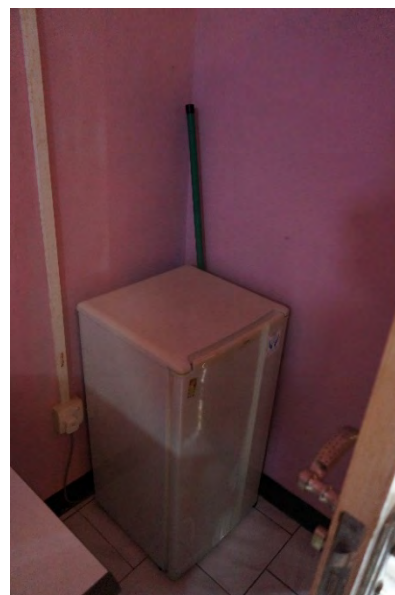


Figure 5: Refrigerator for the accommodation unit

2.1 Data Logging – Office

Meter data logging was carried out over a week from the 1st of March 2018 to the 8th of March 2018. During that time, the hydrogen generator was not operational, other than for a 10-minute period on the 8th of March around 3pm.

The data for the office shows a highly variable load of around 2kW which operates on/off with a period of around 10 minutes.

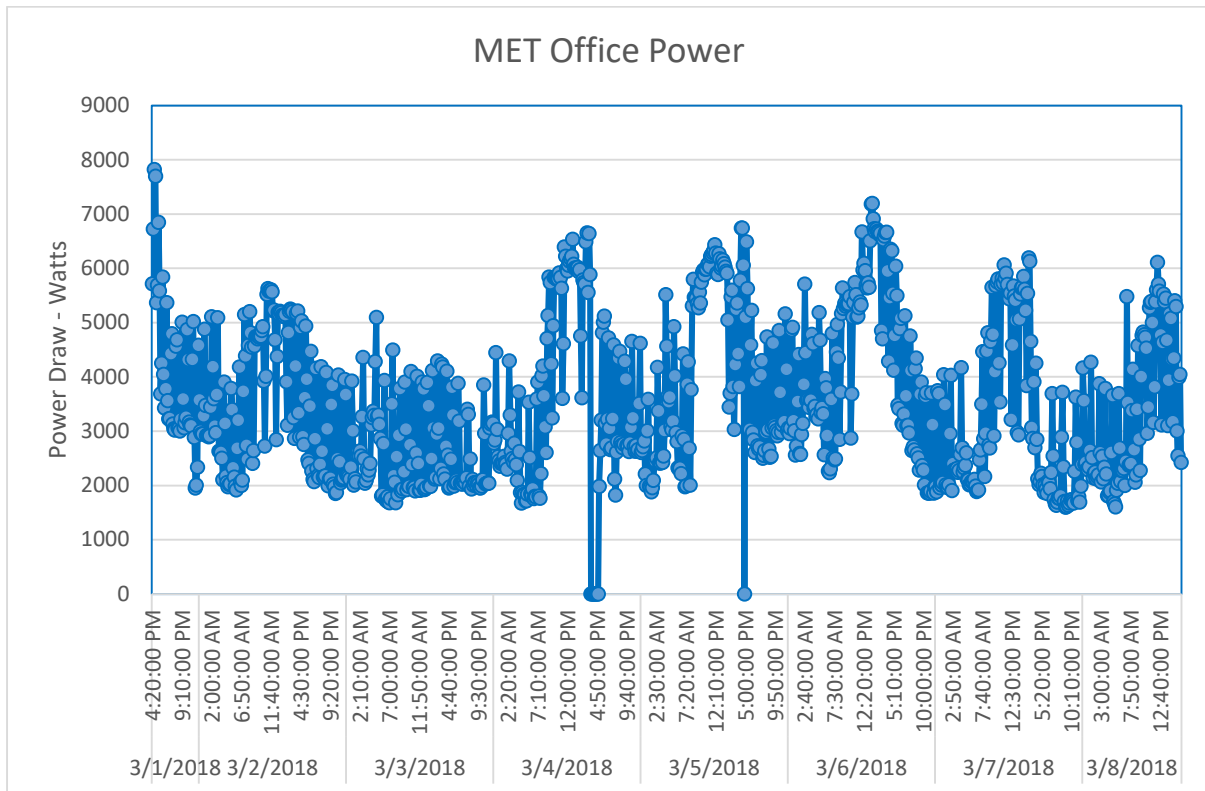


Figure 6: Energy logs for the MET office buildings

A review of the equipment on site indicated that the most likely cause of the $\approx 2\text{kW}$ jumps is the wall mounted air conditioning unit to the storage shed. This unit is not provided with an inverter and is required to operate 24 hours a day.

The plot above shows a very consistent power draw over each day, reflective of the very consistent weather patterns in the Maldives. As shown in the graphs below, climatic conditions are very consistent throughout the year, with only the increased rainfall and relative humidity in November showing a significant correlation with power consumption:

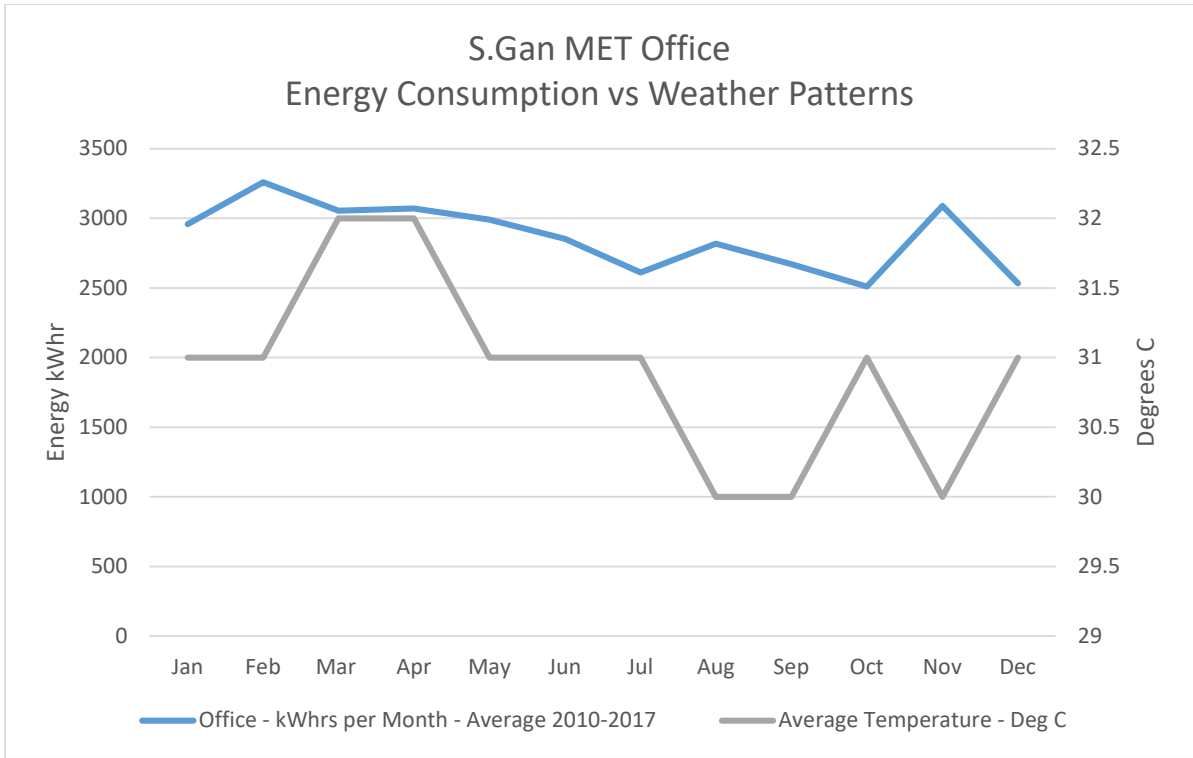


Figure 7: Energy Consumption versus Weather Patterns for S.Gan MET Office

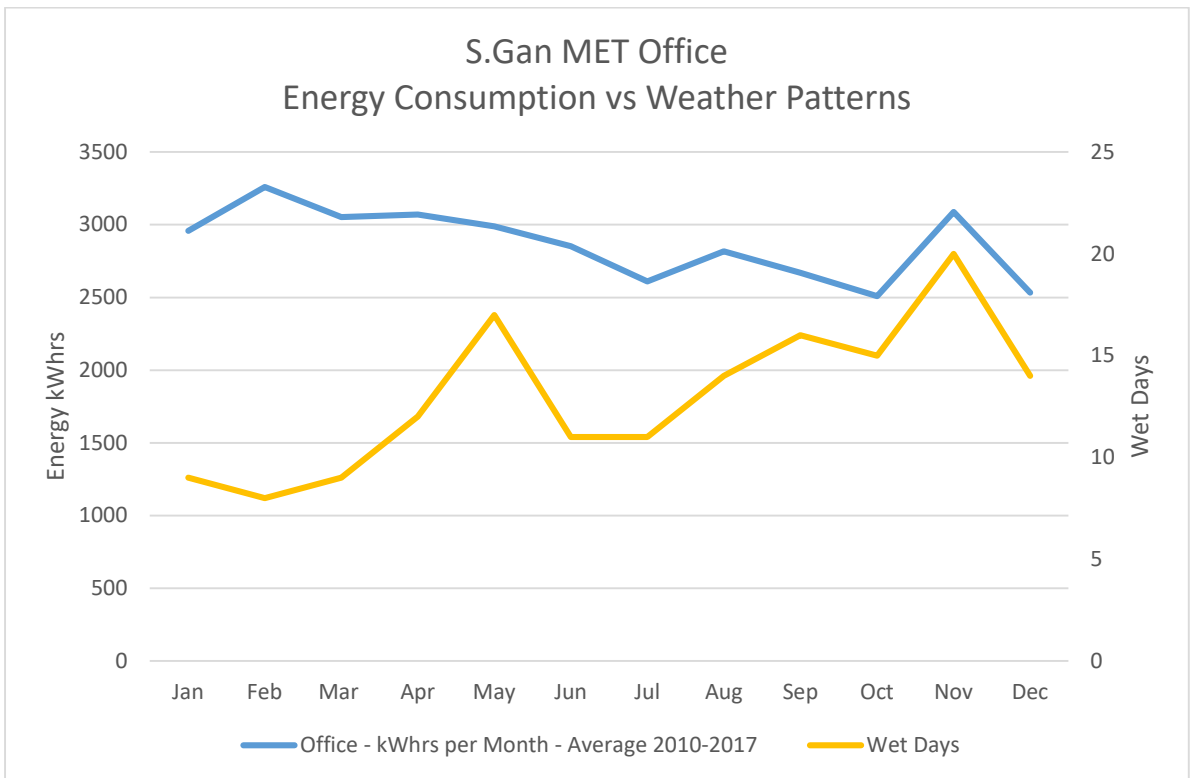


Figure 8: Energy Consumption versus wet days for S.Gan MET Office

Whilst the hot and humid external conditions contribute to energy consumption, the consistent nature of the weather patterns means that there is limited observable correlation between weather and power as other, more changeable variables have a greater influence.

The plot below shows the consumption in dots with the line representing an average over an hour:

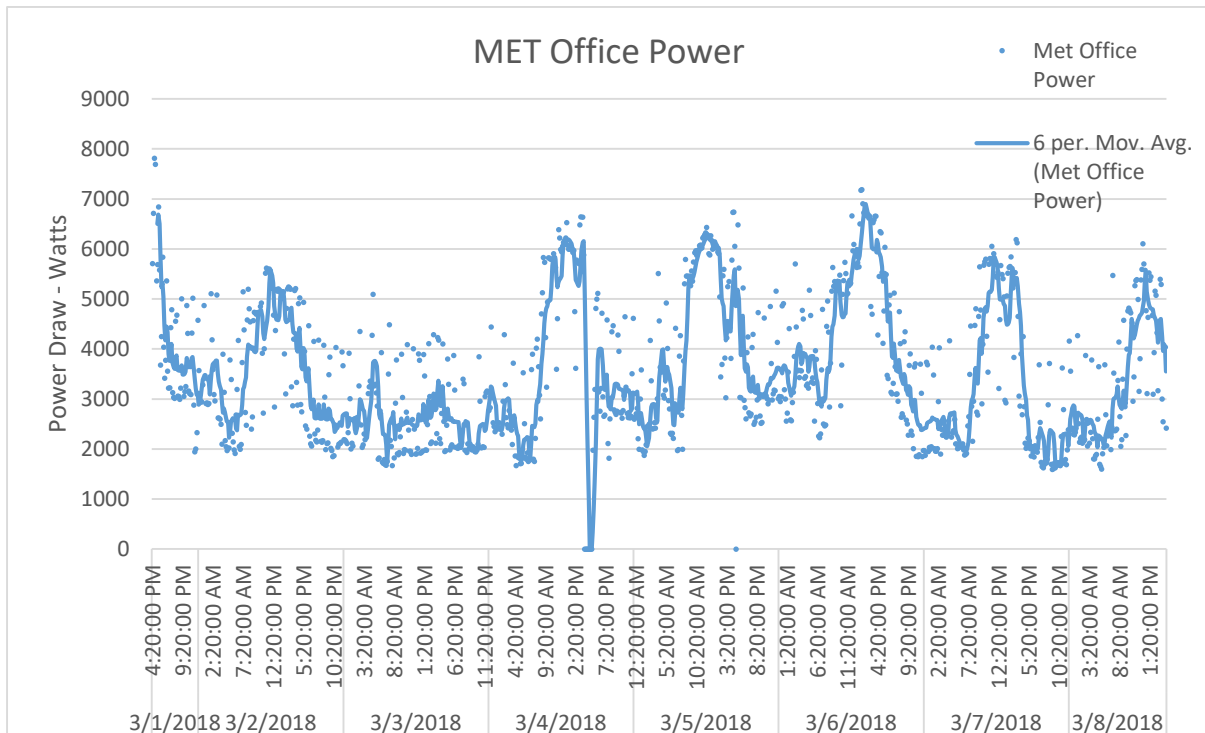


Figure 9: Average energy consumption per hour

Peaks in usage are evident for the weekdays and Friday, with Saturday being a period of marked low consumption. The base load is consistent overnight and reflective of minor quantities of air conditioning units and equipment running overnight – as would be expected for a building which operates 24/7.

2.2 Data Logging – Accommodation

The accommodation unit was logged for a eight-day period from the 11th of March to the 19th of March.

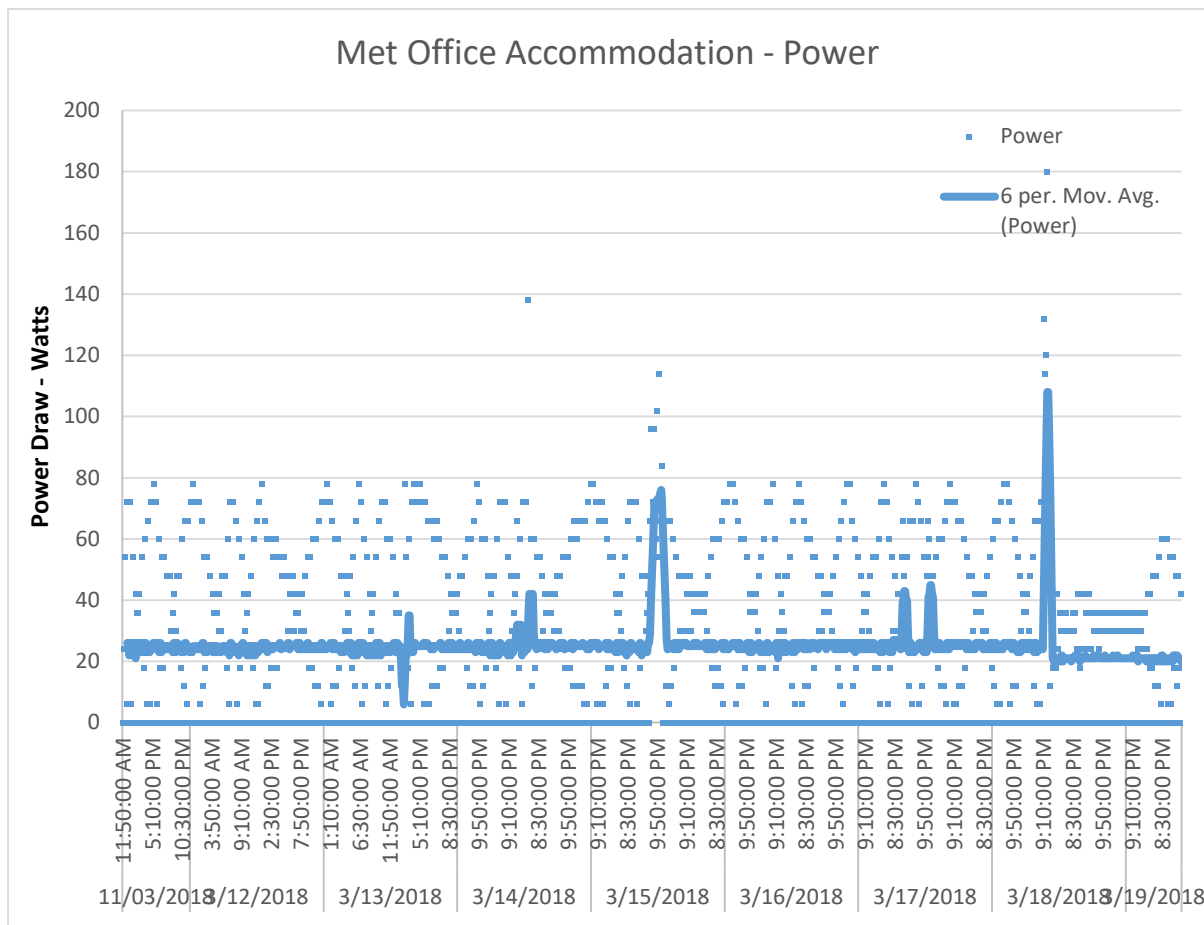


Figure 10: Energy logs for the MET office accommodation unit

The power consumption in the MET Accommodation unit is categorised by rapidly fluctuating power draws over 10-minute periods, hence, the graph above shows the actual data points as dots, with the hourly trend line plotted in solid colour. The data indicates that the building has an average draw of around 25W – which fell to around 20W from the 19th of March, which is most likely representative of the refrigerator turning on and off.

The plot shows brief periods (around 1 hour) of operation on the 15th and 18th, with other, shorter periods of operation on the 13th, 14th and 17th.

The most likely cause for these spikes is the operation of the air conditioning unit.

Similarly to the office, the consistent weather patterns over the year means that there is limited observable correlation between the weather and energy consumption – other than the increased humidity in November:

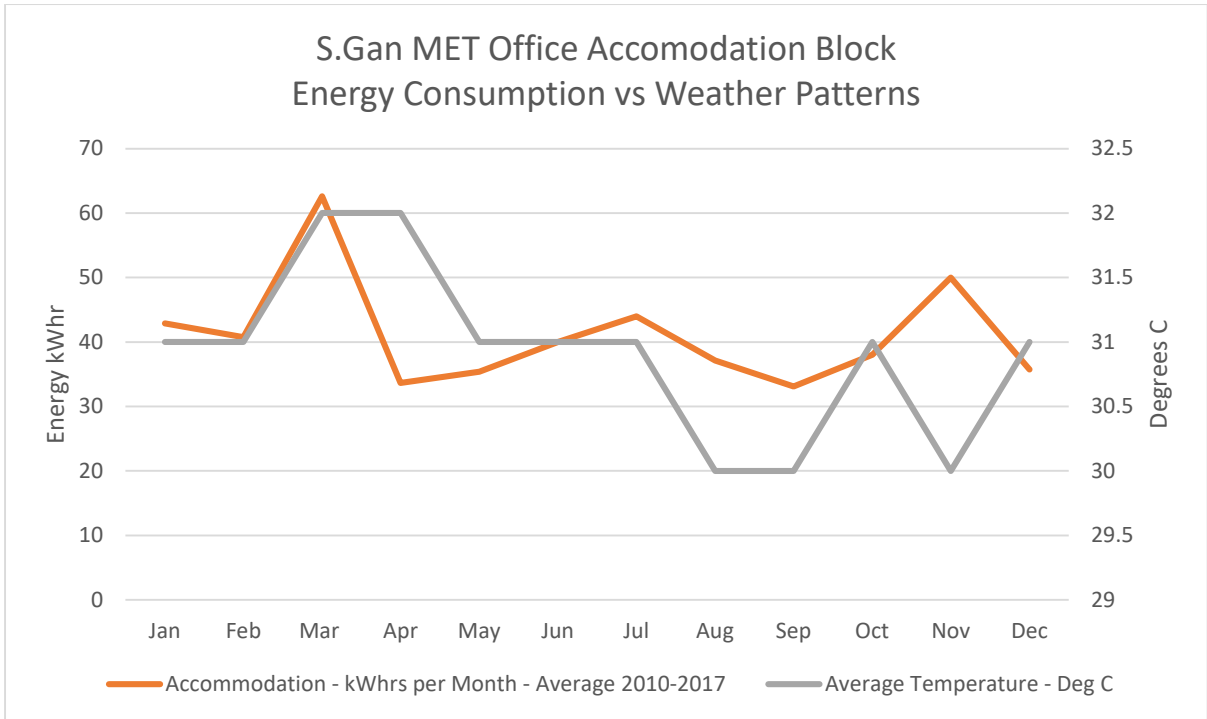


Figure 11: Energy Consumption versus temperature for S.Gan MET Office Accomodation Block

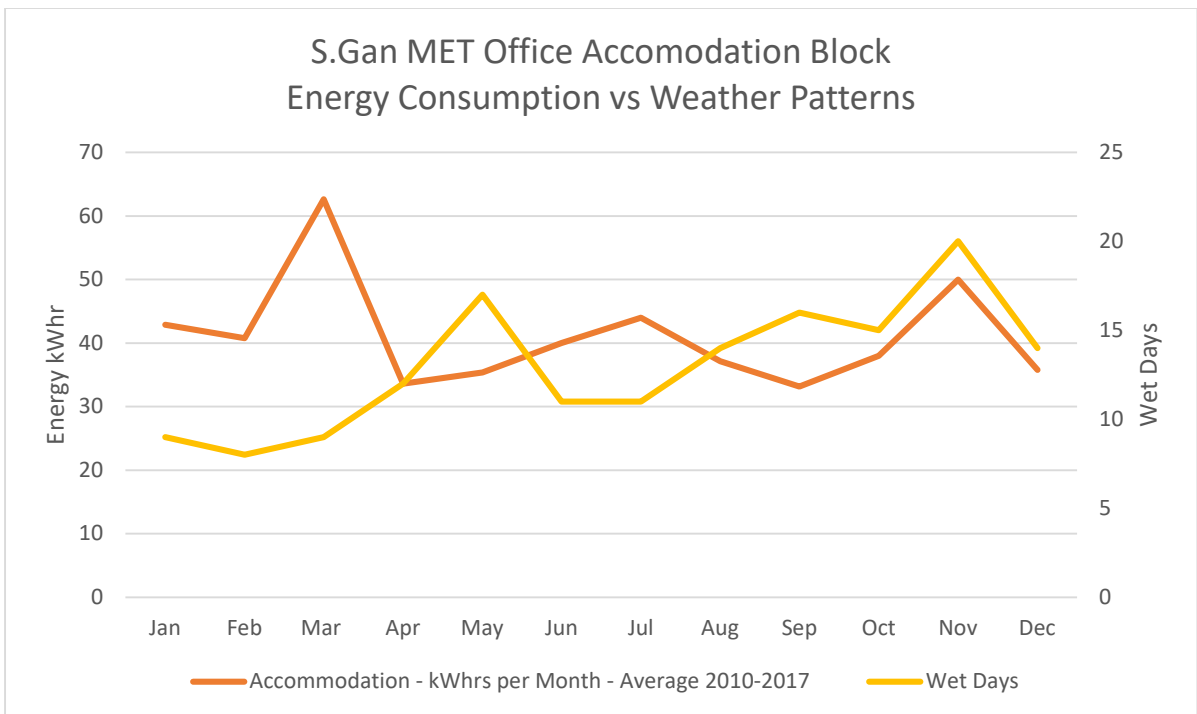


Figure 12: Energy Consumption versus wet days for S.Gan MET Office Accomodation Block

3 Site Visit Observations

The Team visited the site on the night of the 1st of April and the morning of the 2nd of April to observe the building operation and to interview occupants regarding their accommodation and operational practices. The following sections describe key energy consumption features for the site.

3.1 Air Conditioning

Air conditioning has been installed for all occupied spaces, however, it is only in use during occupation. Air conditioning in both accommodation areas were off during the time of the visits as the spaces were unoccupied.

Air conditioning (AC) units are generally good quality and in good working order. All units – other than the wall mounted AC for the storage room – were inverter type with good Coefficients of Performance (measure of efficiency). The data logging indicates that the wall mounted air conditioning unit draws a considerable amount more power per unit of cooling than the other units and consistently stages on/off when in use.

The air conditioning unit in the accommodation block is old and in relatively poor condition. It has a relatively poor Coefficient of Performance and runs on R22 refrigerant, meaning it is likely to require replacement when it has any significant maintenance issues. It is not clear what, if any, ongoing maintenance is being conducted on this unit.

Area Served	Cooling Capacity	Power Draw	Coefficient of Performance	Refrigerant	Comments
Accommodation Unit	2.6 kW	1.95 kW	1.33	R22	Very poor efficiency.
Office	5.2 kW	1.58 kW	3.29	R410A	
Managers' Office	7.0 kW	2.05 kW	3.41	R410A	
Accommodation Room	5.2 kW	1.95 kW	2.67	R22	Refrigerant now superseded, requires replacement
Main Office	7.0 kW	2.17 kW	3.22	R 410A	Generally only operate one unit at a time.
	7.0 kW	2.17 kW	3.22	R 410A	
Storage Room	5.0 kW	3.0 kW	1.67	R 410A	

Table 1: Air conditioning unit details for the Gan MET office buildings

Temperatures within the occupied spaces were generally around 25 degrees and 50% or lower relative humidity.

3.2 Building Fabric

Both the office and accommodation facilities were constructed using the same method – masonry walls and metal roof. The roof for the accommodation is grey and is generally well shaded by an adjacent tree, whilst the roof for the office is a pale green. Modification of roof colour for the office to a lighter colour would reduce heat gain.



Figure 13: Roof of MET office accommodation unit

Colour	Solar Absorptance
Classic Cream™	0.32
Surfmist®	0.32
Paperbark®	0.42
Evening Haze®	0.43
Shale Grey™	0.43
Sandbank®	0.46
Dune®	0.47
Windspray®	0.58
Pale Eucalypt®	0.60
Bushland®	0.62
Headland®	0.63
Wilderness®	0.65
Jasper®	0.68
Menor Red®	0.69
Woodland Grey®	0.71
Loft®	0.71
Monument®	0.73
Ironstone®	0.74
Cottage Green®	0.75
Deep Ocean®	0.75

Figure 14: Colour verses solar absorptance

The image above shows the accommodation block as having a largely shaded, white or grey roof. The image below shows the exposed, light green roof of the office.



Figure 15: Roof of MET office building

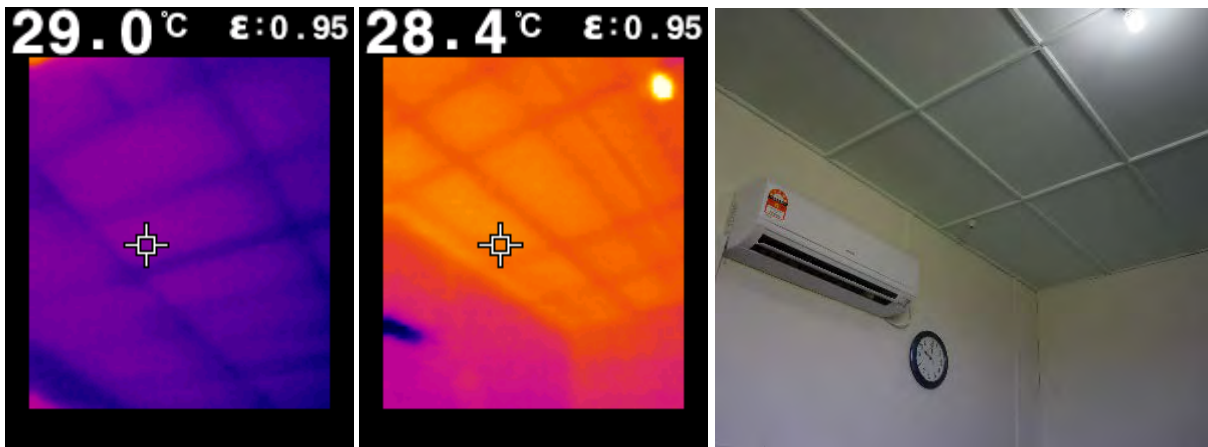


Figure 16: Thermal image of the ceiling of MET office building

Thermal image above shows timber ceiling elements as cooler than the general roof. This indicates the timber is providing more insulation than the adjacent void above the ceiling.

The storage shed is not believed to have any insulation in walls or roof and is a light weight construction.

3.3 Glazing

The accommodation block had very little glazing and the glazing that was there was either boarded up or covered by shutters. This reduces heat gain to the space, however, provides very limited opportunities for natural ventilation or air movement for occupants. Consequently, the room had poor air quality.

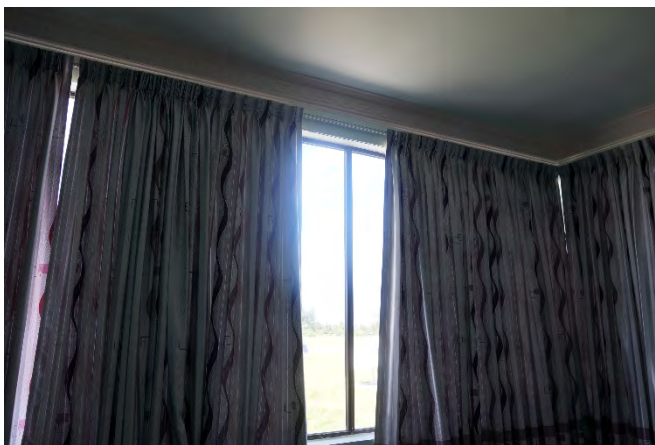


Figure 17: Glazing in the managers' office of Gan MET office

Glazing for the office building was well shaded on the long axis, however, glazing to the managers' office was unshaded and faced south – this is likely to result in heavy glare and heat gain issues for much of the year.

Glazing for all office areas was provided with curtains which will achieve some reduction in glare and direct solar heat gain.

Glazing to the managers' office is shown left.

The storage shed had no glazing or any form of controlled outside air provision.

3.4 Building Orientation

All buildings are located with their long axis running approximately north/south, which leads to extensive east /west facing walls and windows. Large overhangs to the west (office) and east (accommodation) would provide some shading. Generally the exposed facades have non-conditioned spaces – such as ensuite – to reduce the impact of direct solar radiation. The storage shed has no shading.

3.5 Building Sealing

The buildings are not well sealed. Doors do not have seals or weather strips and occupants commonly leave doors or windows open – particularly to non-conditioned spaces, such as corridors, tea preparation areas or bathrooms / ablutions facilities. The buildings are very exposed to winds. This means that the buildings have very poor sealing capabilities and would be expected to leak a lot of energy when being air conditioned.

The image on the right shows the kitchenette, with the exhaust fan not sealed and louvres for ventilation over the windows. The room is not directly air conditioned, however is open to the rest of the building which is conditioned and is considered a significant energy leakage path.

These holes in the building envelope prevent effective sealing of the space.



Figure 18: Image to the right shows the kitchenette

3.6 Vertical Transport

There are no vertical transportation systems on site. All buildings are single level.

3.7 External Lighting

The site has very limited external lighting. Verandah areas are provided with fluorescent tube or compact fluorescent bulbs to match adjacent spaces.

These lights are maintained and controlled by the Gan MET Office staffs.

3.8 Internal Lighting

All rooms are provided with individual lighting control. Switches generally control 1-2 fittings (three fittings in the case of the large office) and occupants generally only turn lights on when required.

Lighting is as follows:

- Single Tube T8 – 1500mm long – (~45W)
- Single Tube T8 – 1200mm long – (~36W)
- Compact fluorescent light – (~20W) – right

There were no LED lights obvious during the inspection.

Note all wattages above are estimated, bulb power draw markings were generally illegible and tubes may have been replaced with different wattages.

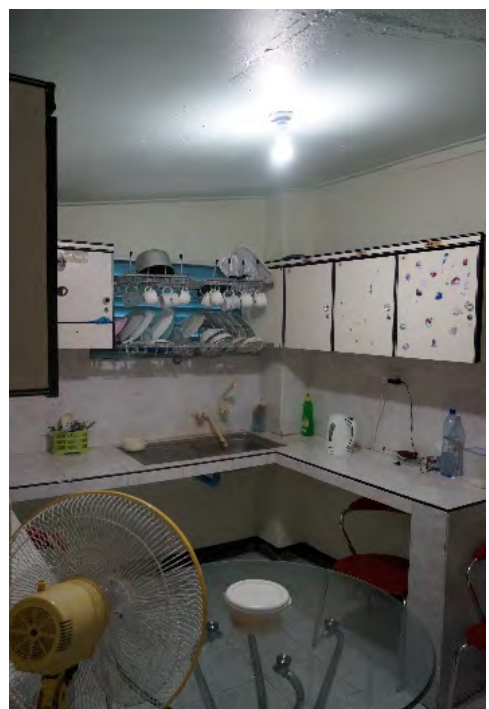


Figure 19: Image to the right shows Internal lighting for kitchen area

Space	Compact Fluorescent Bulbs ~20W	T8 1200mm Bulbs ~36W	T8 1500mm Bulbs ~45W	Comments
Accommodation	3	1	-	-
Corridor	1	2	-	-
Kitchenette	1	-	-	-
2 Work Station Office	1	-	-	~154 Lux – considered very low for administration type space
Manager’s Office	1	-	1	350 lux on desk
Main Office	6		8	~130 Lux – considered very low for administration type space. Note, not all fittings were lamped / operational
Accommodation – in office	3	1	-	-
Storage Shed	1	1	-	50-100 Lux - considered very low for administration type space. Note, not all fittings were lamped / operational

Table 2: Luminaire details and lighting levels for the MET office buildings

Lighting design power density is considered relatively poor and could be improved with replacement of compact fluorescent bulbs with similar luminance LED’s. Consideration should be given to replacing the tube lighting with LED’s.

3.9 Equipment

Equipment Item	Number of	Comments
PC towers	14	
Monitor	14	
Laptops	3	
ACs	4	AC unit in the storage room is an old model and has a cooling capacity of 5300W using R-22 refrigerant
Printers	2	
Aethalometer	2	Special equipment to detect air pollution
Hydrogen Generator	1	

Table 3: Equipment inventory of S.Gan MET Office Building

The site includes a hydrogen generator which consumes up to 45A (when in operation). The unit was operated at around 3pm on the last day of logging which indicated ~1kW power draw. The unit is shown left.



Equipment was generally tower type PC's which are approaching the end of their economic life and should be considered for replacement. Consideration should be given to laptop computers as they are substantially more energy efficient.

Consideration should be given to decommissioning the fridge within the accommodation unit as this represents almost 100% of the power draw for the building and is not currently in use.

Figure 20: Image left shows the Hydrogen generator



The managers' office also included an air monitoring station, which include a PC and is operational 24 hours a day, shown below.

Figure 21: Image left shows 24/7 air monitoring station at Gan MET Office

3.10 On Site Generation

The building includes no onsite generation.

The office building includes consistent loads and would be well suited for a 3-4kW solar array, however, the roof pitch is not ideal for solar panel efficiency.

The accommodation block does not have sufficient load to warrant installation of solar panels and, in addition, the roof pitches and overshadowing by surrounding trees would compromise the effective generation capacity of any array.

3.11 Power Supply

The office building is provided with a three-phase power supply to a relatively old meter and switchboard (left). The accommodation unit is provided with single phase power through a similarly aged board and metered arrangement (right).



Figure 22: Existing single-phase power board at MET Office Accommodation Block



Figure 23: Existing three phase power board at MET Office

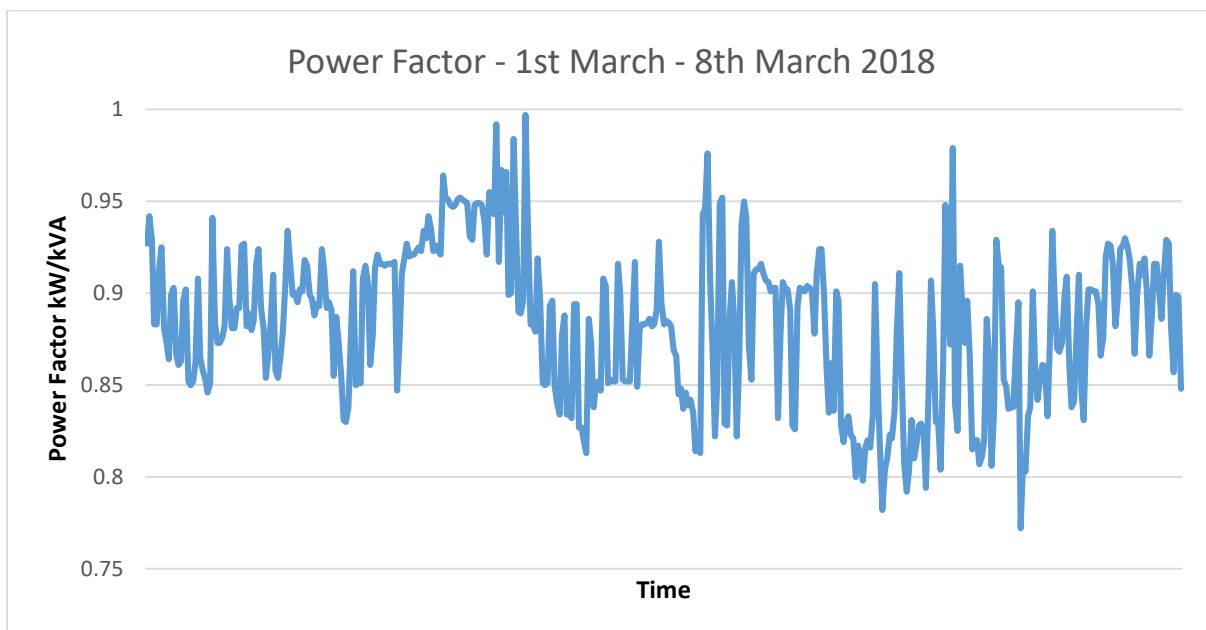


Figure 24: Power Factor for Gan MET Office block

The plot above shows the power factor over a one week period for the office building. The overall average for the period is around 0.88, which is considered fair, however, there are some periods with power factor as low as 0.77.

3.12 Occupant Comfort

Measured conditions within the occupied spaces would be considered comfortable for the Maldives, with temperatures generally around 24-25 degrees C and 40-60% relative humidity.

Ceiling fans are provided for sleeping areas and the managers’ office. The main office area (operational staff working area) is not provided with ceiling fans and is operated at a lower temperature than the surrounding spaces.

Provision of ceiling fans in all occupied rooms would be expected to save energy without compromising occupant comfort. This is because humans reject heat better to moving air than still air. Hence, temperatures with moving air can provide similar levels of occupant comfort to temperatures with still air.

Room Description	Work Settings	Internal Temperature / Humidity	Comments
2 Workstation Office	2	28.2 / 49.8%	
Managers’ Office	1 + Air monitoring station	26.8 / 50.7%	
Main Office	~5	24.7 / 38.4%	Much lower temperature and humidity than other spaces.

Table 4: Number of workstations in MET office building

3.13 After Hours Consumption

The Team visited site at around 8PM on the 1st of April to observe building operation outside of typical hours.

The building was operational, with staff in the main office area. Other portions of the building were inactive, with lights and equipment not operational.

3.14 Occupant Survey

As part of the audit staffs were surveyed for their understanding of energy efficiency and how their behaviours influence energy consumption on site. The findings indicated staff are generally responsible for operation of their own lighting and equipment, with staff generally shutting areas and systems down when they leave.

Bill payment and procurement is handled by the Male office with local staff having limited input in terms of review of energy consumption or control over equipment selected. There have been some instances of feedback to the office administrator to reduce energy consumption, however this feedback has generally not been provided to staff.

Staffs are interested in energy consumption but are not aware of their current performance or how they can influence energy consumption.

3.15 Building Control

Building controls are manual for air conditioning, lights and ceiling fans – as shown right.

Controls are utilised for relatively small areas, with light switches generally controlling 1 or 2 fittings only, however, all plant relies on occupant engagement to activate / deactivate as needed.

Air conditioning remotes are used for temperature control and, in some instances are mounted in areas which are influenced by air movement from the unit directly, providing a false reading on temperature within the space.

Sensors should be located in the air body, but outside of the air stream controlled by the air conditioning unit.



Figure 25: Figure above shows the fan, air conditioning and lighting controls for the office building

4 Energy Budget

4.1 Accommodation Block

Based on the audit, the expected annual energy consumption for the accommodation block is ~6.8MWhrs when occupied and approximately 0.45MWhrs when unoccupied.

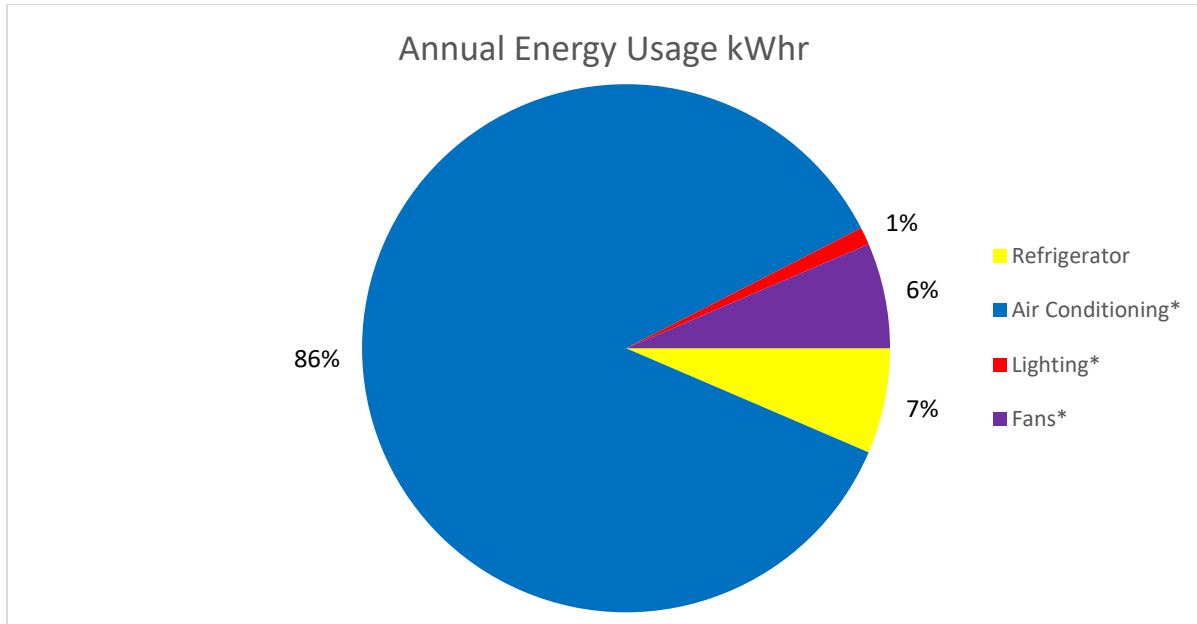


Figure 26: Expected annual energy usage by equipment groups for the accommodation unit

Comparison against recorded consumption shows the building is rarely fully occupied.

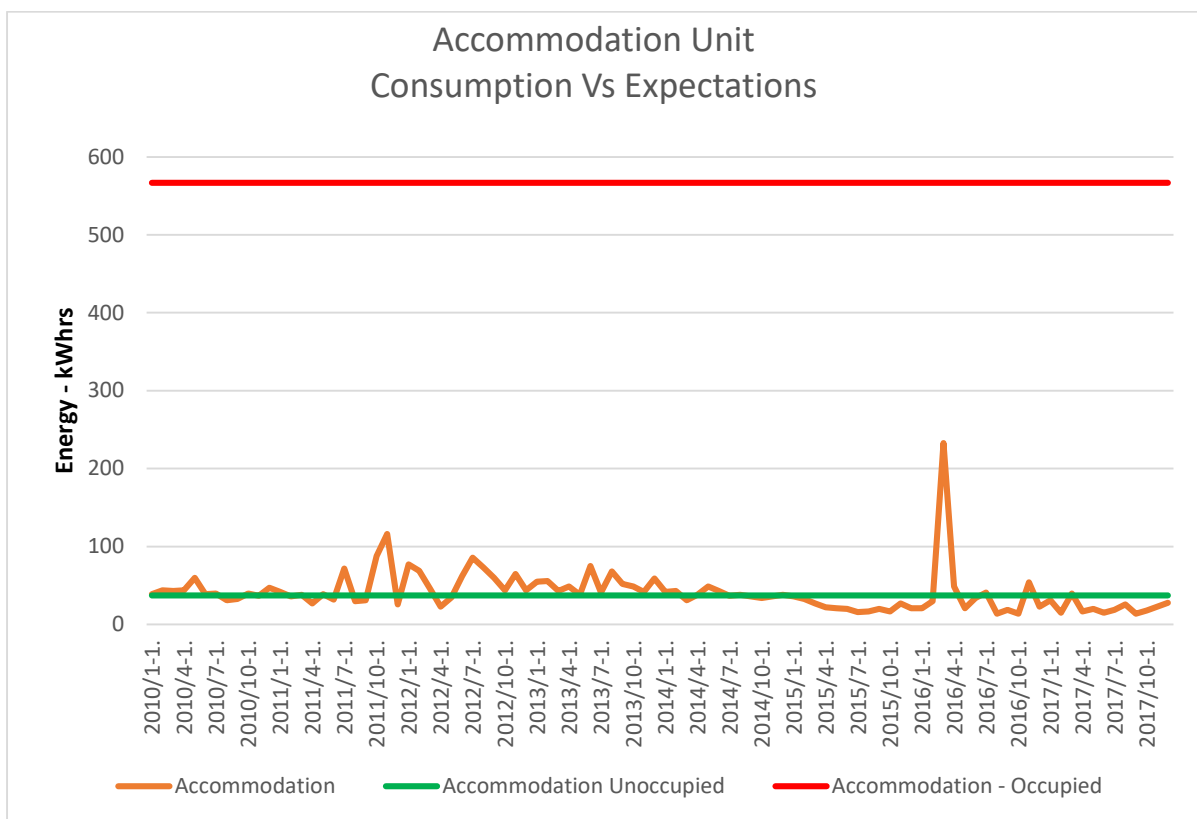


Figure 27: Energy consumption versus expectation for the accommodation unit

4.2 Office Block

The expected energy consumption from the office building is shown below.

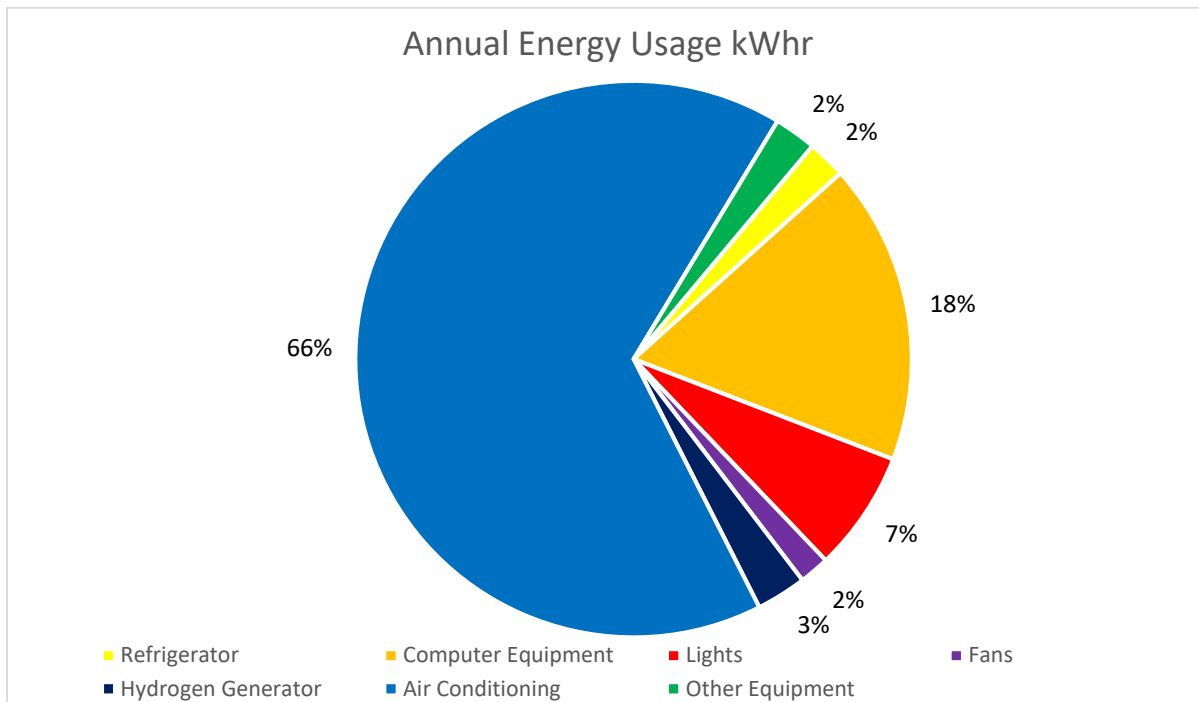


Figure 28: Expected annual energy usage by equipment groups for the office block

The consumption is expected to be dominated by computer equipment and air conditioning, due to size of the connected load and the extended usage times of the services. The chart below provides an approximate breakdown of consumption by air conditioning unit.

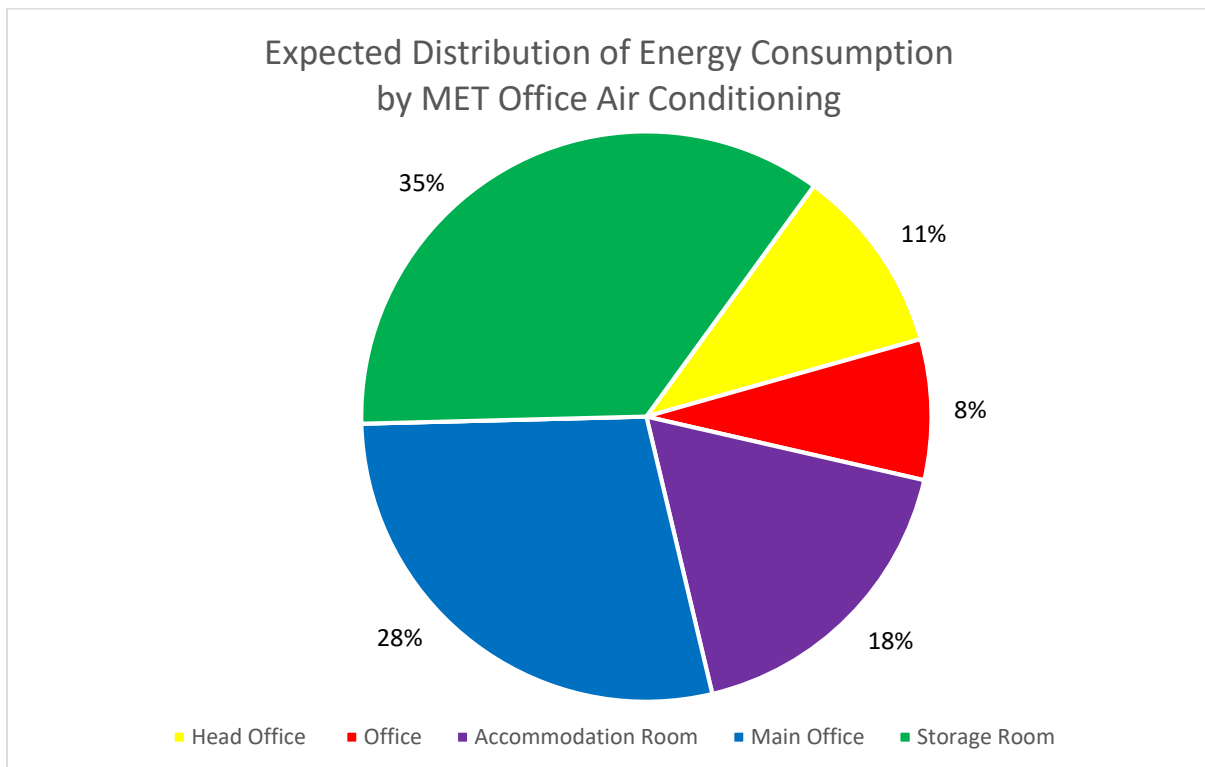


Figure 29: Expected annual energy usage by air conditioning units for Gan MET office

The chart below provides a review of expected consumption against previous months bills.

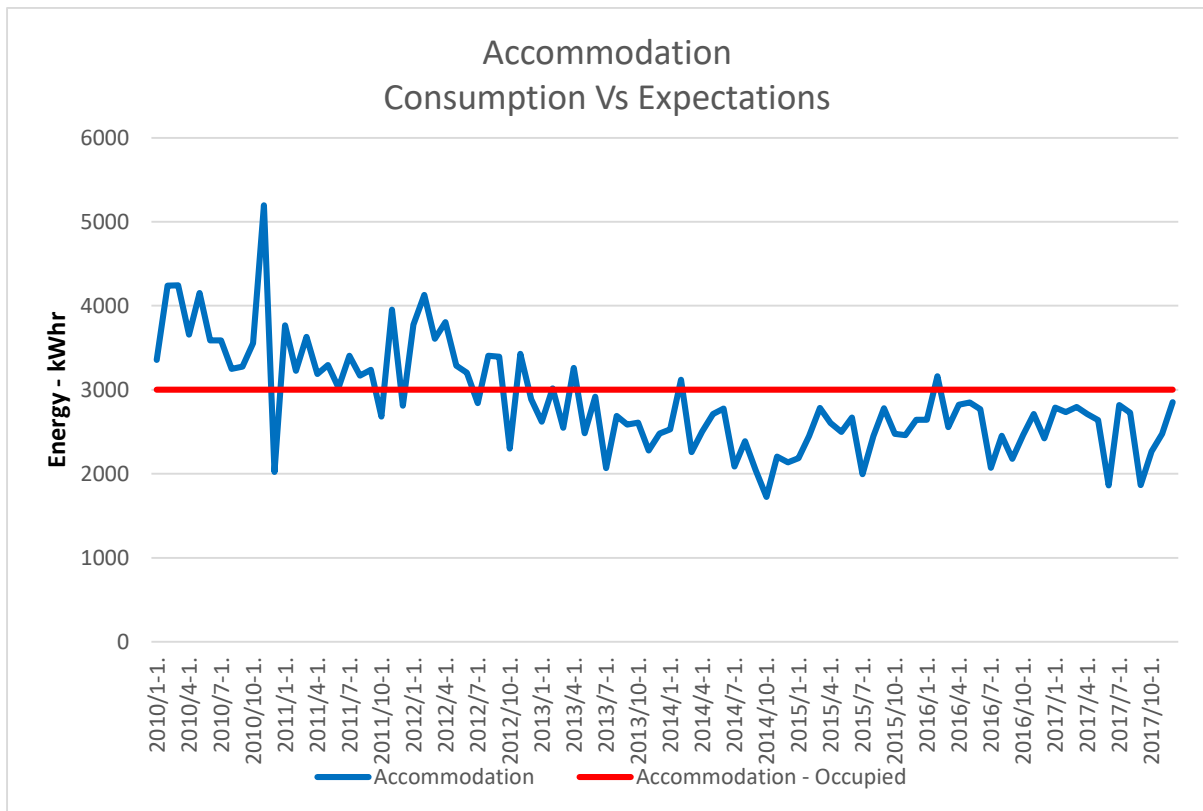


Figure 30: Energy consumption verses expectation for the Accommodation block

Consumption is generally in accordance with expectations based on observations during the site visit. Recent months have seen occupants consistently outperform expectations.

5 Recommendations

Following recommendations has been considered for this site.

- Power Factor Correction
 - Power factor correction is not considered applicable for this site. The accommodation utilises single phase power only and the quanta of energy consumed by the office is not likely to contribute to an economically advantageous installation of power factor correction for the office.
 - Power factor improvement will likely be achieved by upgrade / replacement of mechanical air conditioning plant as discussed below.
- Lighting
 - Current lighting is considered to be relatively inefficient and power consumption would be expected to be halved through the installation of new light fittings. Current fittings are generally approaching the end of their useful life and should be replaced entirely.
 - External lighting for the reviewed buildings is minimal, however, site level lighting would also benefit from replacement.
- Air Conditioning
 - Air conditioning in general is in good condition. Performance improvements would be limited to the accommodation unit being replaced and the storage room, wall mounted package unit.
 - Units should be replaced with similar capacity systems, with separate condensers and fan coil units, inverter technology and peak COP's of no less than 3.0 at design conditions.
 - Other units should be maintained at least 6 monthly, including cleaning / replacing of filters and clearing of coils / condensate pumps as necessary.
- Controls
 - Air conditioning controls (manual) are not easily modified and are not recommended for a technical intervention. Consideration should be given to occupant education and feedback (through energy audits and bill information provision) on energy efficiency, including the importance of operating air conditioning units at 25-27 degrees set point.
- Occupant Engagement
 - Occupant engagement is critical for energy reduction. Provision of general education and operational performance tracking should be regular and structured. As a minimum, occupants should:
 - Be provided with monthly billing data
 - Undertake energy audits once a quarter – at varying times of the day – to observe plant items that are operating and review if they could be safely turned off
 - Be advised about influencing factors on energy consumption in air conditioning, including temperature set points and leaving windows / doors open.
- Equipment selections
 - The main energy consuming equipment on site are the computers used by office staff. Upgrade of computers to laptops is recommended.

5.1 Expected Savings

As discussed above, the expected energy savings from the opportunities are discussed below:

Action	Energy savings kWhrs/year	GHG savings* kgCO ₂ (e) p.a.	Comments
Upgrade Lighting – Office Building	625	562.5	Based on use of LED fittings
Upgrade Lighting – Accommodation Building	36	32.4	Based on use of LED fittings
Replace Storage Unit Air Conditioner	1,000	900	Based on inverter, split DX unit, average COP of 3 or greater.
Replace Accommodation Unit Air Conditioner	1,500	1,350	Based on inverter, split DX unit, average COP of 3 or greater.
Occupant Engagement	2,500	2,250	This figure is based on a 15% reduction in energy, based on experience with similar programs held elsewhere
Upgrade of Computers	2,000	1,800	This is based on conversion of modern laptops in lieu of existing desktops

Table 5: Expected energy savings from proposed recommendations

** Based on 2009 emissions factor of 0.9 kgCO₂(e)/kWhr for Male – pg 163 of 2016 State of the Environment 2016 – Ministry of Environment and Energy Republic of Maldives*