Ministry of Environment

ASSESSMENT AND DESIGN OF COST EFFECTIVE ENERGY EFFICIENCY IMPROVEMENTS FOR SELECTED BUILDINGS

Velaanaage Building

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

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Ministry of Environment

Strengthening Low Carbon Energy Island Strategies (LCEI) Project

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Consultant:

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In partnership with Anser Technical

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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 building are Velaanaage Office Building, Hulhumale' Flat 110 (a residential building), K. Guraidhoo Mosque (Masjid-ul Sidheeq) and Maldives Meteorological Service's 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 details the findings for Velaanaage Office Building.

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 with the gathering of facility information. The Consulting Team ("the Team") visited the site in March 2018 for detailed assessment of the building. The assessment included a review of the site and surrounds, envelope (including materials and window to wall ratio), orientation of openings compared to sun-path and local wind patterns, occupancy patterns, and building systems (e.g. lighting). Following on the site visit and collection of data, a detailed energy audit report was prepared.

The building had an energy density of ~189kWhrs per m^2 (NLA (Net Lettable Area)) over calendar year 2017.

The building has a peak load of ~600kW with a baseload ~150kW with consumption rising sharply every morning around 6AM and remains high through to around 2PM when it falls gradually until midnight. Power logging indicated the power factor for the building averaged between 0.90 and 0.95, which is considered good practice. In addition to data logging, a detailed occupant survey was carried out with participants from every tenant of the building. Opportunities for improvement include lighting, air conditioning, power management and occupant engagement. Details of these improvements are given in Design Recommendation section of the report.

The total upfront cost of all recommended options is under MVR 11 million with an average payback period of just under 5 years. Recommended improvements will give a total energy saving of approximately 600,000KWh per year and annual greenhouse gas emission savings of 540 tonnes of $CO_{2(e)}$/year. In addition, upgrade of existing VRV will contribute to a further 175,000KWh per year energy savings, approximately 150,000kgCO_2e.

As it is unlikely to be economically viable to roll out all of these options concurrently, proposed improvements were priortised based on cost, payback and energy savings. With this approach, the Team has recommended prioritisation of options with a payback period of up to one year which costs under MVR 1 million. The resultant energy savings are estimated to be 520,000KWh/year, i.e., 85% of potential overall savings. This gives greenhouse gas emission savings of approximately 470 tonnes of CO2(e)/year.

A monitoring plan was prepared to assess the outcomes of the proposed design improvements. This included expected energy usage reduction, data collection equipment and methods for verification. Additional energy meters are recommended for major energy users. This will further assist in engaging occupants to achieve energy efficiency.

An Energy Efficiency Policy and an Energy Management Plan was prepared for use in government sector with a particular focus on Velaanaage Office Building. This was developed in line with ISO50001 standard. These documents cover management responsibilities, energy planning, implementation and operation, documentation, checking and review process that shall be adapted to achieve set targets in energy efficiency

Section 1
Energy Audit

1.1 Site Description

Velaanaage building was the tallest building in the Maldives up until 2018 having 15 story office complex. It is holds most of the government administrative offices and services would be easily given to customers from one single location. The building construction was completed and opened to service on 2011.

The building is in Male' and is surrounded by other, relatively large, government buildings. It is the tallest building within its close proximity and does not experience any significant shading from adjacent buildings below the lower few levels.

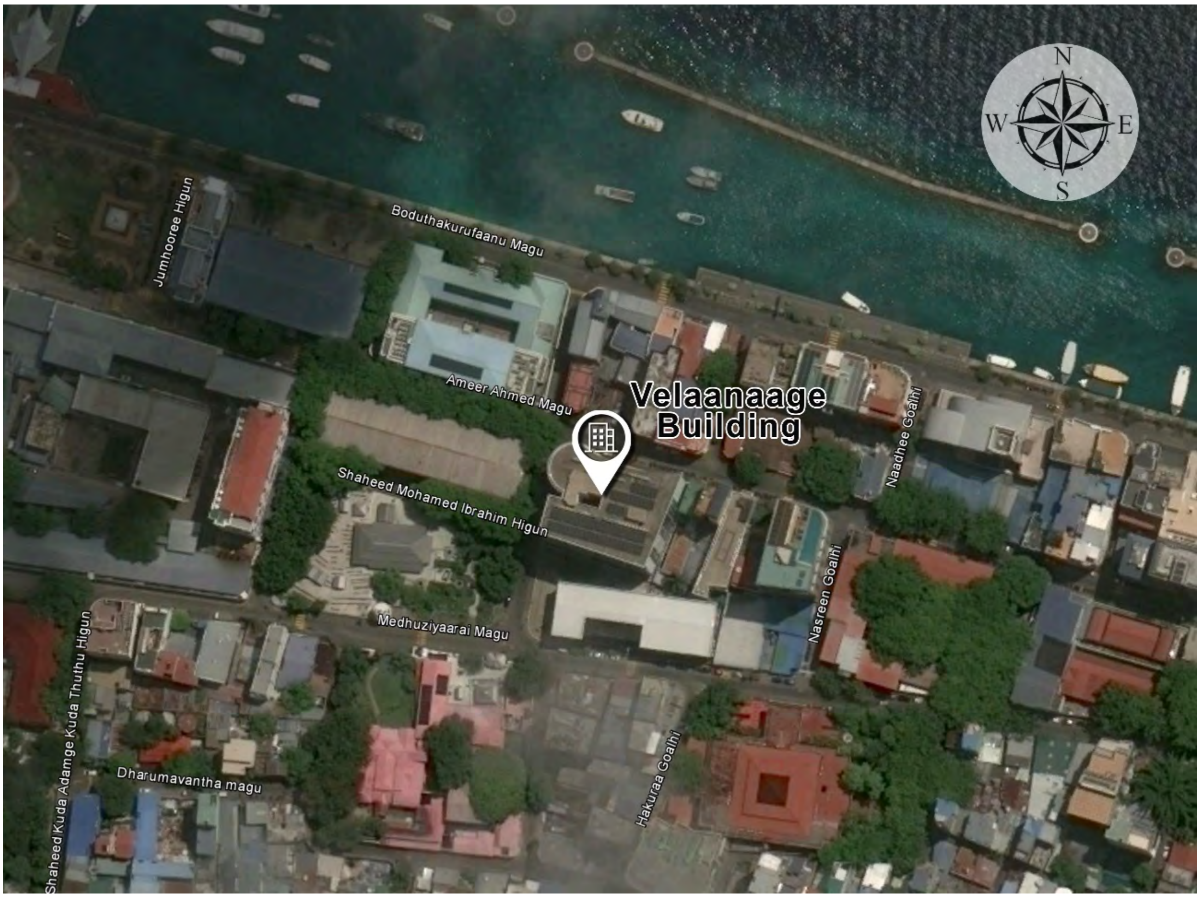

Figure 1-1: Aerial view of Velaanaage and surrounding area

The image on the left shows the surrounding buildings and north west corner of the Velaanaage building.

Figure 1-2: Street view of Velaanaage

1.2 Site Visit

The Velaanaage Office building was visited on four separate occasions between the 26th to the 29th of March 2018. The visits included an early morning (4:00AM) visit to check after-hours energy consumption and occupant patterns, as well as a complete walkthrough and interview of all tenanted spaces across the building. Full details of these audits are included in this report.

1.3 Pre-Visit Analysis

Prior to visiting the site, the Consulting Team ("the Team") reviewed historical electrical consumption data for the building and some of the occupied floors. The graph below shows consumption – the sum of all sub meters within the building - over the recorded period.

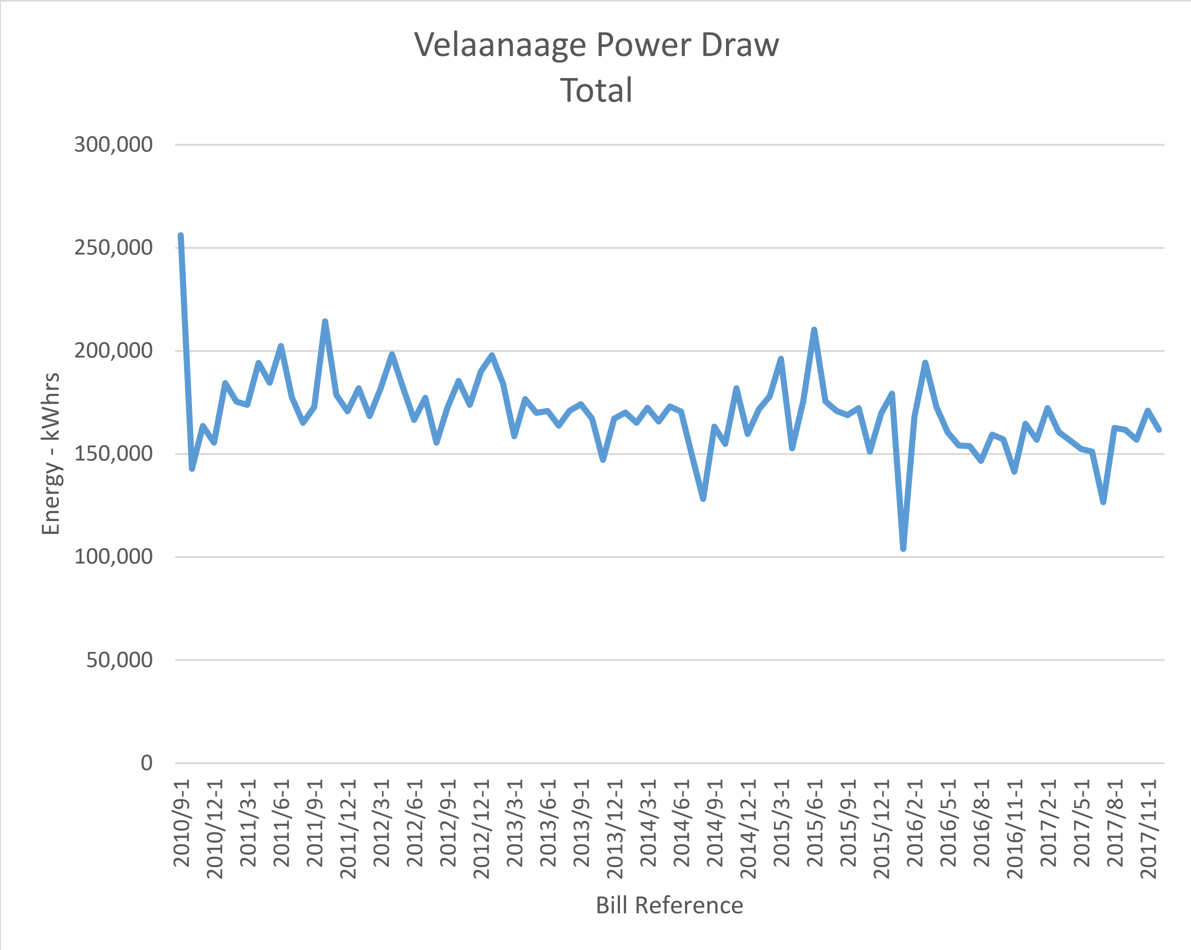

Figure 1-3: Energy consumption for Velaanaage building

Based on the drawings provided for analysis and occupancy density recorded during the visit, the analysis used the following information to normalise consumption:

Overall area	10,003m^2 – Occupied Office Area
Overall Occupants	889 people (based on surveys)
Number of Computers	987 computers (based on inventory)
Hours of use	36.3 hours per week (area weighted average from surveys)

Table 1-1: Summary of the data from individual floors with power data logging

Performance over the 2017 calendar year is considered very strong, when assessed against peer buildings in Australia, for the same area and climatic zone.

Further commentary is provided in the following Sections.

1.4 Data Logging Review

In addition to reviewing power consumption from bills, the Team undertook data logging on the main electrical feed to the office building, as well as for some of the tenants with high energy demand. Data was collected on instantaneous power draw every 10 minutes over the monitored period, with consumption data shown below:

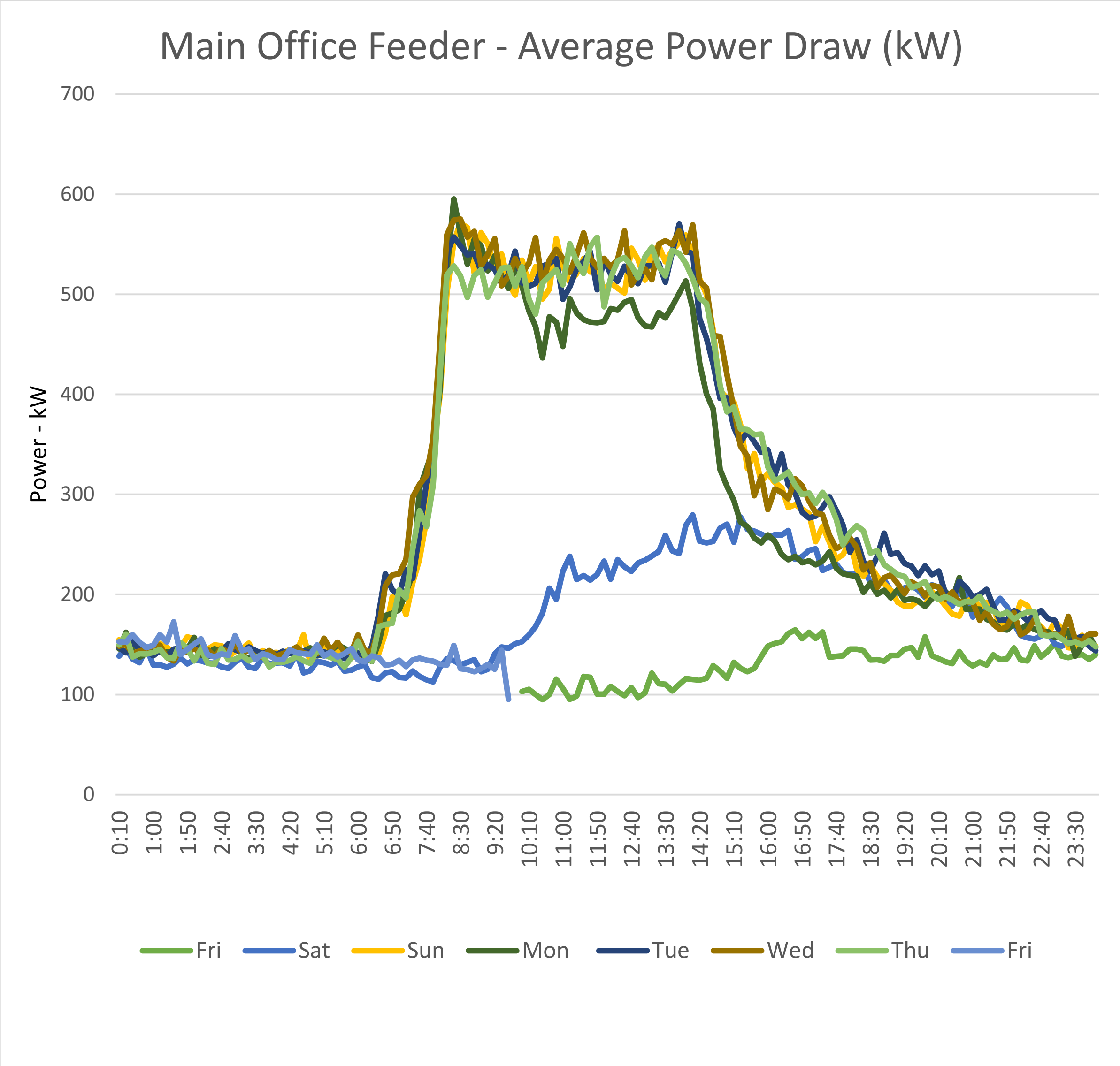

Figure 1-4: Power consumption logs for the Velaanaage building

The figure above shows very consistent power draw patterns over occupied days, with unoccupied periods also matching well.

The building appears to have ~150kW dead load throughout the building, which is very close to what would be expected based on the communications rooms on each floor.

Consumption rises sharply every morning around 6AM and remains high through to around 2PM when it falls gradually until midnight.

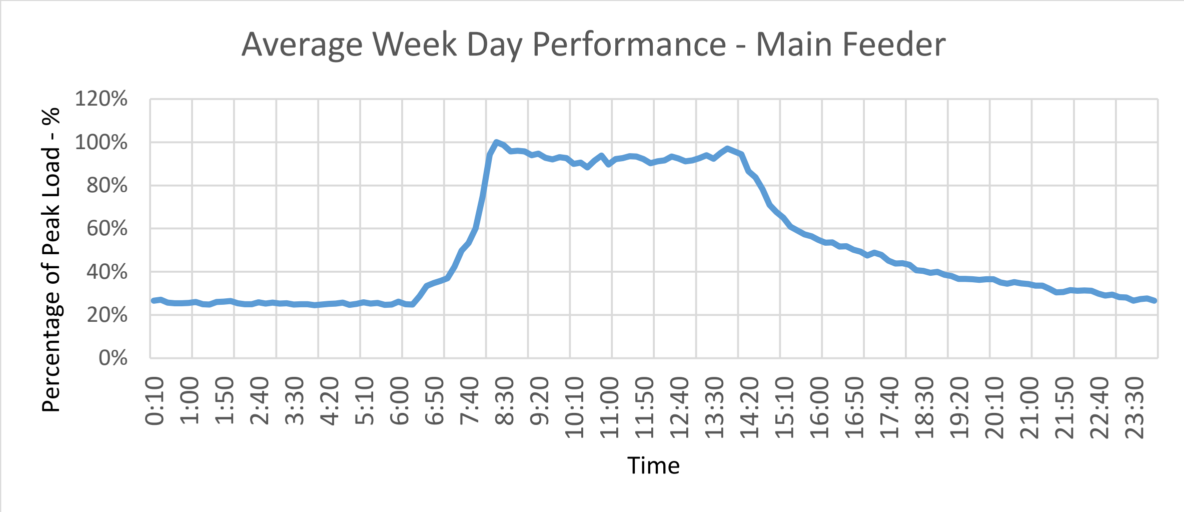

Figure 1-5: Average weekly power demand for the Velaanaage building

Feedback from building maintenance staff indicated building checks at ~8AM, 4PM and midnight on weekdays, which correspond to minor changes in building consumption. Based on the above, we would estimate average occupancy would be from ~7:30AM to ~4:00PM or 8.5 hours a day on weekdays, which is considerably longer than the occupancy surveys.

1.4.1 Data Logging – Individual Floors

In addition to the main site meter, power data logs were installed on six tenancy boards, on three levels, representing the highest power consuming floors in the building – levels 1, 4 and 6.

The table below summarises data taken for these floors from the surveys and site inspections.

Meter Reference	1A	1B	4A	4B	6A	6B
Tenant Name	Dept. Of Immigration	Dept. Of Immigration	DNR	MMPRX and SEZ	Attorney General	Attorney General
Approximate Area (m^2)	440 m^2	219 m^2	470 m^2	357 m^2	470 m^2	400 m^2
Survey Start Time	8:00 AM	8:00 AM	8:00 AM	8:00 AM	7:30 AM	8:00 AM
Survey End Time	6:00 PM	6:00 PM	2:30 PM	4:30 PM	6:00 PM	9:30 PM
Survey Occupant Numbers	40	28	52	30	33	33
Number of Computers	40	28	56	35	33	33
Calculated Lighting Density	13.6 W/m^2	15.4 W/m^2	3 W/m^2	22.2 W/m^2	13.3 W/m^2	13.3 W/m^2

Table 1-2: Summary of the data from individual floors with power data logging

Analysis was carried out over ~5 days for each tenancy, with average weekday performance shown below.

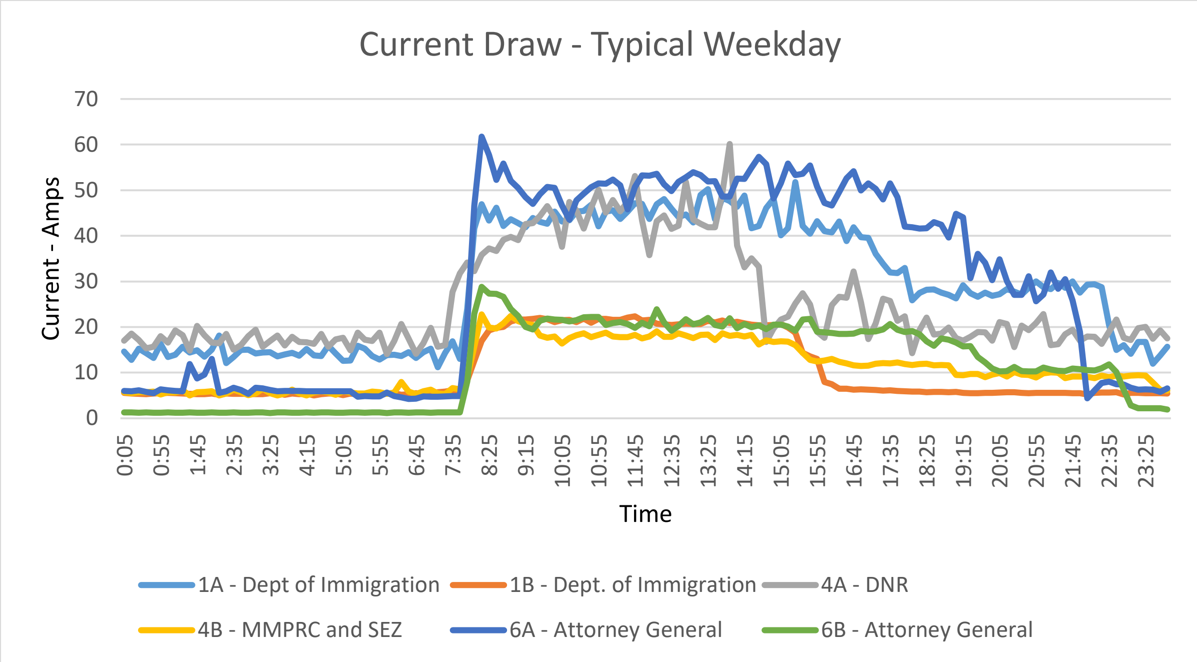

Figure 1-6: Weekday power demand for individual floors

The extended hours of operation for the Attorney General and the south half of the Department of Immigration is clearly observable, however, the northern half of the Department of Immigration seems to shut down at around 3:30/4:00 PM.

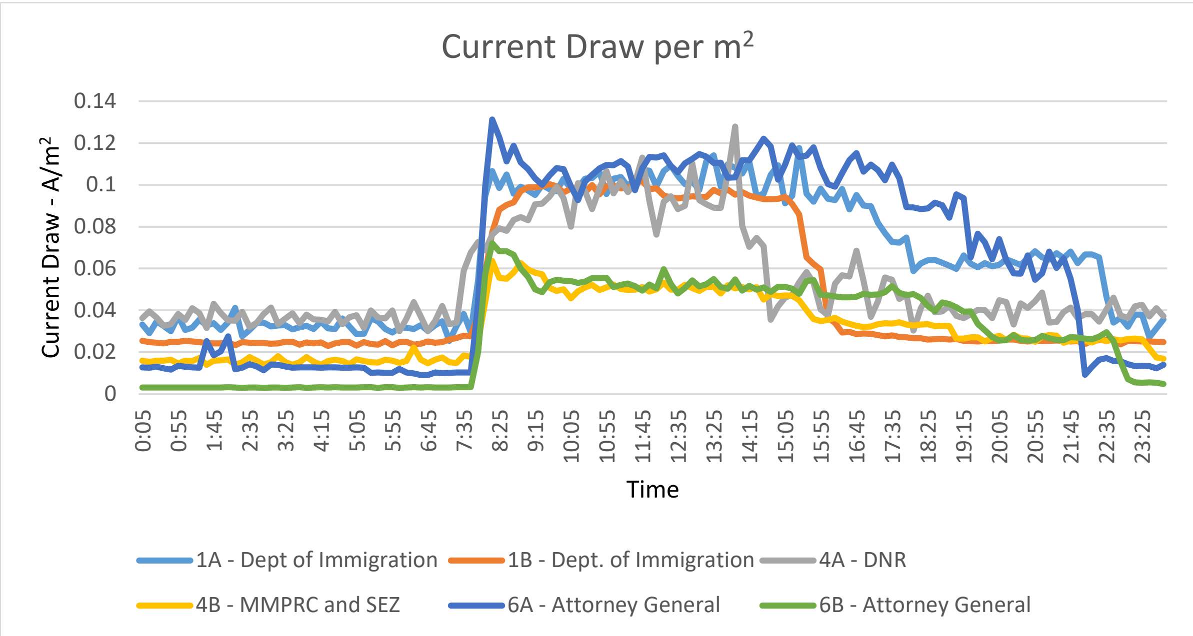

Figure 1-7: Weekday power demand per square meter for individual floors

When the data is normalised per m^2, the northern half of the Attorney General's Office (6B) and the Maldives Marketing and Public Relation Corporation (MMPRC) / Special Economic Zones Maldives (SEZ) (4B) are clear outliers at around half the energy density of the other levels. Based on observations on site this is due to lighting being upgraded for a significant portion of level 4, with LED downlights, estimated at $3W/m^2$, utilised. For level 6B, a significant portion of the floor was being refurbished at the time of logging, meaning reduced occupant density and usage.

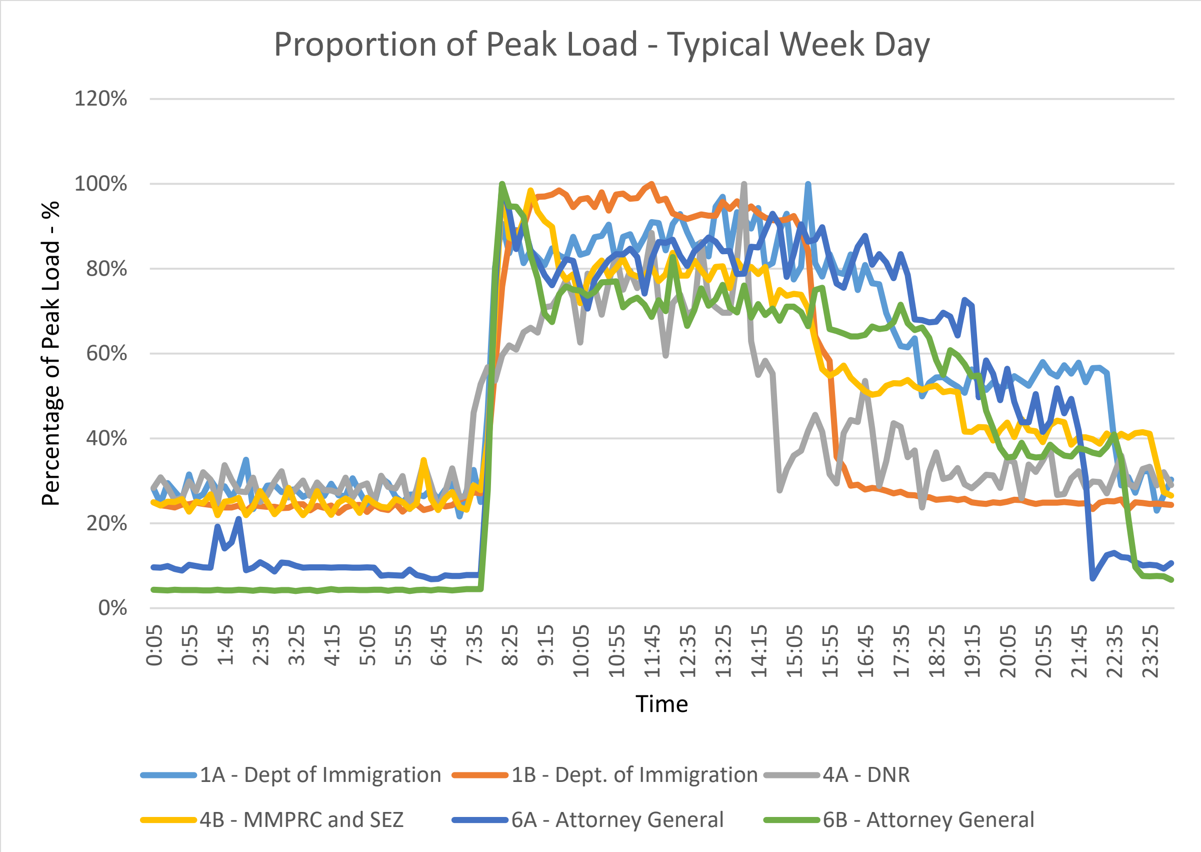

Figure 1-8: Proportion of weekday power demand for individual floors

Reviewing proportional consumption for typical weekdays indicates:

- All floors start at approximately the same time, between 7:30AM and 8:00AM.
- Department of National Registration (DNR) closes around 2:00PM
- Department of Immigration – North – shuts down around 4:00PM.
- Department of Immigration – South – shuts down in two stages, at around 4:30PM and 11:00PM
- The Attorney General's Office – South – shuts down in two stages, at around 4:30PM and 11:00PM
- The MMRC and SEZ has three main steps of shut down at 4:00PM, 6:30PM and 11:30PM
- The Attorney General's Office has the lowest overnight usage. Based on site observations, this is due to the tenancy only having one server room and this room not utilising independent air conditioning systems.
- Other floor base loads are expected to be due to the operation of server rooms and after-hours air conditioning systems.

Power logging indicated the power factor for the building averaged between 0.90 and 0.95, which is considered good practice over the logged week. Power factor correction is unlikely to provide significant benefit.

1.4.2 Individual Floors – Energy Use and Weather Patterns

The weather patterns over the logged time period were relatively hot and in a narrow band, meaning there is limited correlation between power consumption and weather patterns, as shown below:

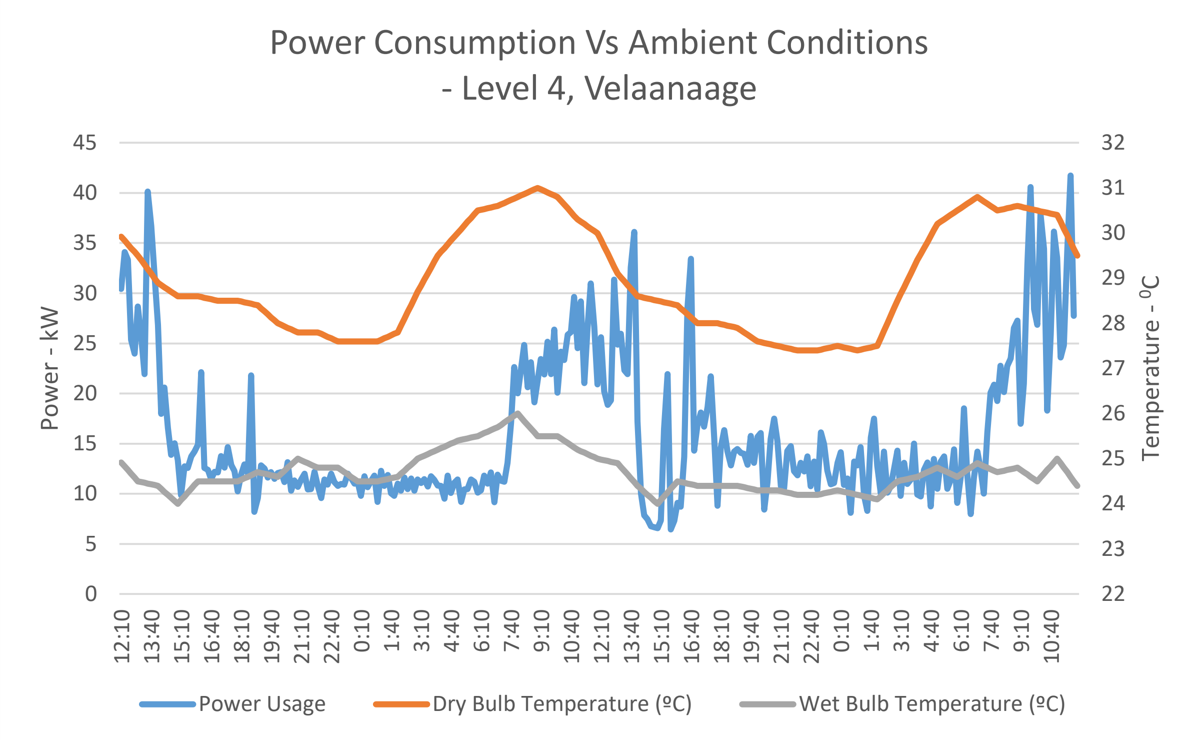

Figure 1-9: Power consumption verses ambient conditions for Velaanaage

There is similarly little correlation with average temperatures when viewed over a 12 month period and averaged across floors:

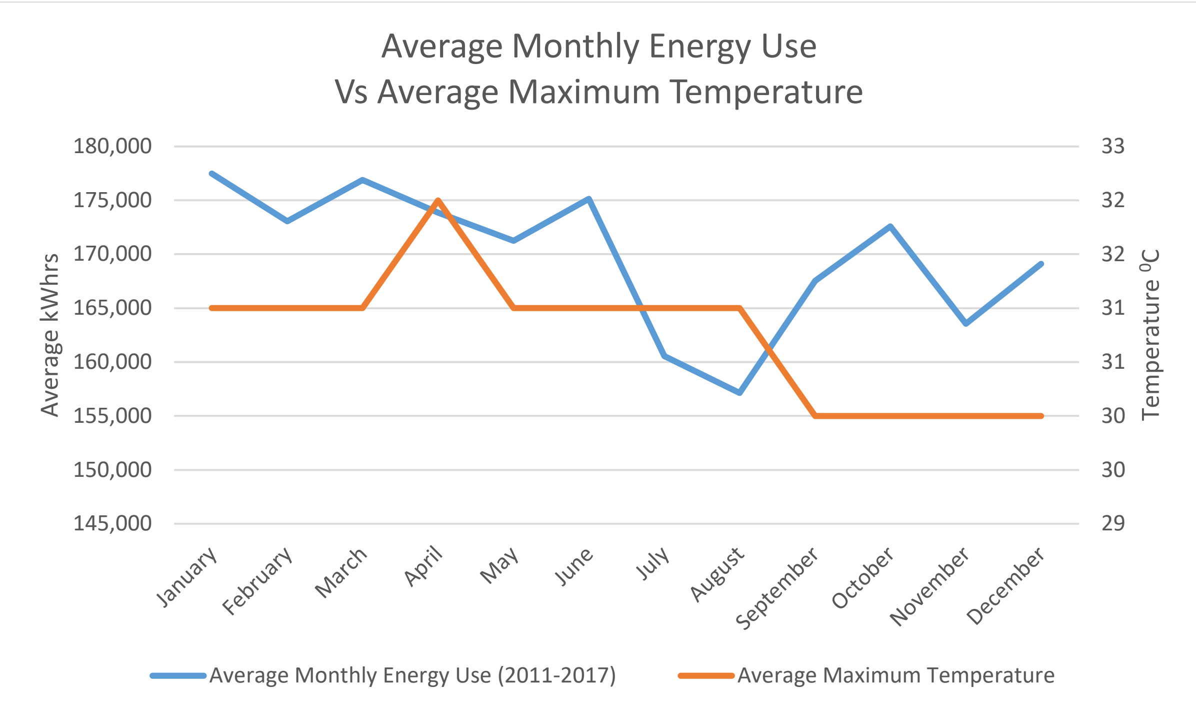

Figure 1-10: Energy use verses maximum temperature for Velaanaage

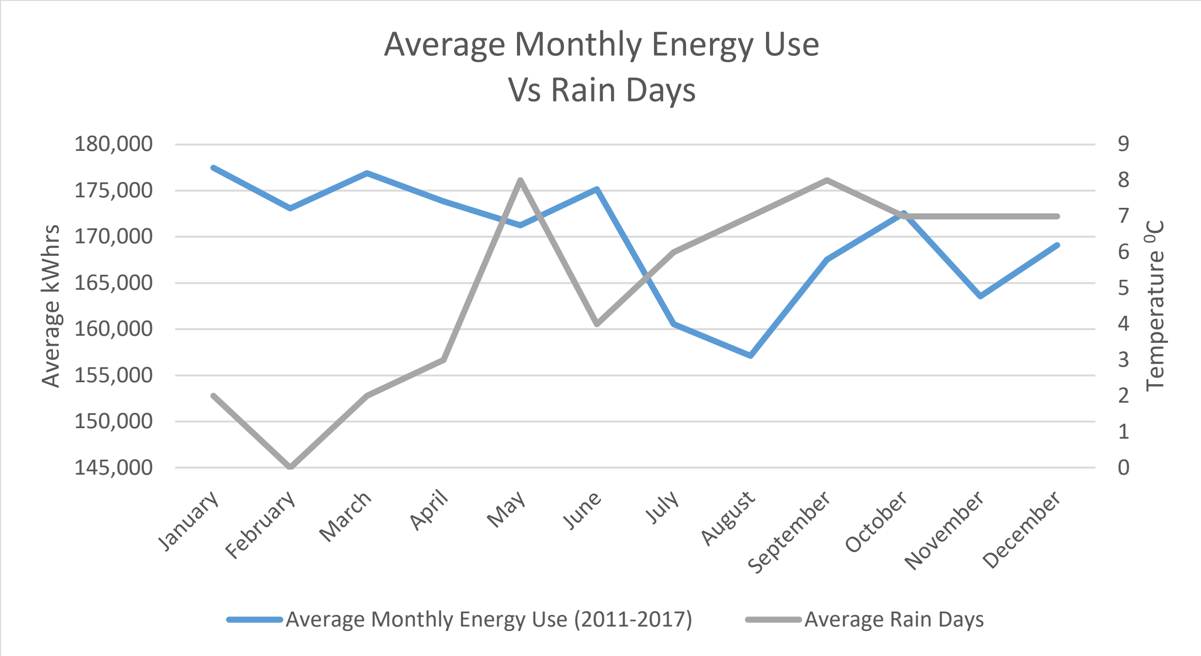

Figure 1-11: Energy use verses rainy days for Velaanaage

Note that energy variation is <15% between the highest and lowest months.

1.5 Site Visit Observations

Site visits were carried out over three days from the 26th of March to the 28th of March, including an early morning (4AM) audit of the building on the 27th of March. The following presents the key findings of the audit. Please also refer to the attached audit summary spreadsheet which details included equipment surveys and summary observations for internal conditions.

1.5.1 Early Morning Audit

The site was attended at 4:00AM on the 27th of March to determine the typical quanta of air conditioning, lighting and equipment that was left on overnight. Findings were as follows:

- Generally, computers were left on sleep rather than hibernated or turned off. This represents some energy wastage.
- Generally, air conditioning to open plan office areas was left off, air conditioning was left on regularly in meeting rooms, where there were no fixed occupants to control the systems.
- Lighting was generally switched off. Very few internal lights were left on.
- Security and facade lighting is considered reasonable, excess lighting for decoration was not observed. Fittings could be more energy efficient, however, are not considered a significant issue over the entirety of the building.
- Most floors have areas which require 24/7 air conditioning operation such as server rooms and printer rooms with sensitive plant (critical to daily operation).

1.5.2 Air Conditioning

The building includes air conditioning for all occupied areas. Air conditioning systems include VRV (Variable Refrigerant Volume) type systems with cassette unit fan coil units within the occupied spaces. All condensers are mounted at roof level.

The plant varies in age from the original installation, to recent replacements and spans VRV II, VRV III and VRV IV systems, as released by Daikin.

Figure 1-12: The image above shows a typical ceiling cassette fan coil unit which is used throughout the Velaanaage office building.

Based on the consistent nature of their use and the marine environment, the Team estimate VRV plant would have a useful economic life of between 7-10 years and, therefore, the VRV II plant is at or approaching the end of its economic life and should be replaced. It is also noted that the VRV II equipment utilises R22 refrigerant. R22 is no longer being produced because of its impacts on the ozone layer and thus represents a significant cost for replacement. This is further reason to replace units with R22 refrigerant (VRV II) rather than repair. New units (VRV III and VRV IV) utilise R410a refrigerant which has a lower Global Warming Potential than R22 and zero Ozone Depletion Potential.

Current allocation of plant types is shown below:

Figure 1-13: The image on the left shows a Daikin VRV IV HE condenser unit. This is similar to the existing units which have been installed recently on site.

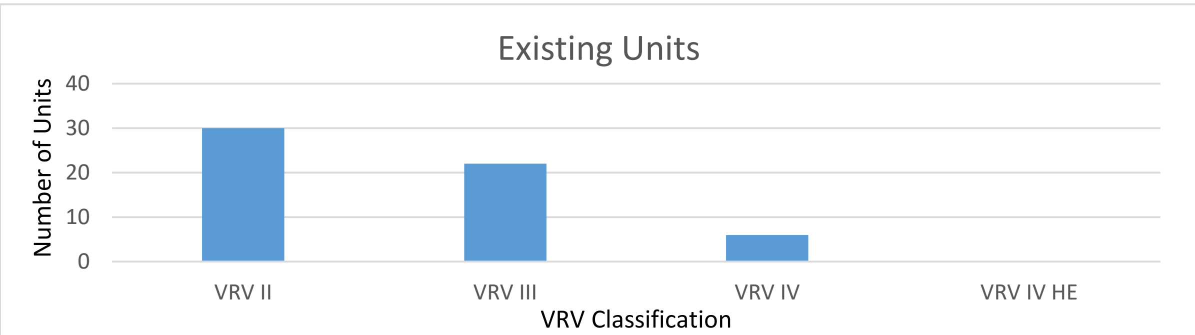

Figure 1-14: Number of air conditioning units by type

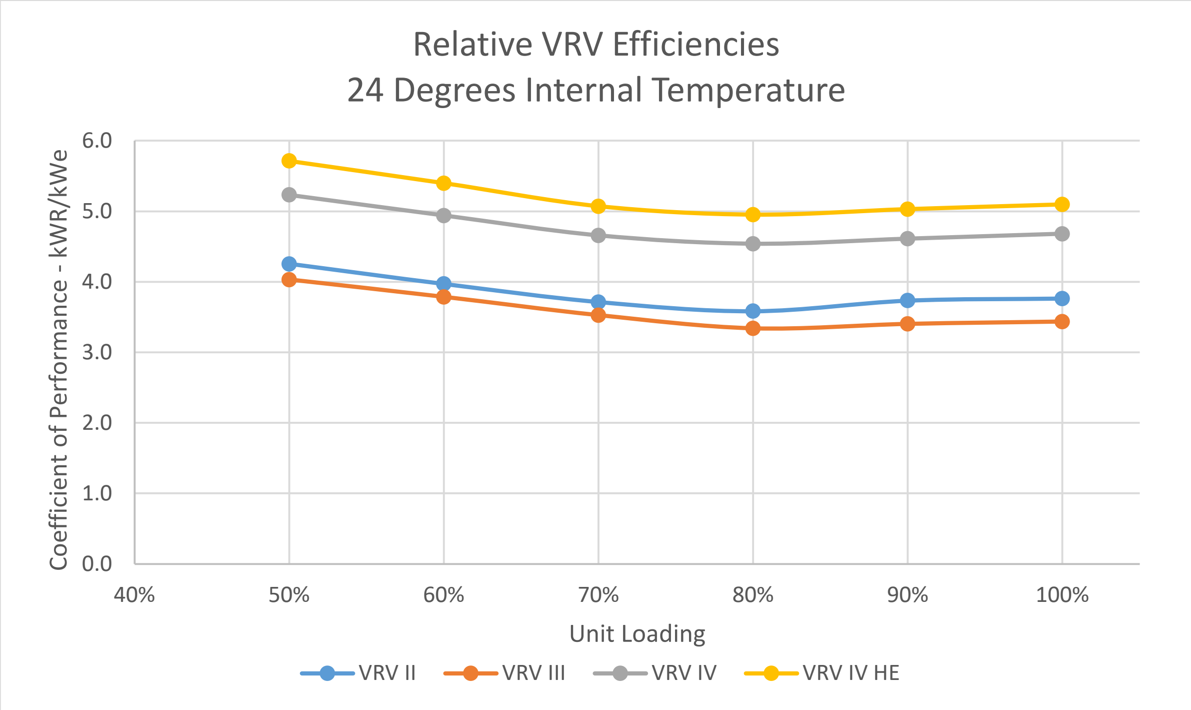

Figure 1-15: Air conditioning unit relative performance efficiency

The graph above shows the relative performance efficiency of the various types of VRV units available for the building. The higher the coefficient of performance the better. VRV II and VRV III have similar efficiency levels, however the VRV IV provides reduced energy consumption of around 20% and the VRV IV HE represents an improved efficiency of around 25%.

Performance curves are based on 24 degrees internal temperatures, 31 degrees external temperatures and published Daikin Data for a 50kW cooling only capacity condenser unit.

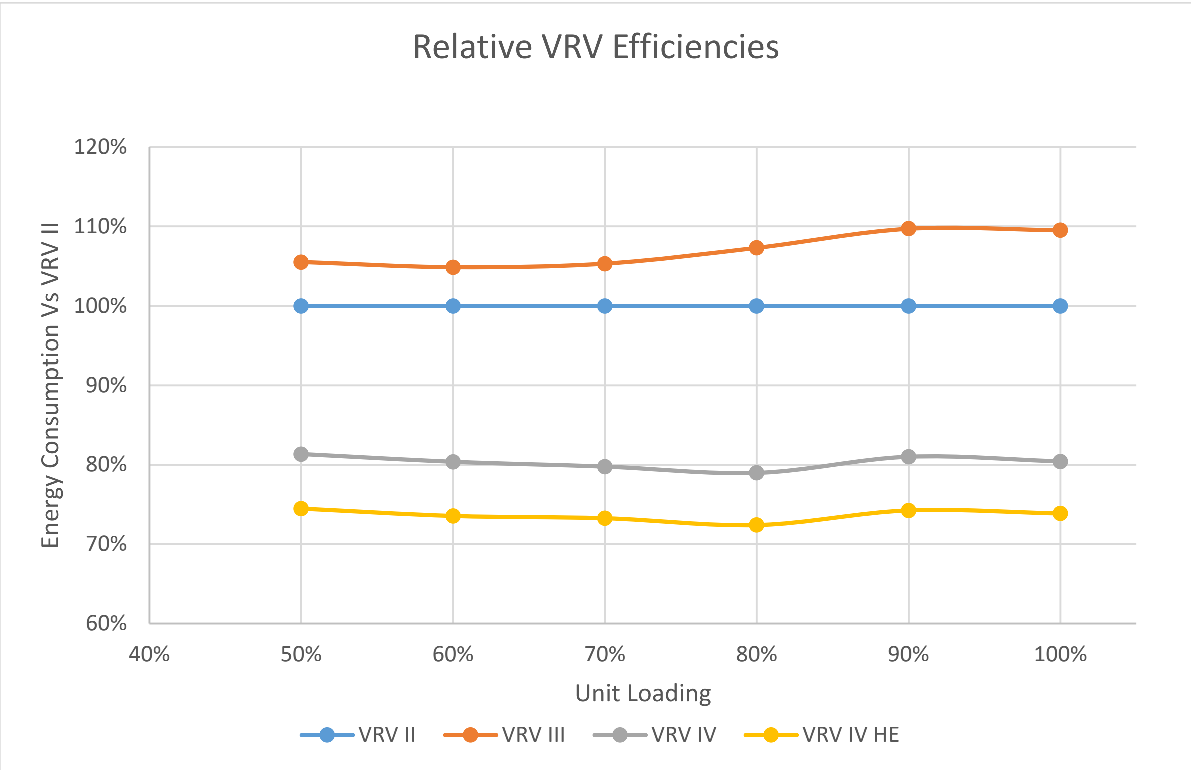

Figure 1-16: Comparative Efficiency VRV Version Vs Capacity

1.5.3 Outside Air Provision

Occupied spaces are to be provided with outside air through heat reclaim ventilation (HRV) units, also from Daikin. Site observations showed these units are rarely in operation, however, when operating, they provided ~30% efficiency in terms of sensible heat transfer and ~38% efficiency on enthalpy exchange. This compares poorly to the published performance of 55-60% efficiency for new units and indicates the systems are in need of maintenance or replacement. Based on observations, the Team expect unit coils are most likely dirty due to lack of filtration and regular cleaning.

The systems are not provided with purge cycles or economy cycles. These would not be expected to provide any significant advantage given the consistent hot and humid climatic conditions.

Air conditioning systems are powered from the electrical distribution board for each tenancy.

Lobby spaces are provided with dedicated air conditioning systems, powered from a common area mechanical board.

1.5.4 Controls

All air conditioning systems are manually controlled, either by wall mounted wired controllers or hand held remote controllers. All units have capacity to be individually controlled with temperature and operational mode – including fan speed – controllable by occupants. Whilst temperatures within and between floors vary considerably, occupants do not generally adjust temperature settings themselves.

Temperature ranges within floors between perimeter and internal zones were not significant.

Controls for the outside air heat recovery systems are independent of the air conditioning systems and are mounted on walls within the tenancy. The controllers generally are not labelled and are rarely used. In many instances, controllers have been built in by cabinets or other joinery and are not accessible.

Temperatures are generally considered 'warm and dry' with comparatively high internal temperatures (albeit 3-5 degrees below ambient) and low internal relative humidity levels.

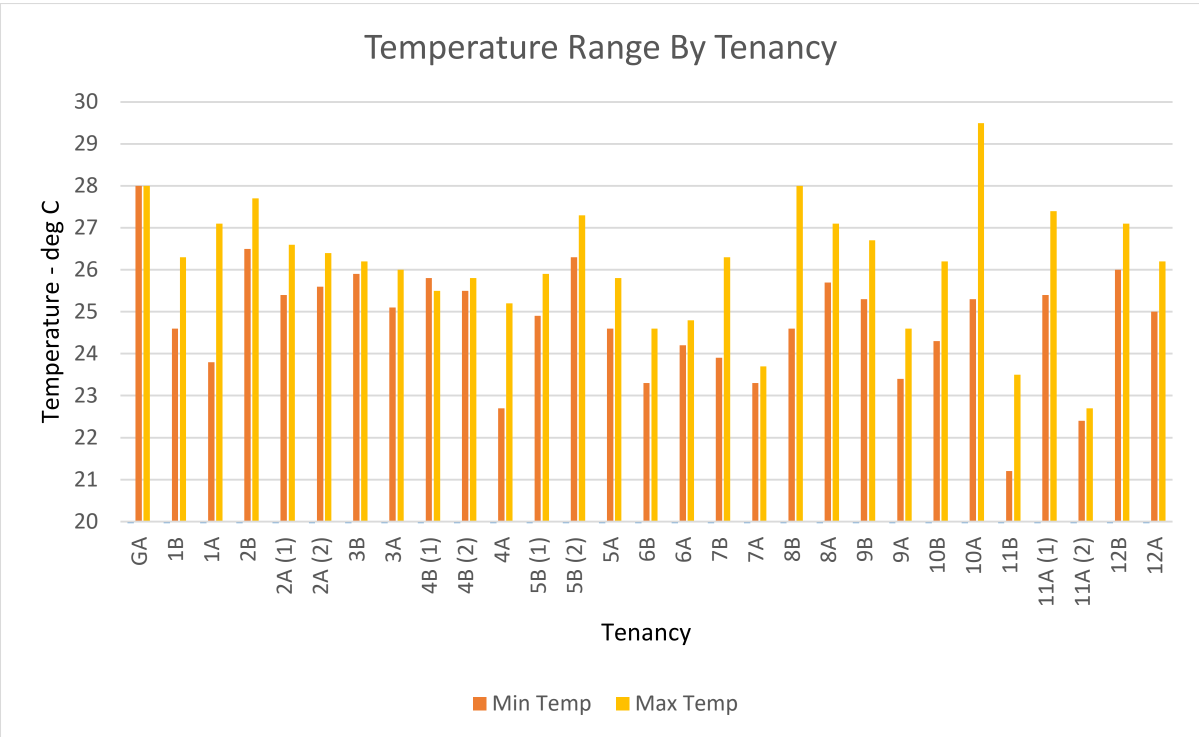

Figure 1-17: Internal temperature range by tenancy

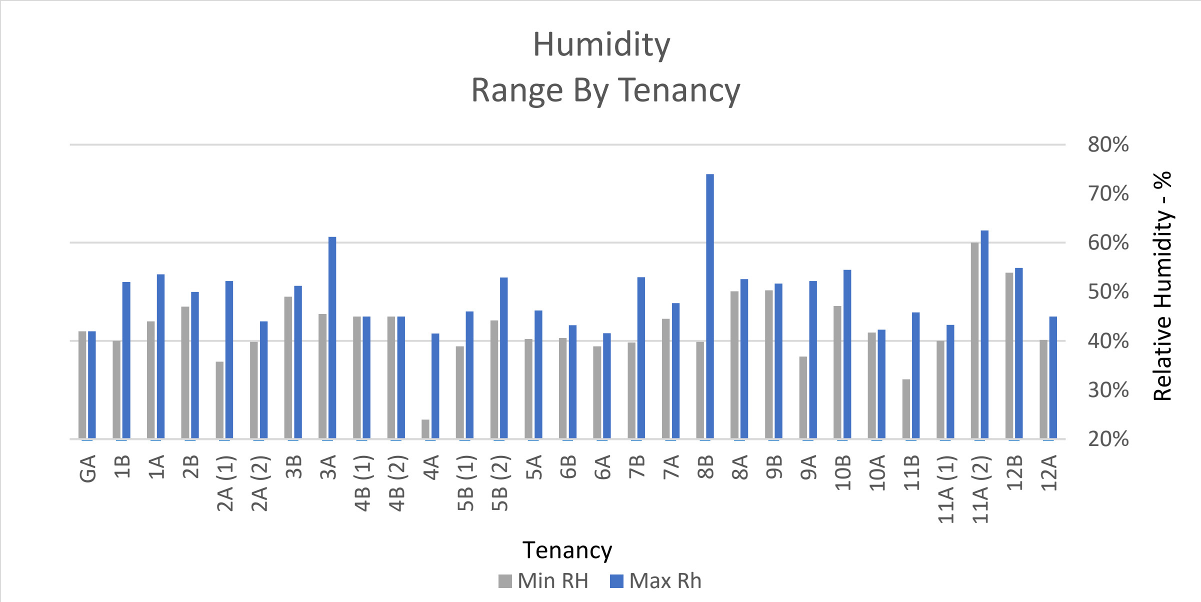

Figure 1-18: Internal humidity range by tenancy

The use of low humidity and high temperatures is considered a good design outcome, as it reduces energy transfer across the building façade, provides good occupant comfort and reduces the risk of condensation and mould growth.

The image below – sourced from ScienceDirect.com [https://www.sciencedirect.com/science/article/pii/S0360132317302032] illustrates occupants experiences of comfort based on humidity and air movement. The pink star represents the average internal conditions experienced during the site visits.

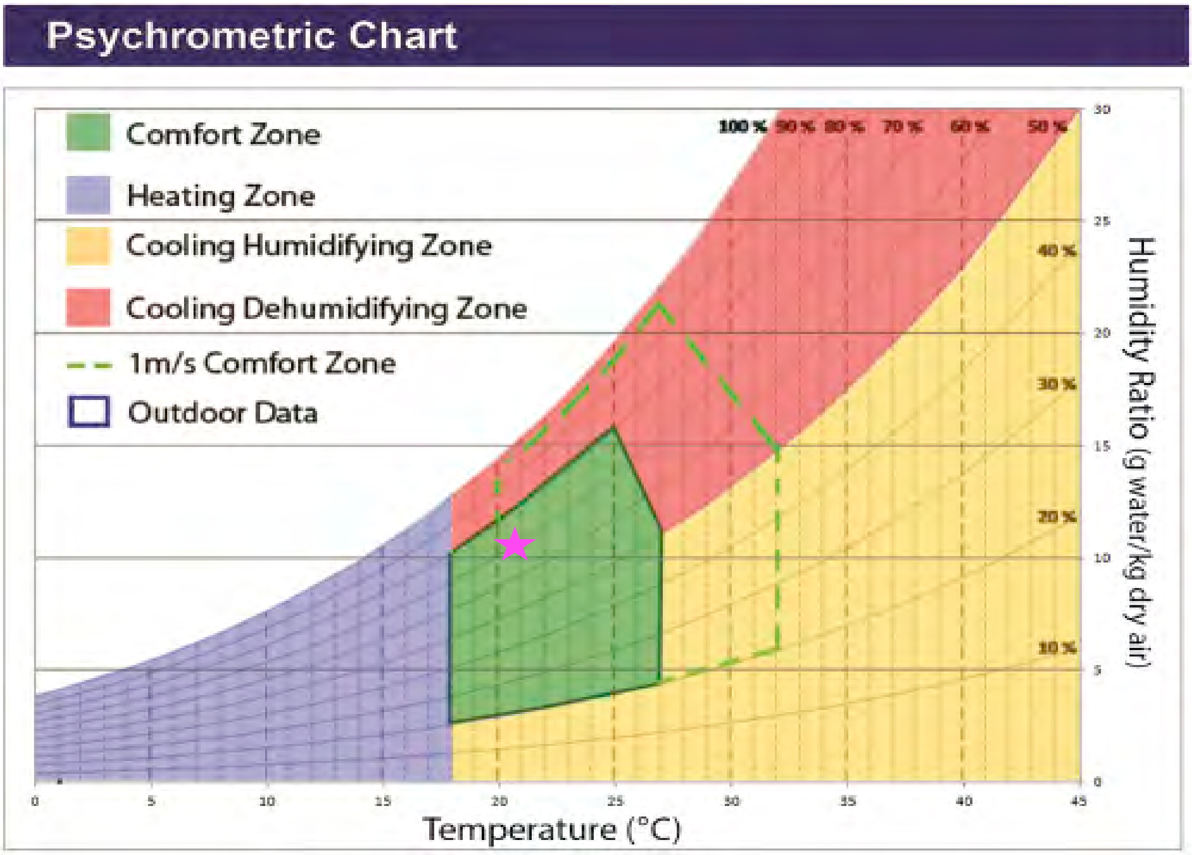

Figure 1-19: Occupants comfort based on humidity and air movement (sourced from ScienceDirect.com)

Review of the energy consumption data for individual tenancies, plotted against internal conditions (normalised for number of computers, area of tenancy and work hours per day) showed very limited correlation between internal conditions and energy consumption.

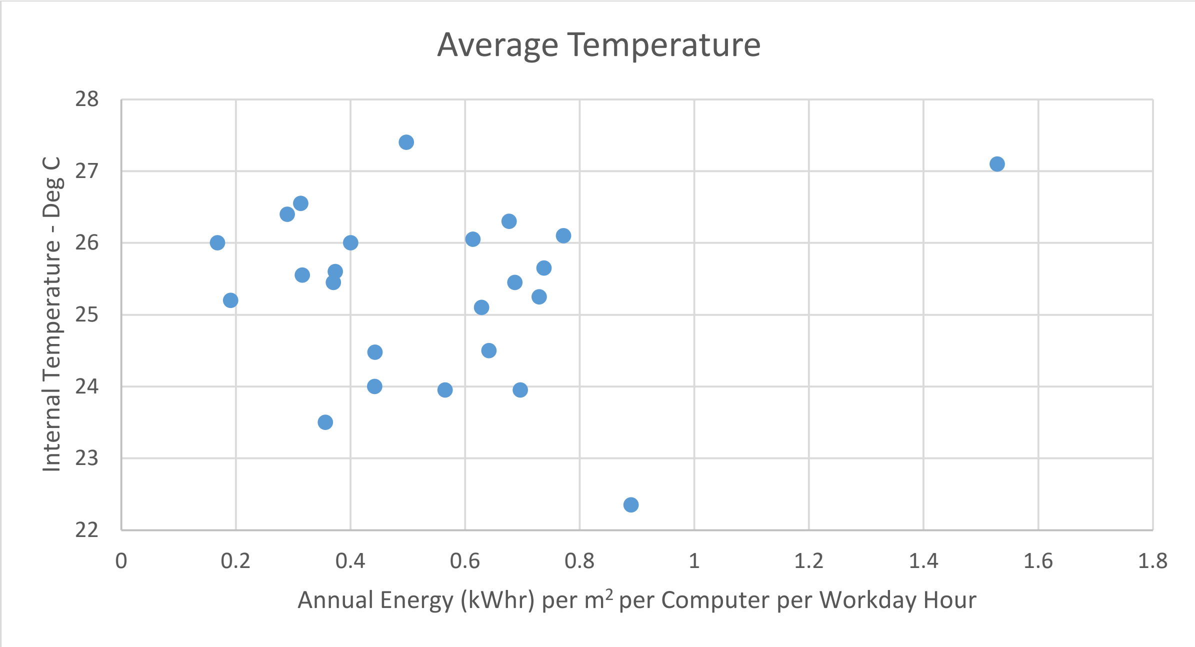

Figure 1-20: Internal temperature per m² per computer per workday hour

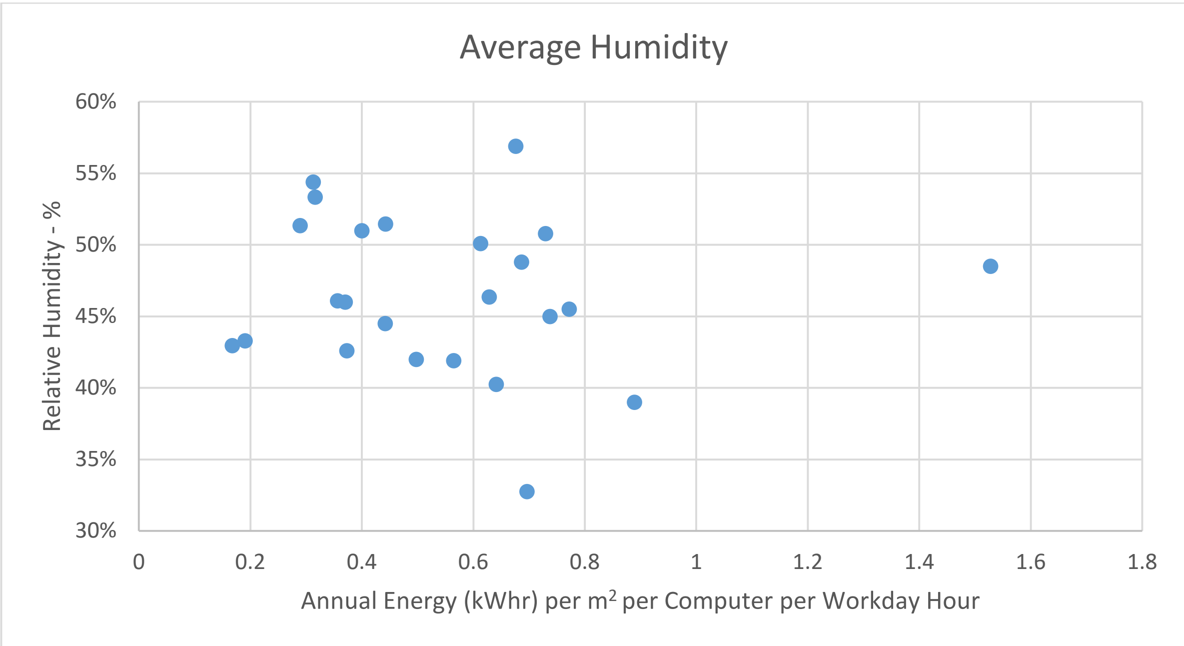

Figure 1-21: Internal relative humidity per m² per computer per workday hour

Based on the above, the conclusion is that the internal temperatures have an inverse relation to energy consumption, i.e., the higher the temperature the lower the energy consumption, (excluding MQA Tenancy, which is an obvious outlier).

The Team note that, based on an ambient temperature of 30 degrees, 80% relative humidity, any internal temperature below 26 degrees is considered a condensation risk.

1.5.5 Building Fabric and Glazing

The building is constructed with a standard curtain wall façade, with glazing comprising between 75% – corner offices – and 47% - open plan office space north and south – of the façade.

Walls appear to be insulated and thermally broken from outside, however, the relatively small temperature differential between inside and outside limits the ability of thermal imaging to confirm the effectiveness of the insulation.

Windows are generally operable, but are kept closed and, in most cases, screened by light weight, low reflectivity internal blinds, which are kept closed for most of the year.

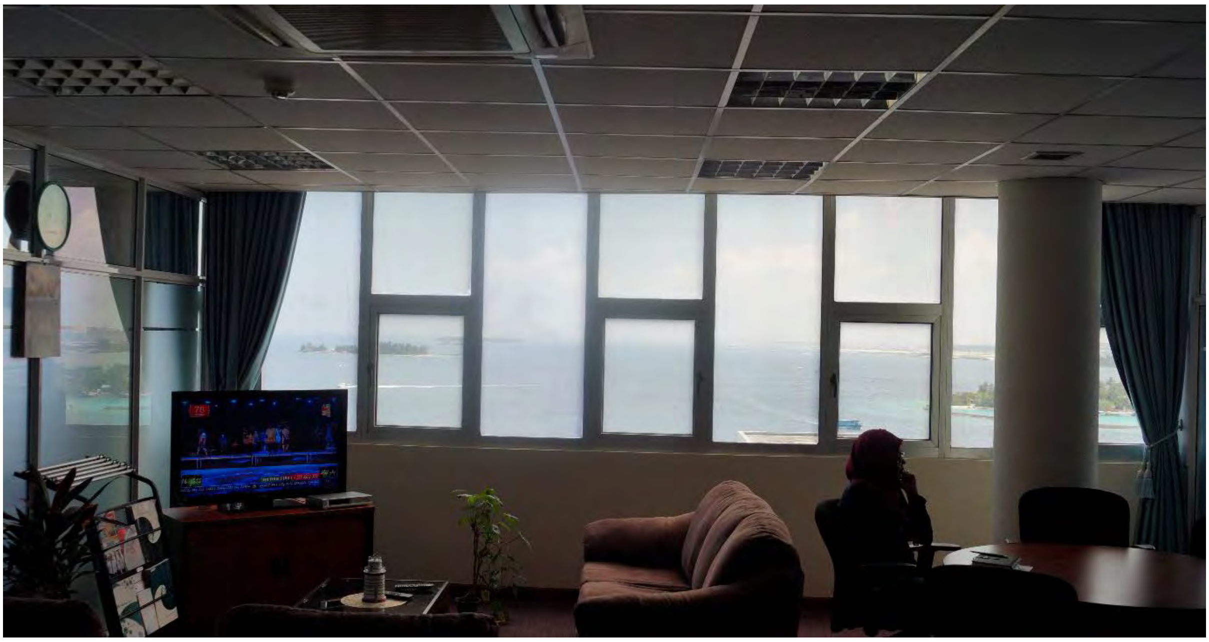

Figure 1-22: Image above shows proportion of glazing typical to northern and southern elevations

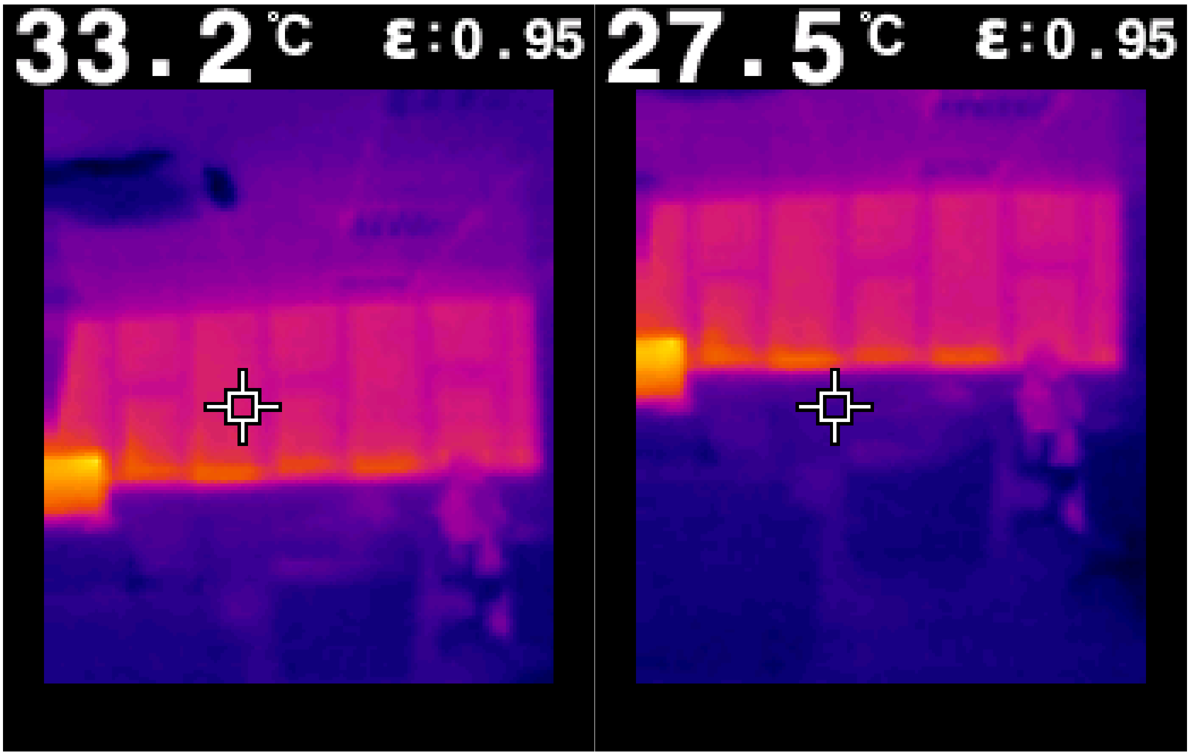

Figure 1-23: Image above is thermographic analysis of the same space shown in Figure 1-22

The thermographic images above show glazing internal temperatures are around 6 degrees warmer than the internal walls and are a significant source of heat gain and glare. The occupant use of blinds to provide some shading and protection is expected – particularly during December and June, when the sun is at low angles to the south and north respectively.

Glazing appears to be clear, or very light tinted, single glazing. Window frames have similar heat transmission properties to the glass.

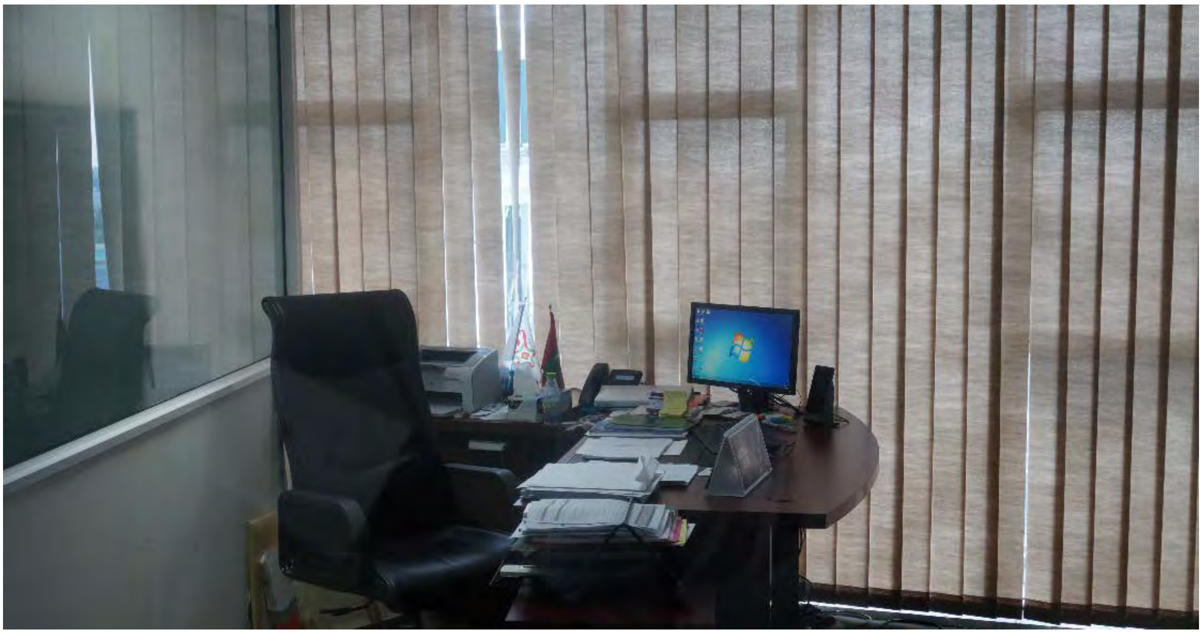

Figure 1-24: Image above shows typical blinds to windows

1.5.6 Building Orientation

The building is well oriented for solar passive design, with the long axis oriented slightly off east / west. This allows the majority of the façade to face north/south, either directly or to the central light well.

As shown on the image right, glazing is provided with some shading at window head height around the north west corner of the facade, however, this only provides protection for high angle overhead sun and is of negligible benefit to the western facade.

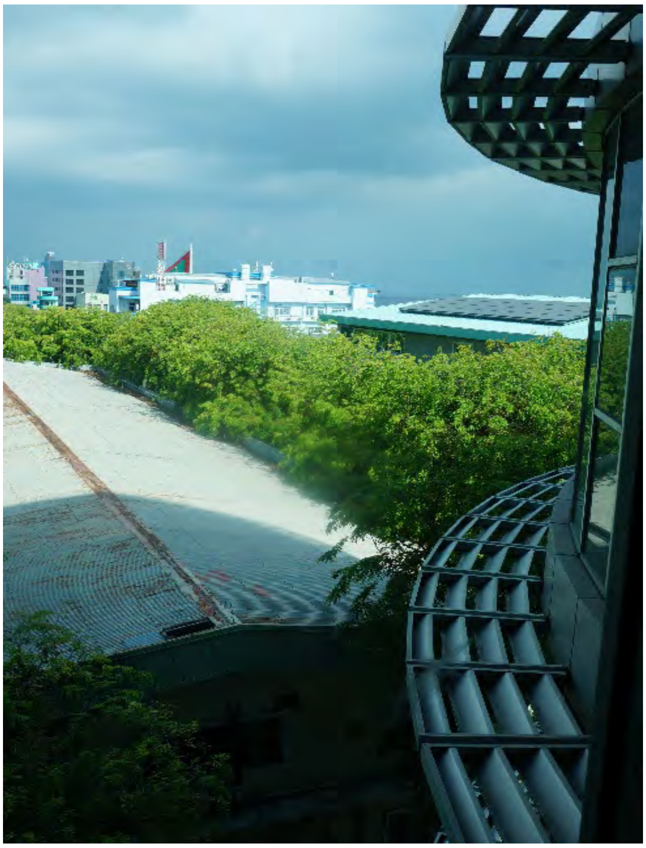

Figure 1-25: Image showing north west façade of the Velaanaage Building

The mark up below shows the general floor layout, including the extent of shading and relative proportion of north and south facades.

Figure 1-26: General building layout showing Image showing shading and relative proportion of north and south facades

1.5.7 Building Sealing

The building is not well sealed. Windows are operable and expected to experience significant leakage under wind loads. In addition, tea preparation areas are generally left open to outside and doors to these spaces are not provided with any form of seal.

Building air leakage could be reduced if the HRV units were operational to provide some small positive pressure internally.

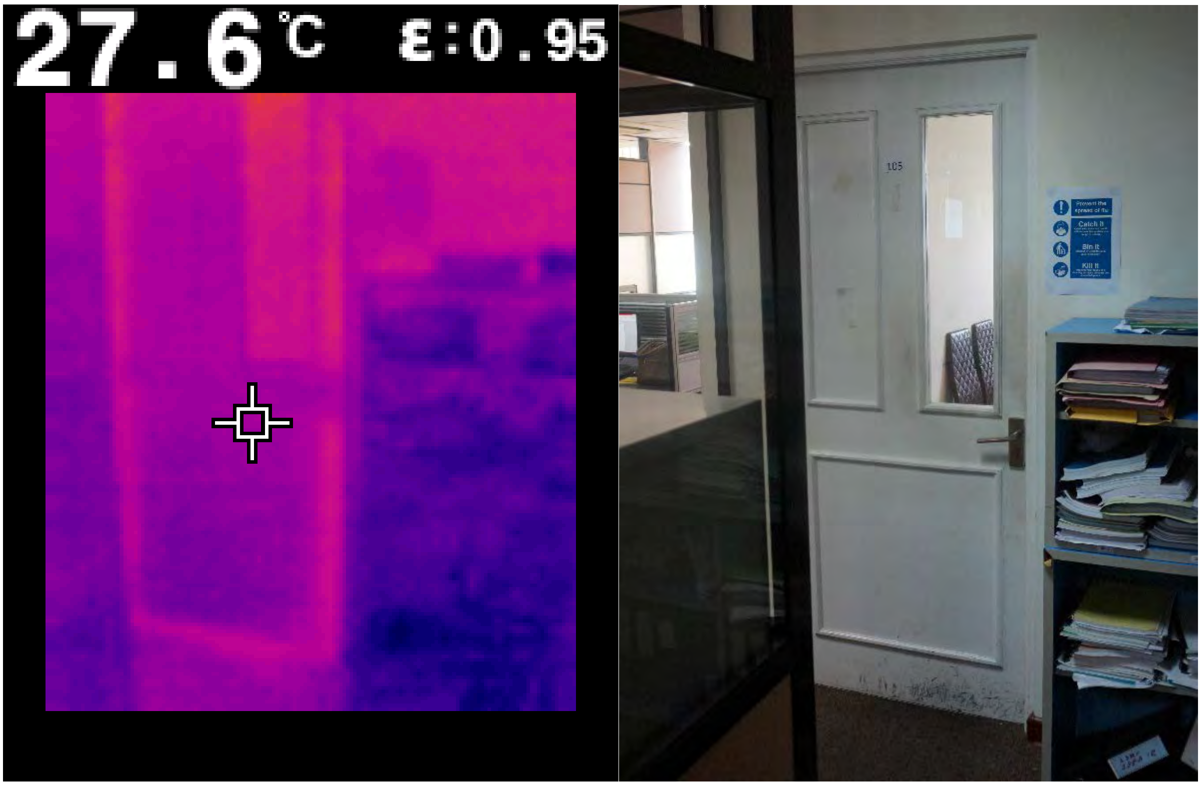

Figure 1-27: Typical team preparation room with thermal image for the same room

The images above show a typical tea preparation room door, with air leakage on all sides and the heat transmission through the glazed element obvious.

1.5.8 Tenancy Interaction

As noted above, tenants play a key role in energy consumption, particularly within the mechanical services. Tenants main area of influence are summarised below:

- Hours of air conditioning system run
- Internal temperature set points
- Building sealing
- Use of blinds
- Design of tenancy services

The final dot point above has not been addressed in any detail above and is hard to quantify, other than in specific instances where services design and installation/operation has compromised the ability of the air conditioning systems to operate effectively, efficiently or at all. General observations from site visits are presented in the following sub-sections:

1.5.8.1 Condenser locations on balconies / obstructed air flow:

Condensers require air movement to reject heat. When they have air movement obstructed, air recirculates and increases the energy required to reject heat. In the area below, air temperature between the condensers was ~4 degrees higher than ambient.

Figure 1-28: Outdoor air conditioning units at Velaanaage building

1.5.8.2 Lack of Insulation to Computer Rooms

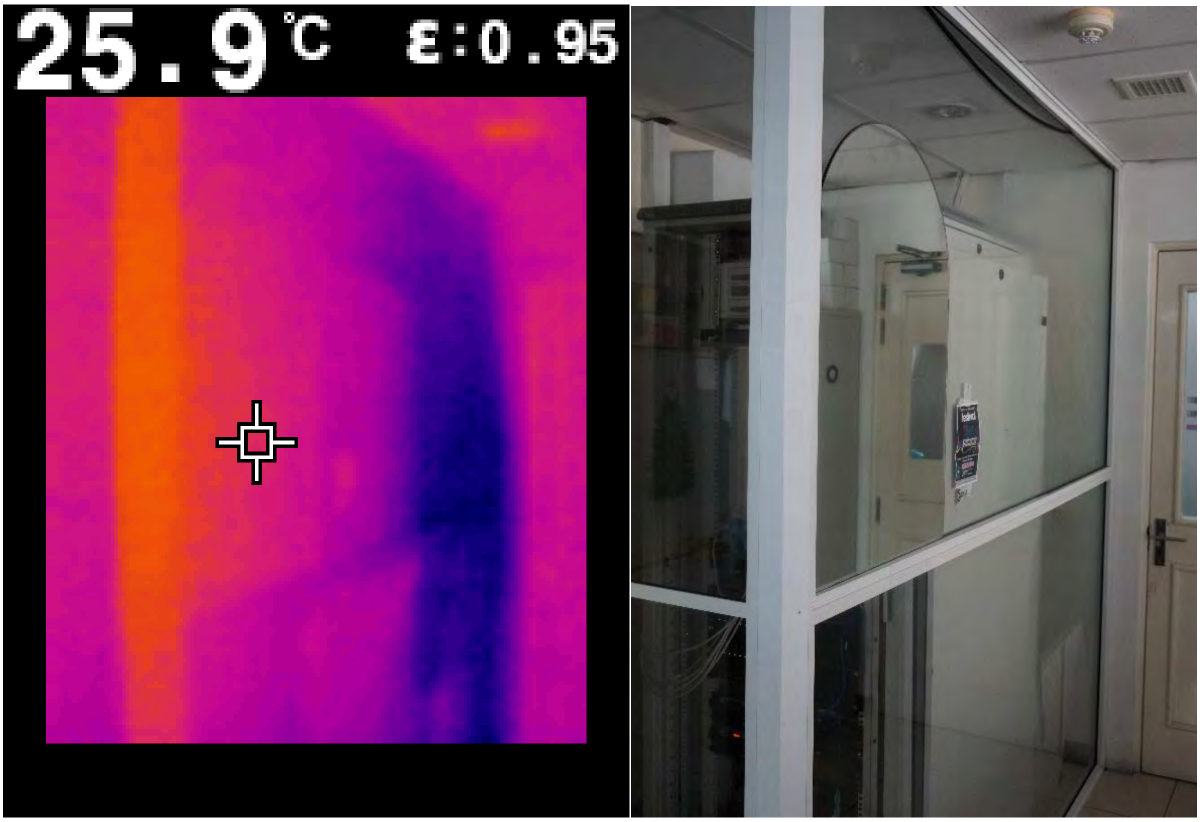

Figure 1-29: Communications room in level 4 of the Velaanaage building and thermal image for the same room

The images in **Figure 1-29** show the installation of a communications room on level 4, within a non-conditioned tea preparation area. The air distribution within the room was poor, with most of the supply air hitting the wall closest to the door (dark patch in the thermal image) and reducing the surface temperature of the glass to below 20 degrees. This resulted in very high quantities of condensation being formed on the outside of the glass.

Whilst condensation on the outside of the glass is not a major issue in this instance, it does highlight the risks of constructing communications rooms from porous, uninsulated material. It also identified the impacts of poor air distribution design and shows a significant energy wastage in condensing water. Indicatively, to condense one litre of water from water vapour requires approximately 0.6kWhrs of energy.

1.5.8.3 Contamination of Air Streams

One tenant noted that the outside air supply system had been deactivated due to a smell of smoke. This is most likely due to the fact that one of the air intakes for the building is located above the eastern balcony area. Occupants smoking, or installing condensers on this balcony will contaminate the incoming air and reduce internal amenity for occupants, as well as increasing energy consumption.

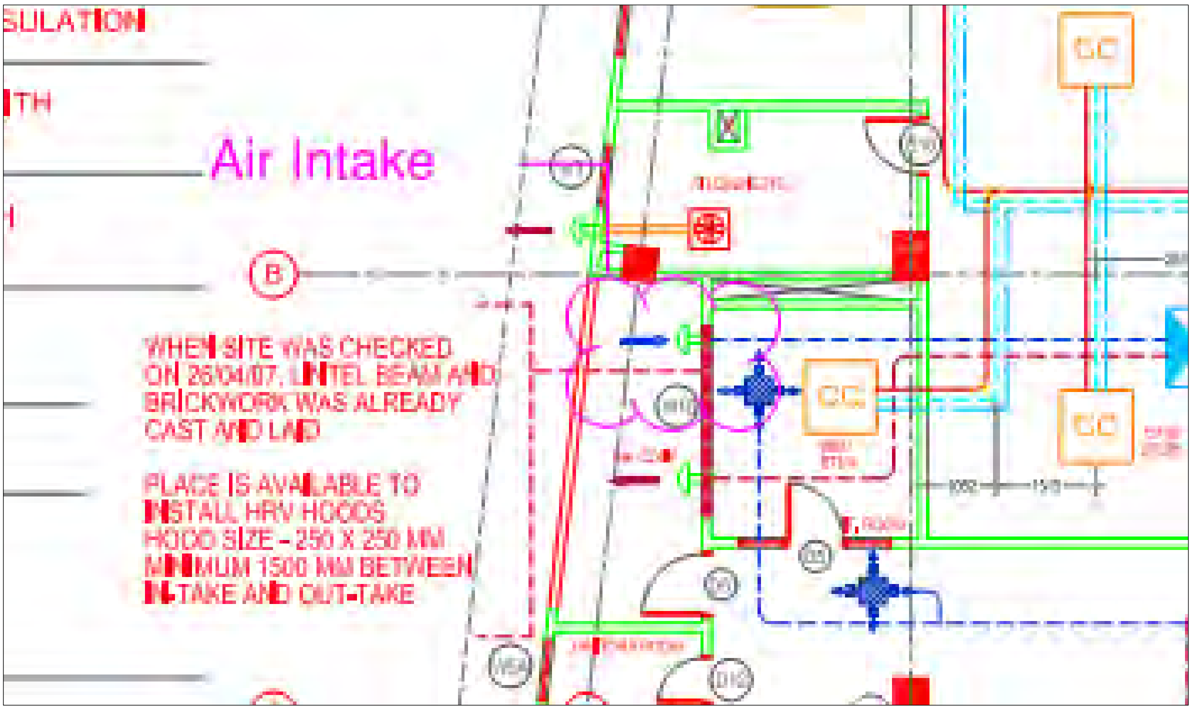

Figure 1-30: Building plan showing one of the air intakes at the Velaanaage building

1.5.8.4 Building Sealing

Leaving windows open can provide increased outside air, however, also results in significant energy wastage. Where tenants have high occupancy densities, additional air conditioning, with controlled air intakes should be provided.

Figure 1-31: Image above internal air conditioning units in a duplicate arrangement

Figure 1-32: Image above showing windows open during office hours at Velaanaage Building

1.5.8.5 Duplicate Air Conditioning Systems

This only occurred on one level, however, the tenant had installed an additional air conditioning system to supplement the base building air conditioning. This can lead to control system conflicts and energy wastage, as well as creating air distribution issues within the space.

1.5.8.6 Internal Partitions Obstructing Air Flow

This is fairly obvious, however, installations such as the below; prevent return air from reaching the fan coil unit, reduces air distribution effectiveness and present a condensation risk.

Figure 1-33: Images showing internal air conditioning units

1.5.8.7 Lack of maintenance

This issue is evident in the number of units dripping water and/or ceiling damage around units. Generally, cassette units, such as those installed in Velaanaage have condensation pumps to remove water from the coil. However, these pumps generally fail in 4-5 years, particularly with the heavy condensation load they are required to manage in an environment like the Maldives. Regular failing and / or water damage indicates pumps are not being replaced. It also indicates that coil air flow is likely obstructed, causing lower air volumes and increased condensation. Both of these issues can and should be addressed by regular maintenance.


Figure 1-34: Image above shows damaged ceiling from air conditioning system water leakage

The above issues all cause considerable reduction in performance for the installed systems and can have significant implications on unit life time. Ideally, all installations should be reviewed by competent mechanical engineers, or at least warranted by the suppliers for suitability.

1.5.9 Vertical Transport

There are four passenger lifts and one goods lift within the building. Lifts consume around 2.7kWhrs per m^2 per annum of NLA (Net Lettable Area), which is considered good practice. There is considered limited opportunity to improve this figure whilst maintaining current levels of service.

Performance could be improved slightly by shutting down lifts during periods of low usage and encouraging stair use.

Some of the lifts provide services to specific levels. There were no labels showing this information. Users can only know servicing levels once they get into the lift. This enables users from requesting for lifts which may not provide service to the floor they need to go.

1.5.10 External Lighting

Building external lighting is considered reasonably low kW, considering the size of the building.

Decorative lighting runs until midnight, with the building manager actively reducing external lighting levels at this time.

The car park level is lit to some level 24 hours a day. This is recommended for security and visibility purposes.

Light fittings could be upgraded to more energy efficient fittings, however, this is not considered likely to pay back within 8 years and, instead, the Team recommend upgrading light fittings when the current bulbs start to fail.

Carpark lighting is expected to have the shortest payback period. The current fittings use 18W T8 lamps. Power use per lux would be expected to reduce by >60% if changed to LED's.

1.5.11 Internal Lighting

Internal lighting design generally falls into two main types within the Velaanaage building. Tenancies which have recently had design changes have tended to install LED type fittings and perform at a high level in terms of both lux provided and power consumed. The majority of the building however uses the original lighting design, with 4 tube T8, reflective luminaires – at a total power draw of 144W when fully lamped.

Figure 1-35: LED light panel– estimated 33W

Figure 1-36: T8 Tube Diffuser in Velaanaage – 144W LED

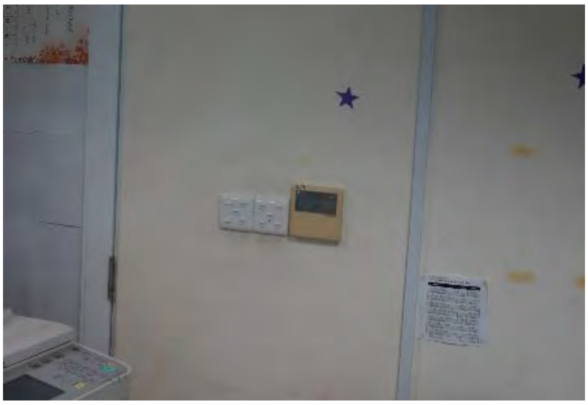

Figure 1-37: Equipment control arrangement

Figure 1-38: Typical tube details in Velaanaage

Lighting controls are simple, manual switches located in the general area of the fittings. Generally, switches control between 2 and 4 fittings, which is considered very fine levels of control. However, switching groups are not arranged to provide high levels of performance. Generally, lighting control groups do not consider internal partitions, meaning switches for meeting rooms often control lights in corridors or office adjacent.

In addition, groups of lights generally run internally from the façade, rather than separately switching the façade lights from the internal area. This means that occupants near windows who could turn off lights and utilise natural daylighting cannot do so, without depriving their colleagues further from the façade from sufficient light to complete their tasks. The sketch below shows current lighting control groups (red) and a more efficient grouping scheme (green).

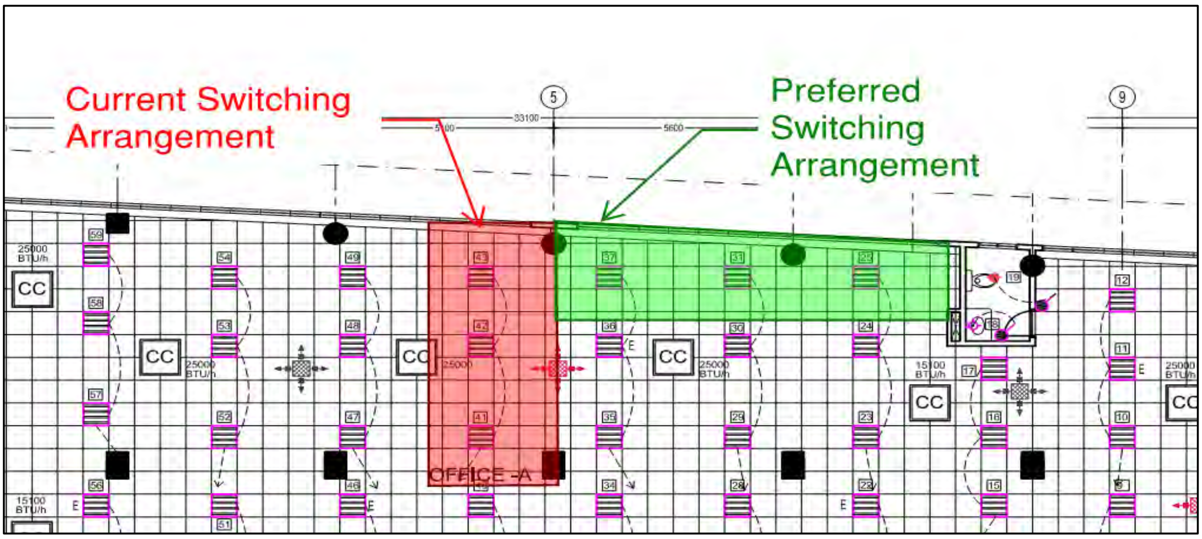

Figure 1-39: Figure above shows current and preferred lighting switching arrangement in Velaanaage

The plot in **Figure 1-40** shows the key lighting efficiency indicators for the Velaanaage office building. Tenant lighting performance is generally in two main groups, reflecting the original lighting design (lighting density around 13.5 W/m^2 and effectiveness around 5 W/m^2 per 100 lux) and LED lighting (lighting density around 4.5 W/m^2 and effectiveness around 1.5 W/m^2 per 100 lux.

The LED lighting is considered best practice for modern lighting design, however, the original T8 lighting design is considered very poor.

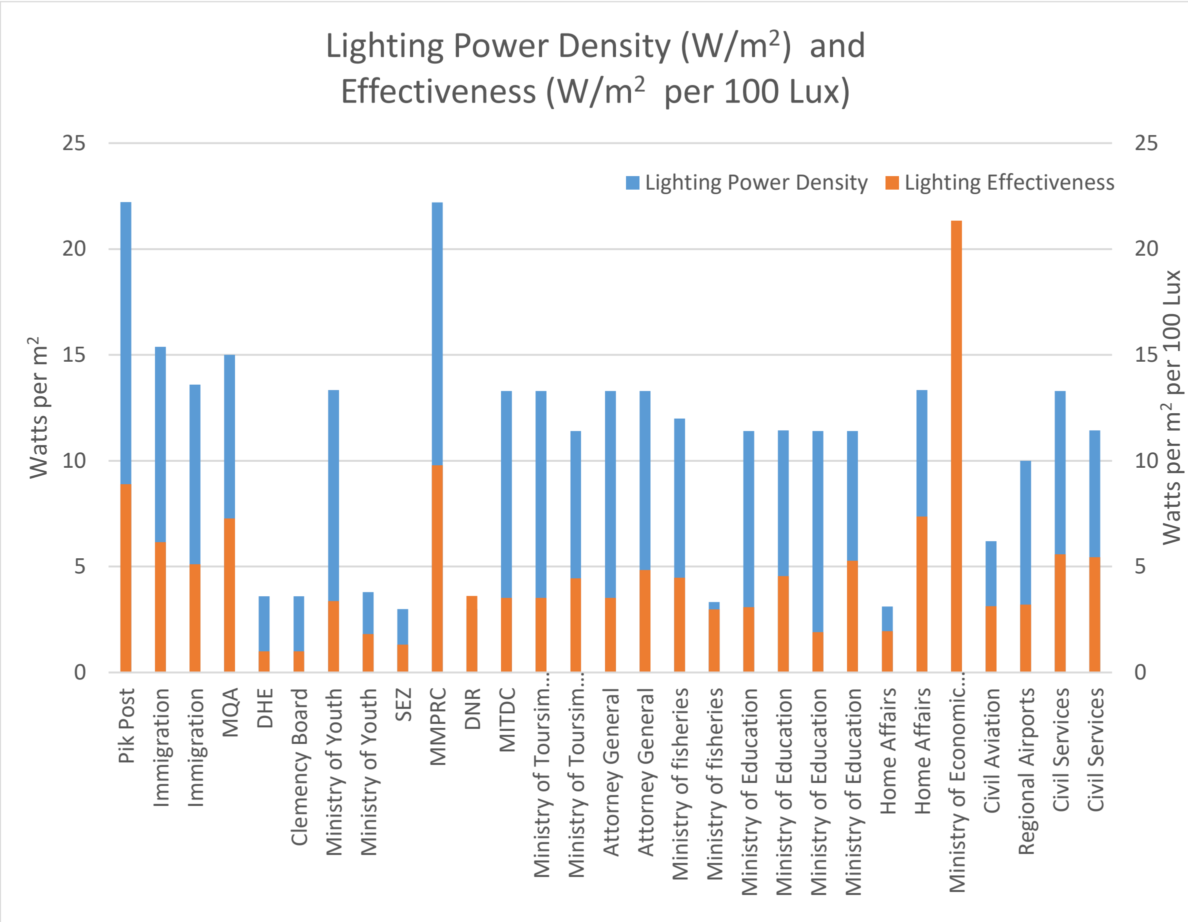

Figure 1-40: Key lighting efficiency indicators for the Velaanaage office building

The original base building light fitting provides a fairly concentrated pool of light directly under the fitting, however, lux levels drop off significantly as you move away from the direct line below the fitting. This means that occupants have both poor light levels and uniformity in zones with the original lighting design.

In terms of energy savings, it is hard to determine expected energy savings due to occupants often leaving lights off and, due to poor maintenance, delamping fittings. However, based on the average usage of 36.3 hours per week, the LED lighting is expected to save around 17.5 kWhrs per m^2 per annum. If all of the tenancies with the original lighting design were upgrade to LEDs, the overall saving would be expected to be around 127 MWHrs per annum – or 7% of the total building energy consumption.

1.5.12 Equipment

The various tenancies contained a wide variety of equipment, summarised in the attached inventory document. The expected total consumption figures correlate well with the 2017 energy consumption, as shown below.

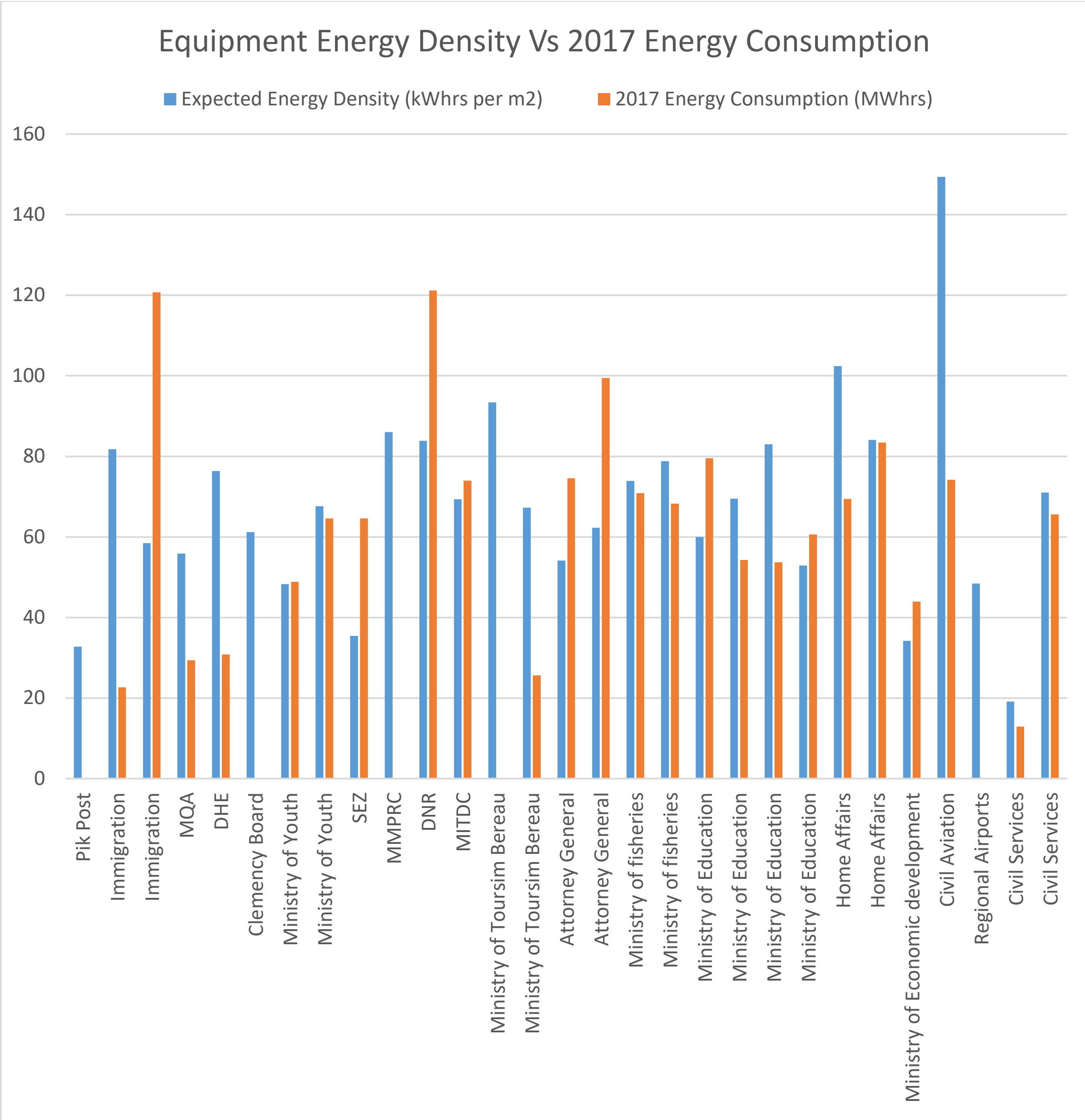

Figure 1-41: Equipment energy density verses 2017 energy consumption for the Velaanaage office building

A high-level summary of the equipment on site is provided below.

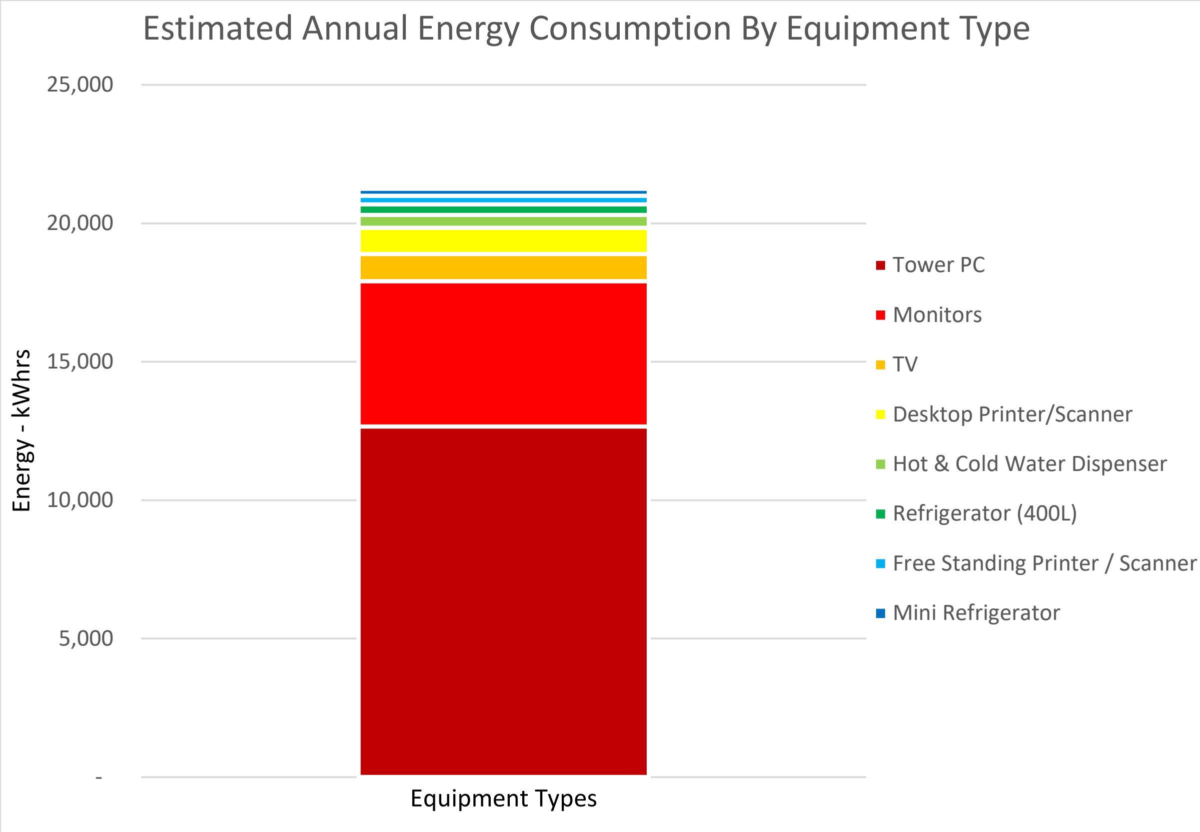

Figure 1-42: Estimated energy consumption by equipment for the Velaanaage office building – refer Table 1-3 for %

Figure 1-42 shows equipment with significant energy consumption only.

Equipment	Expected Peak Draw (kW)	Expected Hours Per Week	Expected kWhrs per Week	Total On Site (Qty)	Expected Annual Energy Consumption(kWhrs)	% of Total
Office Equipment						
Tower PC	0.25	45	12.7	995	12,662	58%
Monitors	0.11	45	5.0	1061	5,252	24%
Laptop	0.05	45	2.3	29	65	<1%
Desktop Printer	0.02	168	3.4	1	3	<1%
Desktop Printer/Scanner	0.02	168	3.4	284	954	4%
Desktop Scanner	0.01	168	1.7	1	2	<1%
Shredder	0.05	36.3	1.8	18	33	<1%
Free Standing Printer / Scanner	0.2	40	8.0	40	320	1%
Plotter (A1)	0.2	40	8.0	2	16	<1%
Laminating machine	0.2	5	1.0	1	1	<1%
Binder	0.02	10	0.2	3	1	<1%

Equipment	Expected Peak Draw (kW)	Expected Hours Per Week	Expected kWhrs per Week	Total On Site (Qty)	Expected Annual Energy Consumption(kWhrs)	% of Total
Kitchen Equipment						
Refrigerator (400L)			14.4	26	375	2%
Mini Refrigerator			250.0	1	250	1%
Rice Cooker	0.2	6	1.2	14	17	<1%
Toaster	0.2	3	0.6	15	9	<1%
Kettle	0.2	3	0.6	31	19	<1%
Microwave	0.2	3	0.6	17	10	<1%
Coffee Machine	0.2	8	1.6	24	38	<1%
Mixer	0.2	3	0.6	4	2	<1%
Hot plate	0.2	6	1.2	1	1	<1%
Hot & Cold Water Dispenser			115.4	4	462	2%
Air Fryer	0.2	2	0.4	1	0	<1%
Other						
TV	0.2	168	33.6	29	974	4%
Small Fan	0.1	36.3	3.6	5	18	<1%
Standing fan	0.15	36.3	5.4	26	142	1%
Wall Fan	0.15	36.3	5.4	5	27	<1%
ID Card Readers	0.01	168	1.7	1	2	<1%
Humidifier	0.2	18	3.6	12	43	<1%
Motorized Projector	0.2	5	1.0	8	8	<1%

Table 1-3: Existing power consuming equipment for the Velaanaage office building

Computers and peripherals are clearly the largest energy consumers on site. A transition away from tower PC's to laptops would be expected to reduce total consumption in this category by around 10MWhrs annual or ~45%.

1.5.13 On Site Generation

The building includes a Photo-Voltaic Array of ~198 panels at ~151W peak output each. This provides a peak output of around 30kW, and an expected total power generation of around 60 MWhrs annually.

The panels are mounted fairly flat, with a slight angle to the north, which provides good solar capture in latitudes close to the equator (like Male') however, does leave the panels vulnerable to build-up of dust and salt. Regular cleaning of the panels – particularly around halfway through the dry season – is recommended to keep generation rates high.

Figure 1-43: Existing PV array on Velaanaage office building

The panels feed directly to the Male' power grid and do not influence energy consumption on site. This notwithstanding, they have been included in the calculations for the net energy performance of the building.

1.5.14 Building Power Supply

The building is powered from a three-phase feed located within the undercroft level.

Figure 1-44: Existing main power distribution board at Velaanaage office building

Power is fed through the building from distribution boards, with the largest of which located on ground floor and containing all tenant sub-meters. This room is provided with air conditioning 24/7.

1.6 Occupant Survey Results

As part of the energy audit, a building survey was completed using an online platform, the results are presented below.

1.6.1 Respondent Location

Most floors provided a response, however, 7th, 9th and 12th floors had zero respondents.

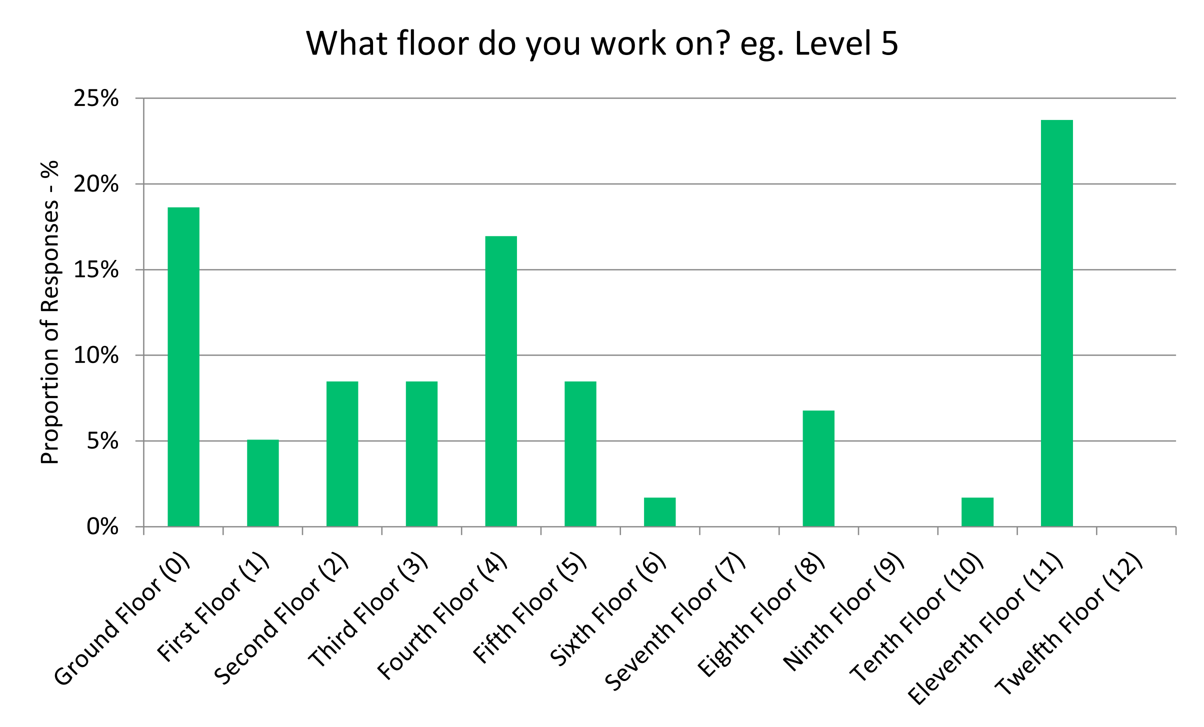

Figure 1-45: Number of response by percentage per level for the online survey

1.6.2 Vacancy Rates

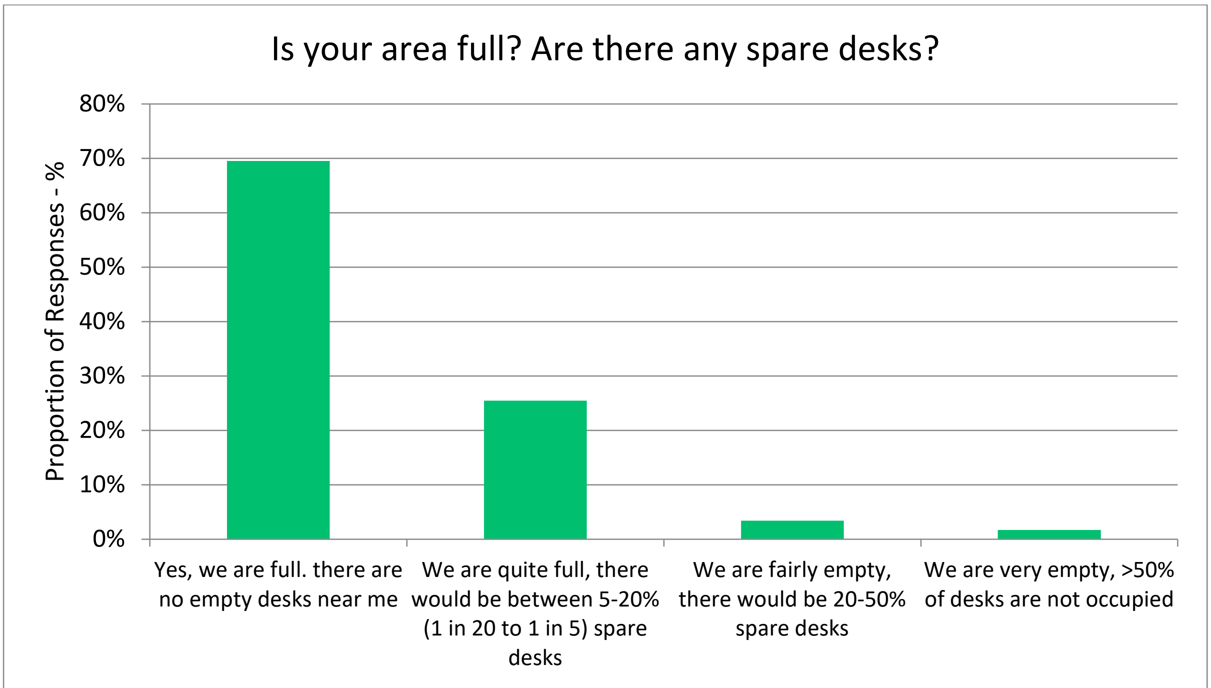

Figure 1-46: Workspace occupancy rate response from the online survey

The responses from occupants indicates the building is close to capacity. The site audits agree with this finding. An overall population density of 10.1m^2 per person is considered densely populated for an office building like Velaanaage.

1.6.3 Other Equipment in Use

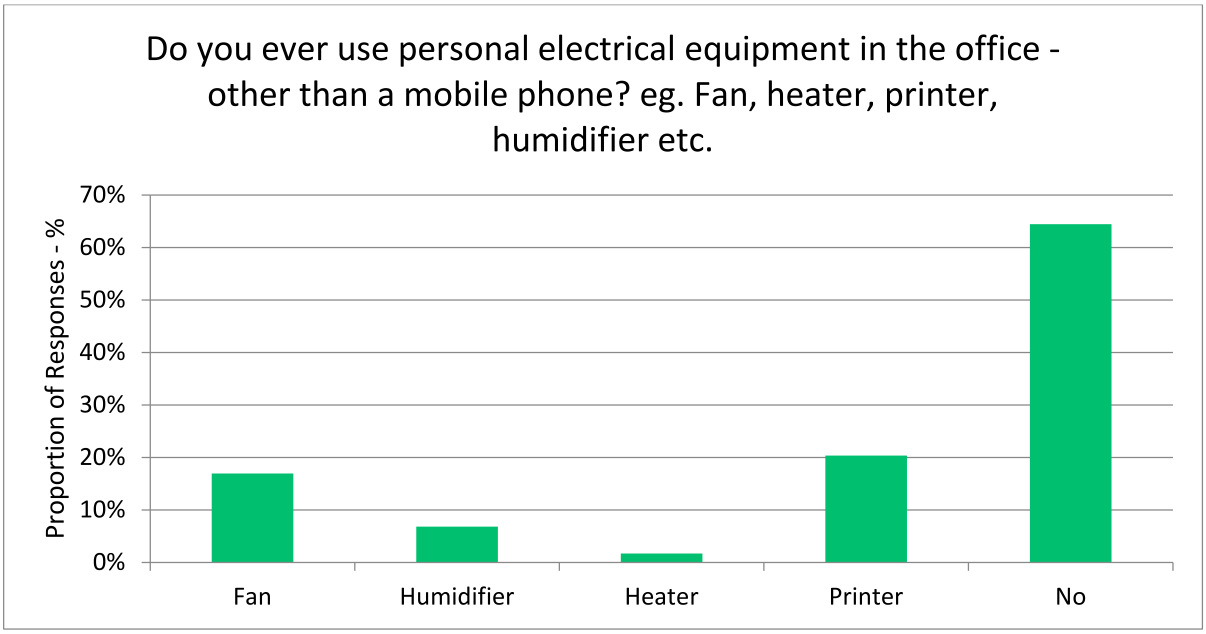

Figure 1-47: Use of personal equipment response from the online survey

Most survey respondents did not use any equipment other than their computers. Around 1 in 5 occupants claim to use a printer at their desk, which is close to the audit review and equipment inventory.

1.6.4 Communications

Occupants were asked three questions about how they communicate at work and whether or not they could work remotely.

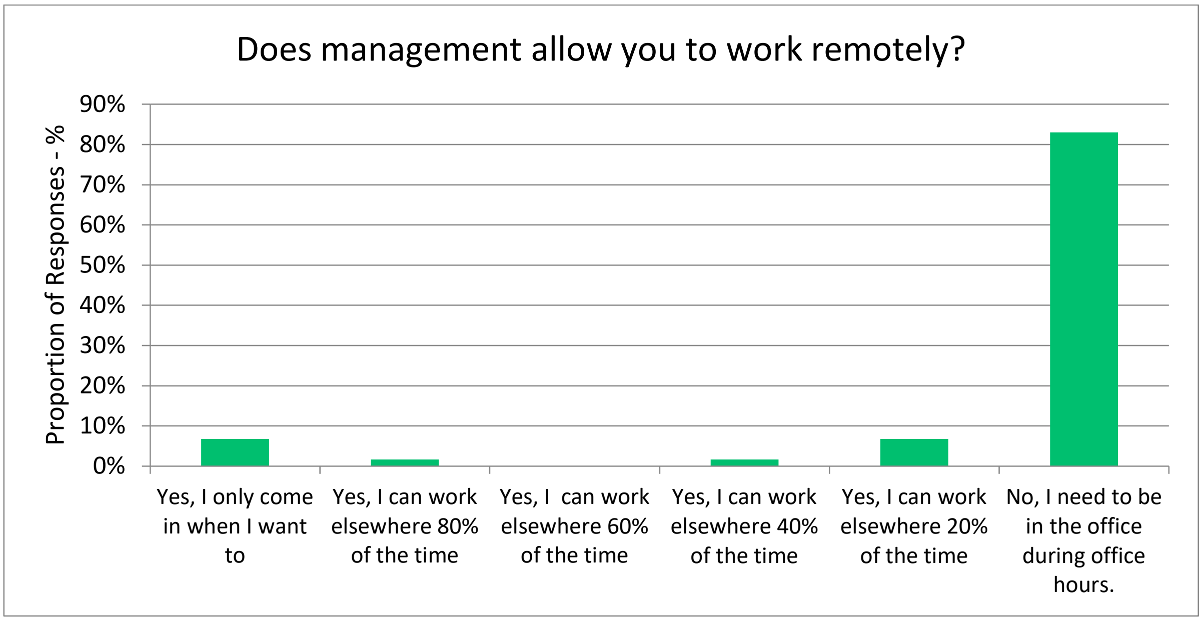

Figure 1-48: Response to the question to check if management will allow staffs to work remotely

The response reflected ~1/3rd of communication was face to face, however, more than 80% of respondents believe they need to be in the office.

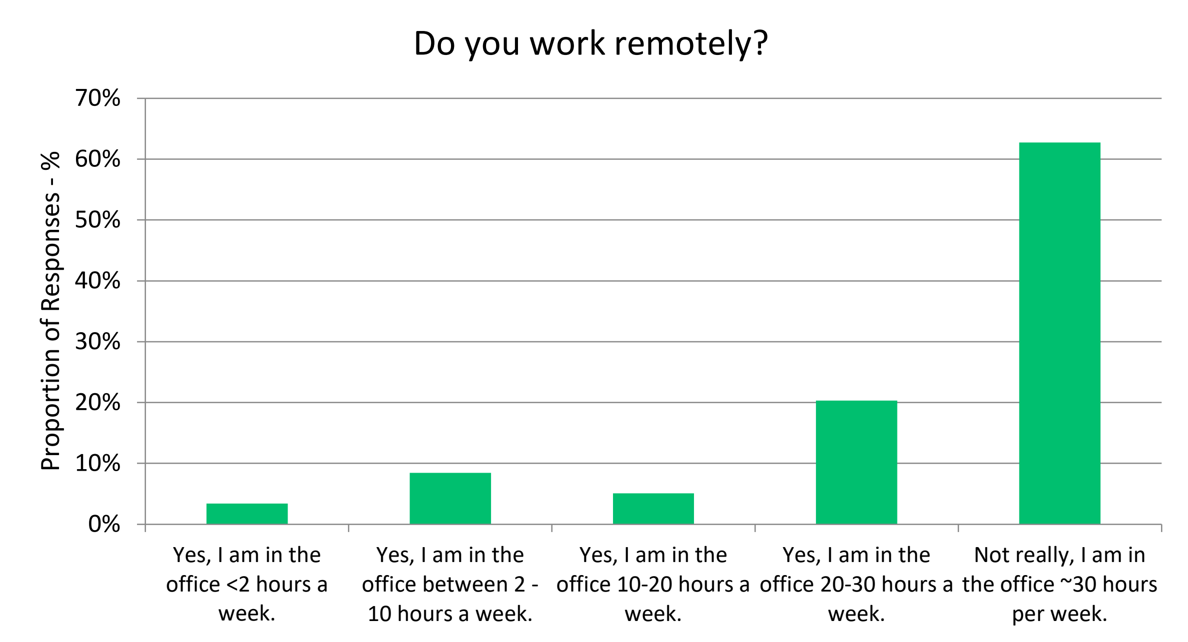

Figure 1-49: Response to the question "do you work remotely" for the online survey

The responses also showed that the majority of people work almost exclusively in the office.

1.6.5 Energy Efficiency Programs

Respondents were asked questions regarding their awareness of and engagement with energy efficiency programs within the building.

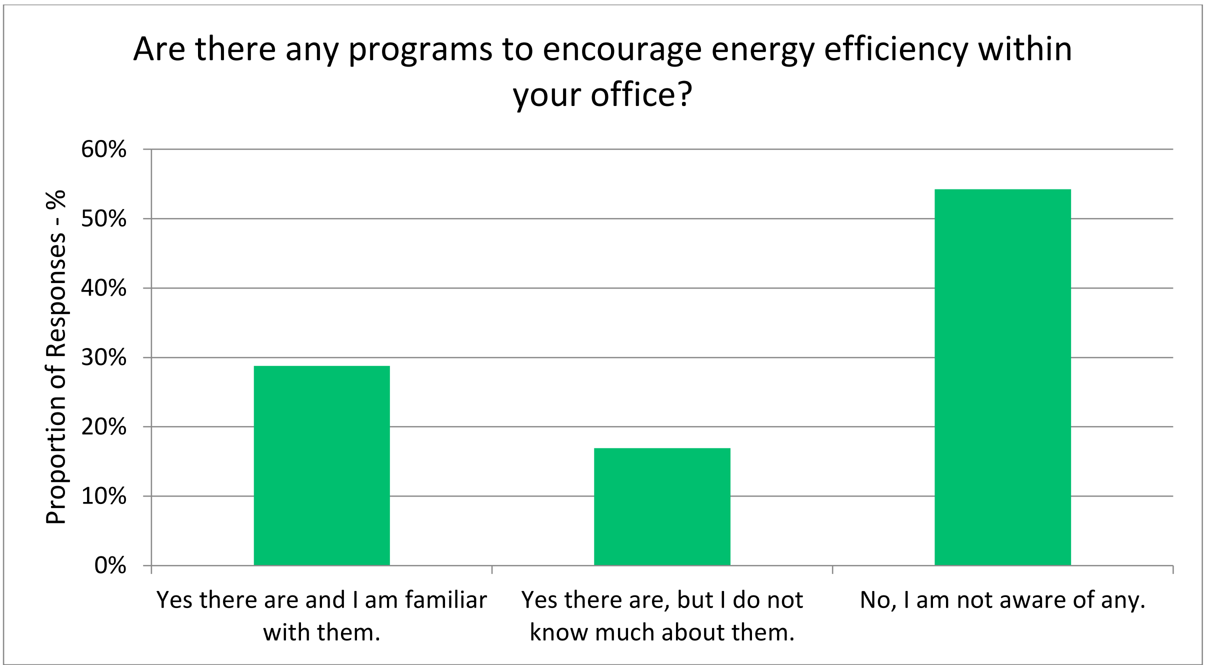

Figure 1-50: Responses for energy efficiency programmes in work environment from the survey

About 50% of occupants are aware of some energy efficiency programs, however, only 30% are familiar with them. This is a clear opportunity for improvement, considering the manual control requirements within the building.

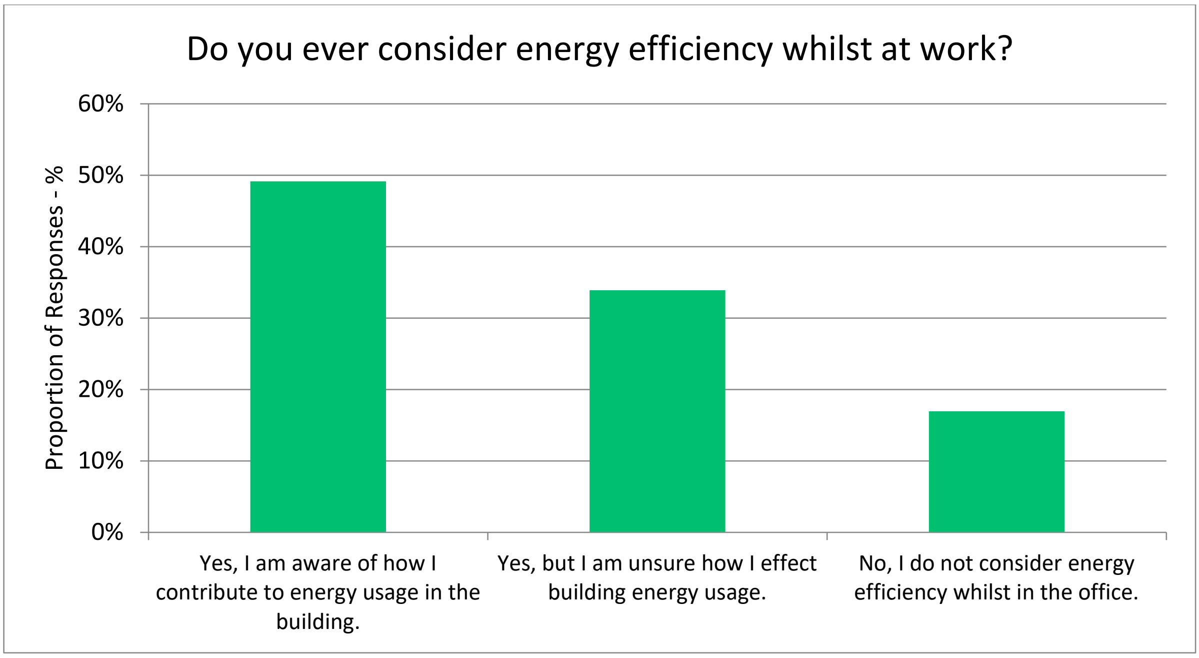

Figure 1-51: Responses for energy efficiency in work environment from the survey

The knowledge and engagement above would be expected to be improved with increased transparency or responsibility for electrical bull payment. Based on survey responses, tenants do not see bills, with all payments handled by the Ministry of Finance. This prevents department heads or area managers from understanding their own power consumption patterns and provides no incentive for tenants to reduce their energy consumption. The following questions demonstrate occupants are interested in energy savings, but are not necessarily able to deliver real outcomes to support them.

Whilst only 30% are aware of ongoing energy efficiency actions within the building, almost 50% understand how they can influence energy consumption. Pleasingly, more than 80% of occupants consider energy efficiency whilst at work. Almost 95% of occupants consider energy efficiency at home.

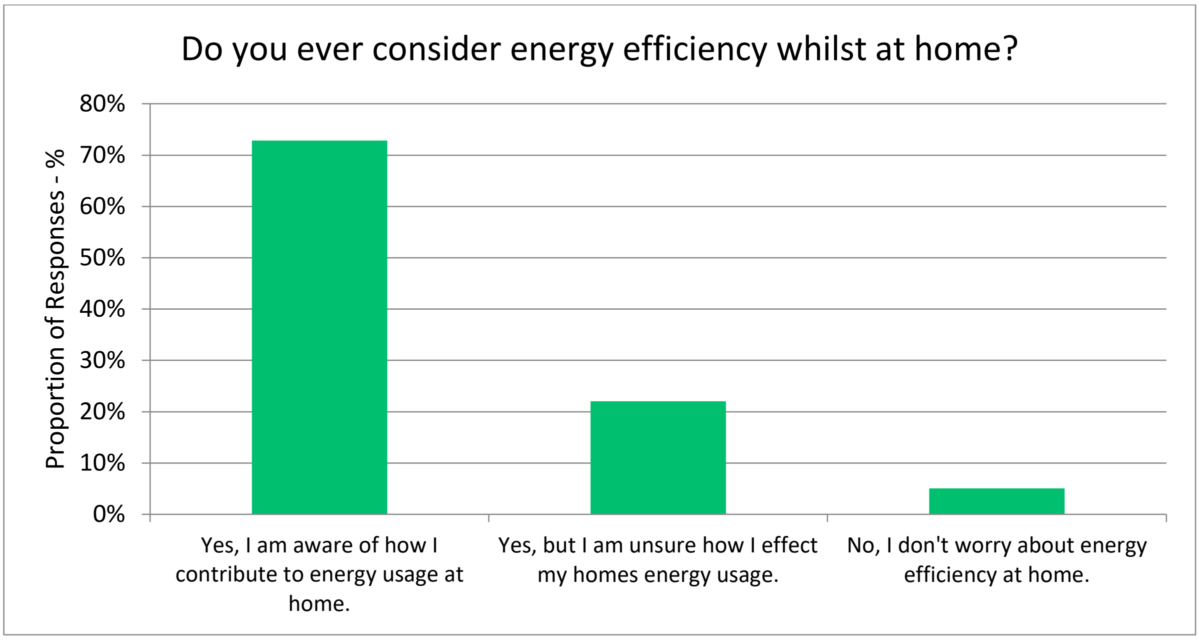

Figure 1-52: Responses for energy efficiency in work environment from the survey

1.6.6 Occupant Actions

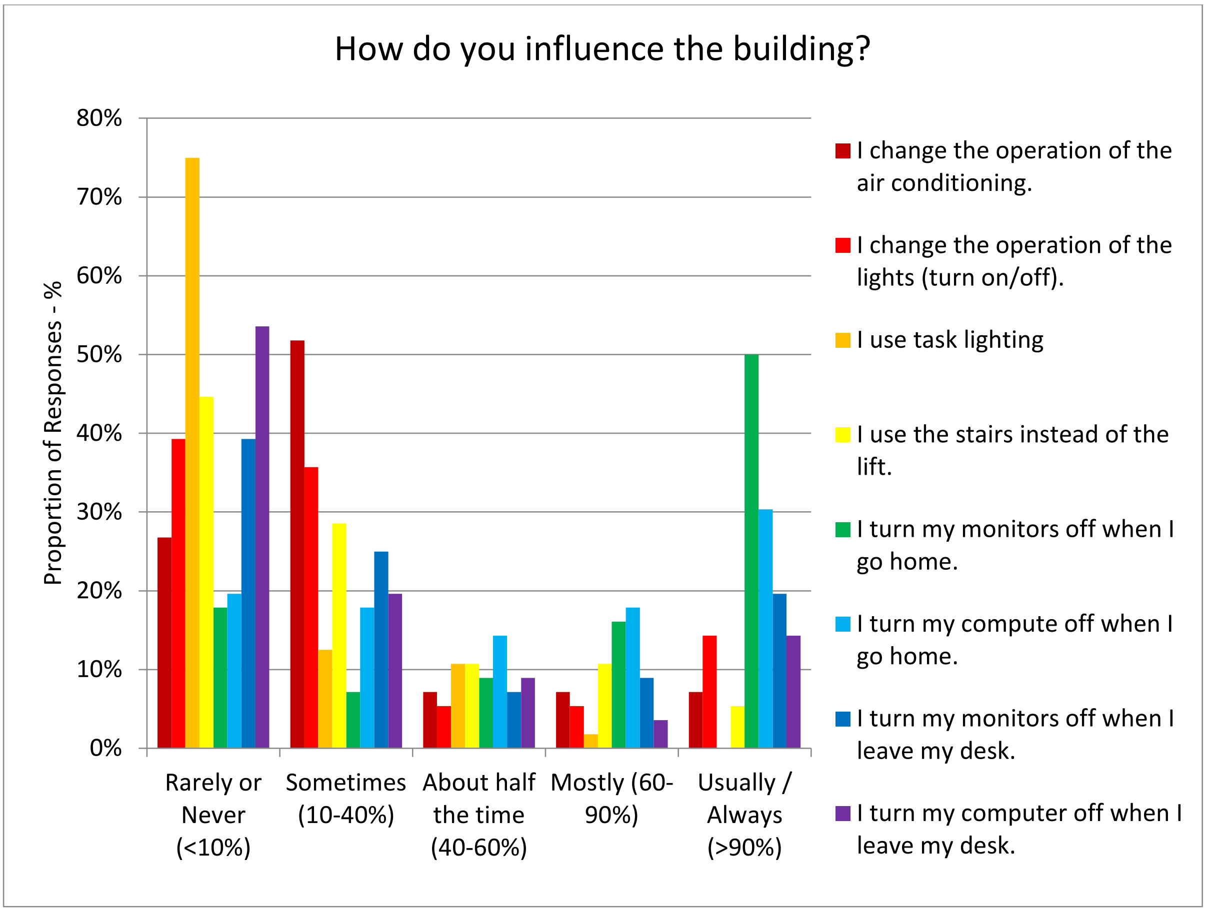

Figure 1-53: How occupants influence energy consumption in work environment from the survey

Occupants were asked how they influence energy consumption within the building.

Generally, responses to all questions were either rare or always, with remarkably few respondents answering sometimes.

Area of Influence	Weighted Engagement
I change the operation of the air conditioning.	30%
I change the operation of the lights (turn on/off).	31%
I use task lighting	14%
I use the stairs instead of the lift.	28%
I turn my monitors off when I go home.	67%
I turn my computer off when I go home.	55%
I turn my monitors off when I leave my desk.	37%
I turn my computer off when I leave my desk.	28%

Figure 1-54: How occupants influence energy consumption per equipment groups in work environment from the survey

The data above shows pleasing levels of occupants turning their computers or monitors off when they go home, however, there are relatively few occupants who either change the operation of air conditioning or lights to suit their requirements.

1.6.7 Occupant Comfort

Occupants were asked questions about their work environment, with surprisingly positive results.

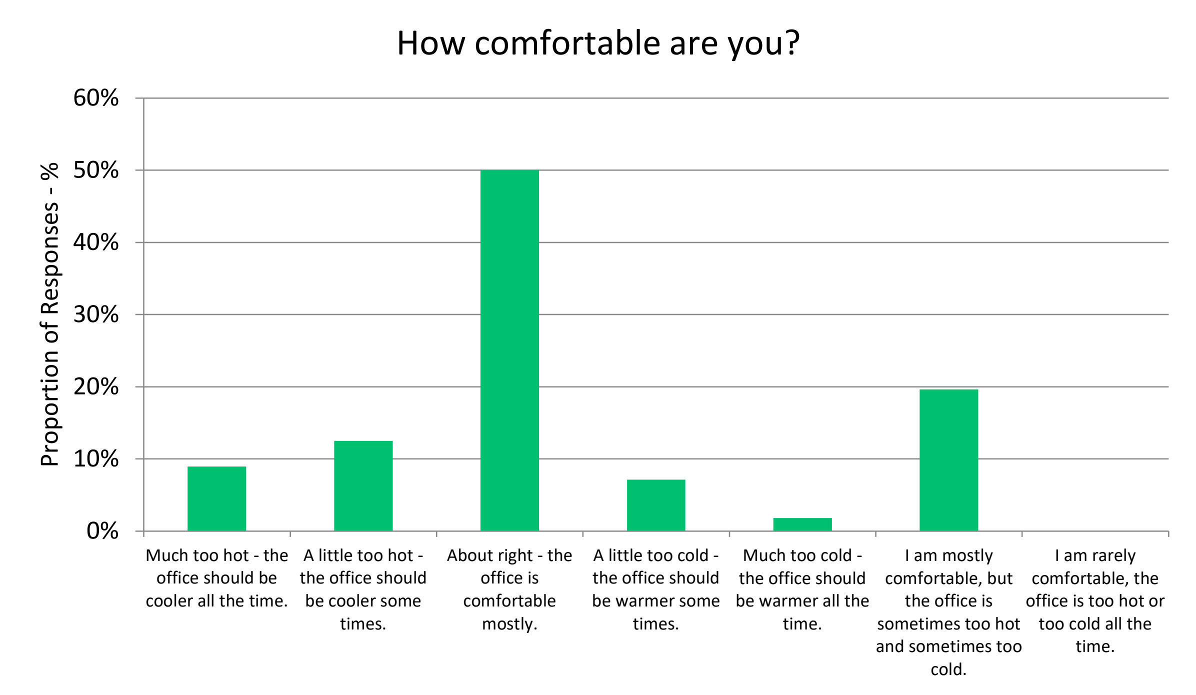

Figure 1-55: Occupants response to comfort in work environment from the survey

Internal temperature measurements within the building indicated a range of internal temperatures – as highlighted in the Air Conditioning Section above. Generally, respondents were happy with internal conditions, with less than 15% indicating consistent dissatisfaction. This is considered good practice.

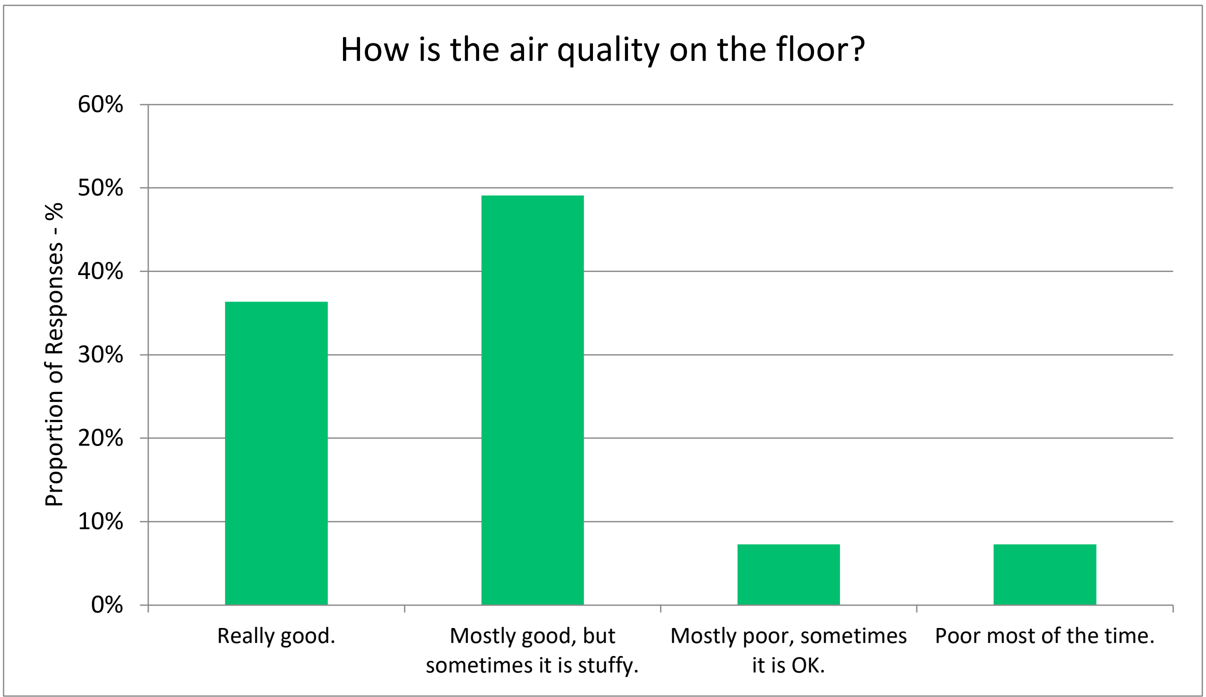

Figure 1-56: Occupants response to quality of air in work environment from the survey

Similarly, air quality responses indicate a high level of satisfaction. This is not in keeping with the audit results, which indicated a general lack of outside air provision.

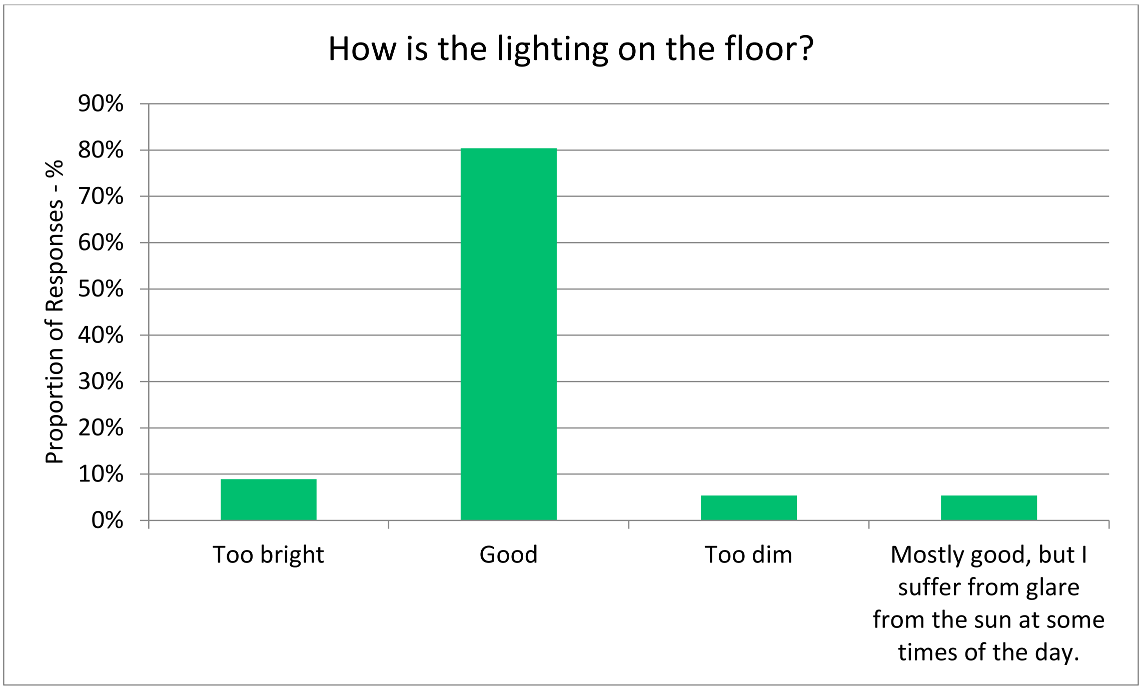

Figure 1-57: Occupants response to lighting level in work environment from the survey

The lighting levels on the floor were generally reported as good, with <10% of occupants feeling that levels were too low. This is most likely due to the high proportion of occupants who work adjacent the façade as the measured lux levels within the occupied space (where not influenced by external light) were considered too low for most paper-based tasks.

1.7 Energy Budget

Based on site observations and calculations, the annual energy budget for the Velaanaage office building was calculated as follows:

Category	Estimated Energy Consumption (kWhrs p.a.)	Percentage of Total
AC	951,692	29%
Canteen	30,000	1%
Equipment	1,128,000	34%
External Lighting	43,800	1%
Lifts	27,000	1%
Lighting	300,300	9%
Security and Lobby	24,000	1%
Server Rooms	876,000	26%
Solar Array	-60,000*	-2%*
Total	3,380,792	
Total – Inclusive of Solar	3,320,792	

Table 1-4: Estimated annual energy consumption for the Velaanaage office building

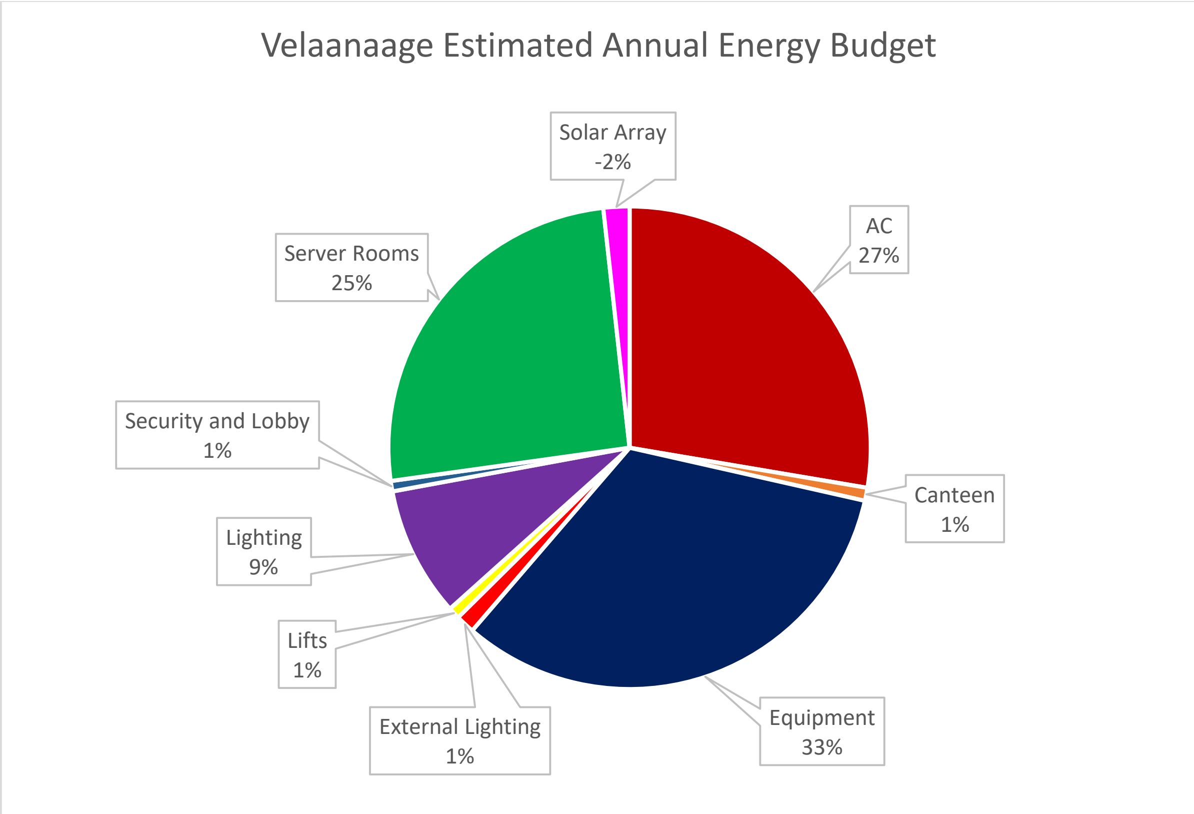

Figure 1-58: Chart showing estimated annual energy consumption by energy consuming equipment groups for the Velaanaage office building

The data shown in **Table 1-4** and **Figure 1-59** match quite well with recent consumption.

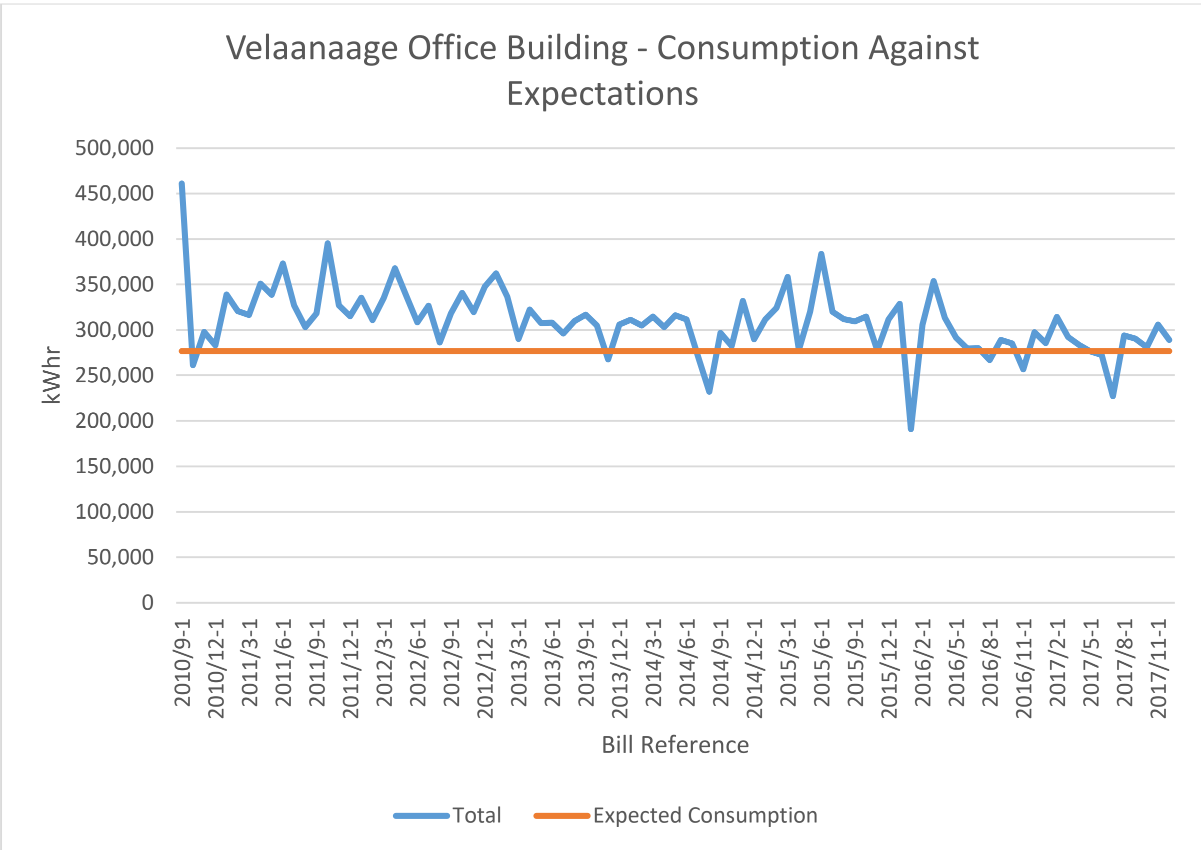

Figure 1-59: Energy consumption verses expectation for the Veelaanaage office building

The most significant power consumers on site are discussed below:

- Server rooms
    - Based on a consistent load of ~100kW – from a survey of the air conditioning systems dedicated to server rooms and a review of the minimum energy consumption from data logs.
- Air Conditioning
    - Based on equipment load profiles and expected efficiency of plant
- Equipment
    - Based on building survey and estimated loading for equipment.

1.8 Opportunities for Improvement

The opportunities for improvement for this site will be discussed in more detail in Section 2: Design Recommendations . However, points considered will be:

- Power Factor Correction
    - Current logged power factors are generally between 0.90 and 0.95, which is considered good practice. Power factor correction is unlikely to provide significant benefit.
- Lighting
    - Existing light fittings provide poor lighting levels and poor energy consumption. Recent upgrades to LED's offer a significant opportunity for improvement. Recommend utilising existing light fittings to re-lamp failed luminaires with progressive fitting change out over the next 2-3 years.
- Air Conditioning
    - Currently, about half of the building air conditioning systems are at or past their useful life. Replacement of VRV II systems with VRV IV HE would be expected to reduce mechanical air conditioning energy consumption by around 15%.
- Controls
    - Manual controls are prevalent throughout the floors and systems. Air conditioning automation should be considered for consistency of temperature set point and the ability to automatically command units off at certain times of the day and when the building is unoccupied. Alternatively, user engagement and feedback could achieve a similar outcome at a reduced cost.
- Power Management
    - Most users, including managers of tenancy areas, are not provided with information regarding their energy performance. Whilst the building manager actively reviews common area energy consumption and seeks to address issues and understand root causes of change, this represents only a small proportion of the overall building energy consumption.

      Ideally tenants would be provided with information regarding their own performance monthly and, where performance differs from the past or is worse than peer tenancies, required to implement changes to address the issues.
- Occupant Engagement
    - Only 30% of occupants are aware of and engaged with any energy efficiency programs within the building. 80% of occupants are interested in or consider energy efficiency at work, whilst 90% consider or are interested in energy efficiency at home. The building occupants are clearly aware of their responsibilities and are interested in assisting, however, do not seem to be aware of how to make a difference.

      This is borne out by the responses regarding actions undertaken by occupants to minimise energy within the building. Whilst occupants are aware of energy efficiency

triggers, they generally do not act, other than turning monitors or computers off when leaving the office.
Upgraded IT infrastructure and tenant education – including providing regular updates on their energy consumption and comparison to peers – would be expected to improve performance levels.

Section 2
Design Recommendations

2.1 Energy Audit Summary

Velaanaage has relatively good energy performance when compared to benchmark buildings in a similar climate zone in Australia. The major energy consumers are equipment (33%), server rooms (25%), air-conditioning (27%), and lighting (9%). The remaining energy consumption is from security, vertical transport, the canteen, and external lighting.

As an established building, the overall building form is considered fixed. Key areas for energy performance improvement are lighting, air-conditioning, controls, power management, and occupant behaviour.

The following subsections of the report summarises different energy efficiency design opportunities and the details of the implementation requirements, costs, savings, and recommendations for each option has been included in this report.

Energy saving calculations shown in this report are based on best available data, expert assumptions, surveys and industrial standards. Actual energy consumption will depend heavily on occupant behaviour.

2.2 Building Analysis

Velaanaage is slightly offset from a north-south orientation. It is taller than the surrounding buildings so receives no external shading beyond the lower levels. There are spectacular ocean views from the building, particularly on the northern side.

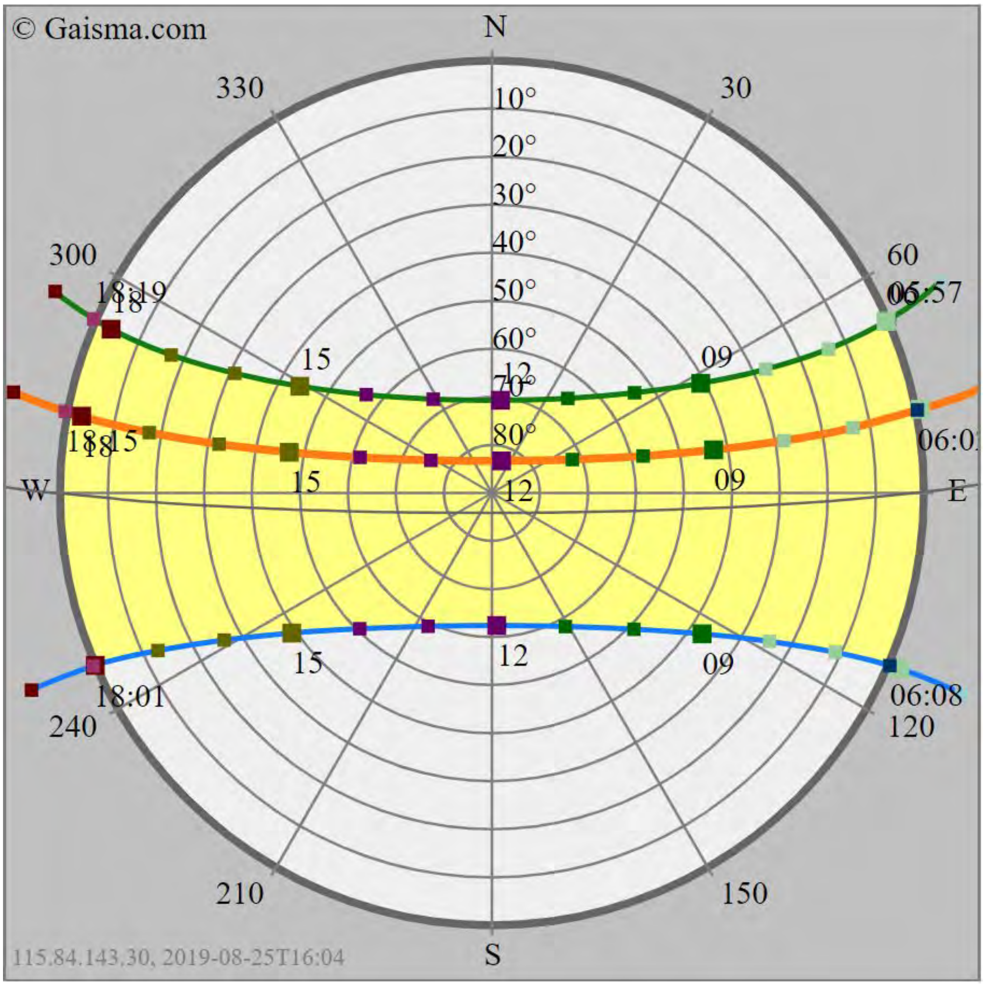

Figure 2-1: Sunpath diagram for Male

Figure 1-1 shows the building location in context. **Figure 2-1** to **Figure 2-4** show sunpath and building simulations that have been used to inform some of the suggestions made in this report. **Figure 2-1** shows the full sunpath for Male'. **Figure 2-3** shows an example of the sun angles (for the December solstice) for 3pm sun position. **Figure 2-2** shows the sun angles and external shading at 3pm on each of the four annual solstices. Importantly, these images shows that both the north-east and the south-west facades are predominantly impacted by high sun, whereas the south-east and north-west facades are predominantly impacted by low sun.

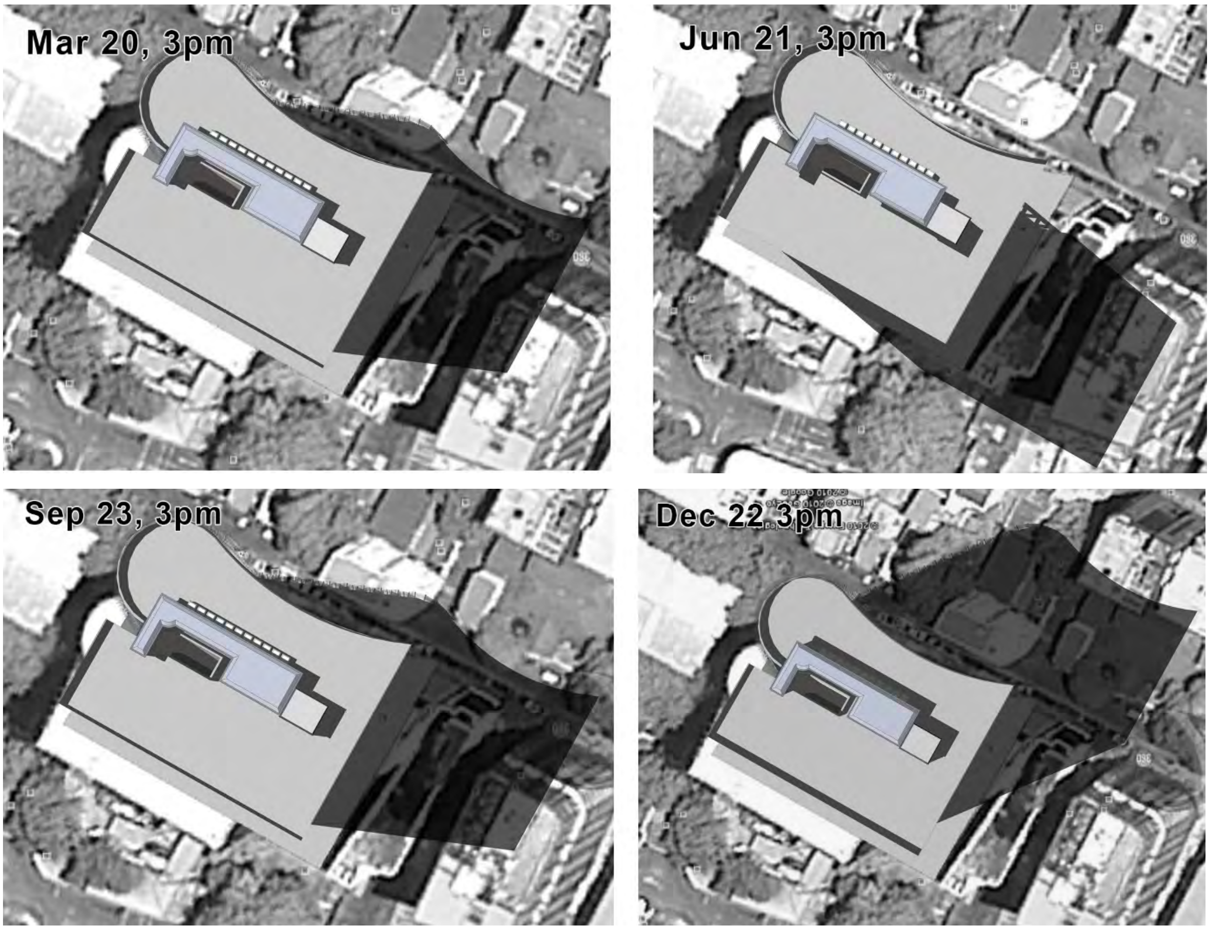

Figure 2-2 Sun-path study on South-west façade

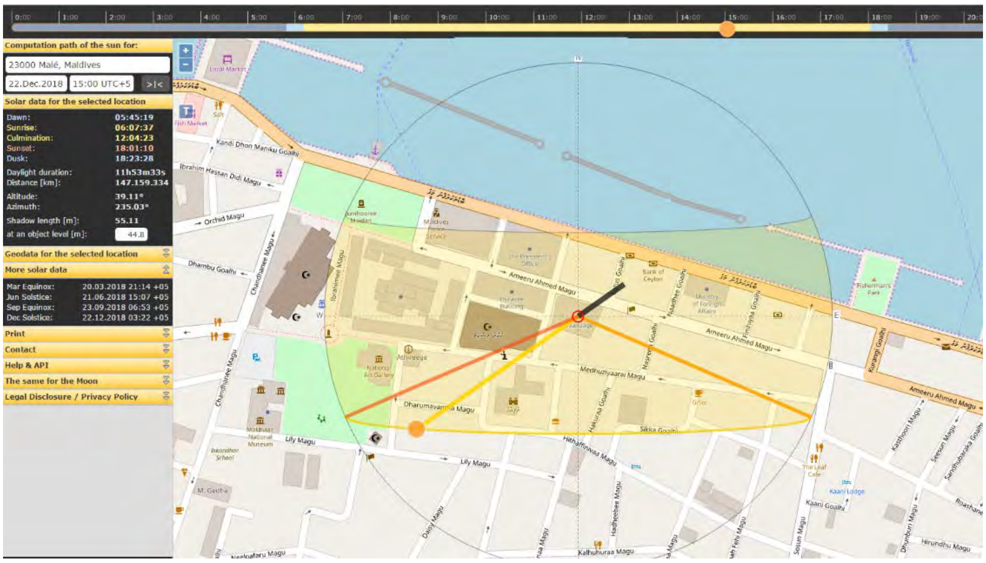

Figure 2-3: Sun path simulation example (December 22nd at 3pm)

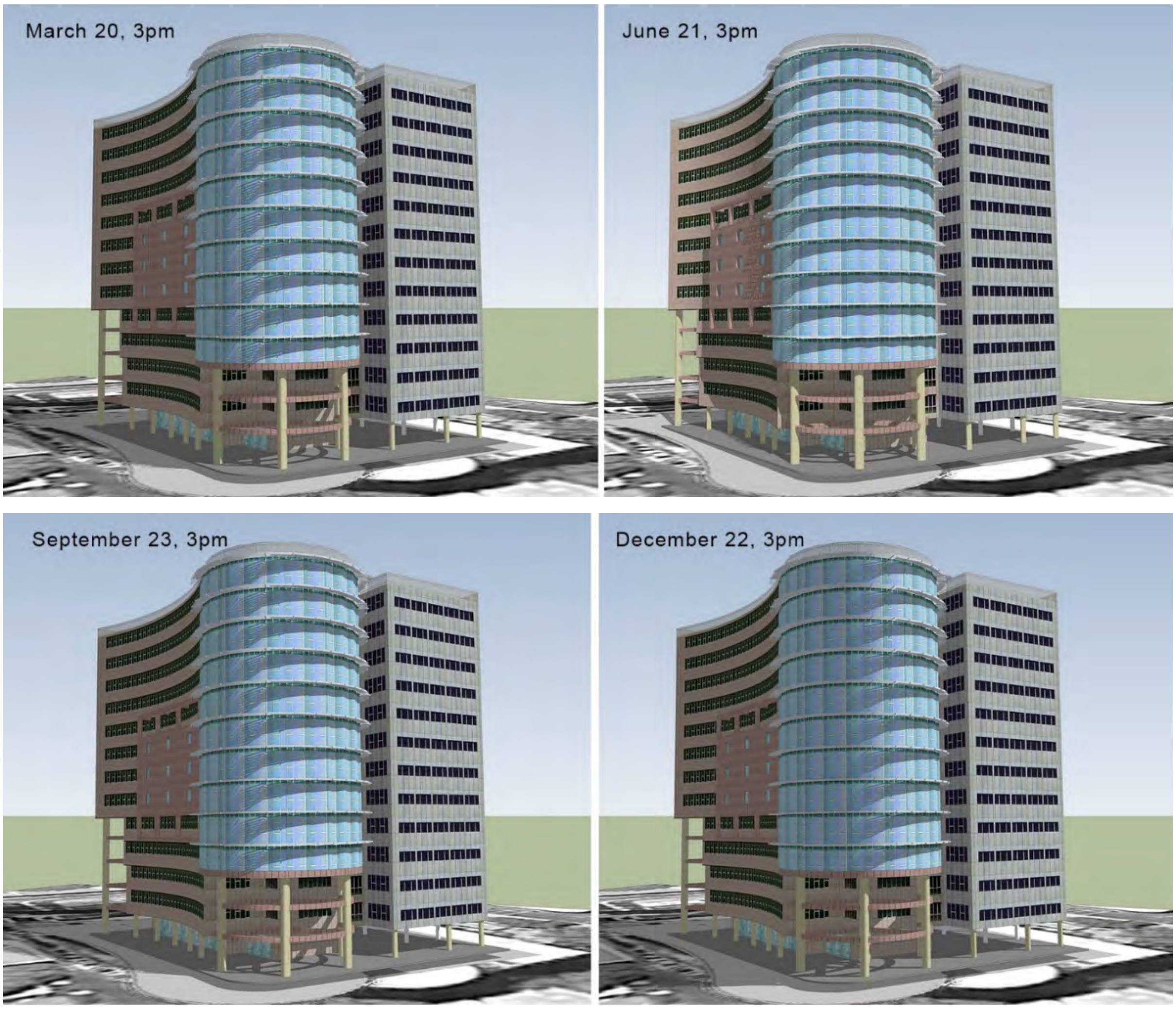

Figure 2-4 North-west facade afternoon sun exposure

2.3 Design Opportunities

2.3.1 Air-conditioning

There are several factors which effect air-conditioning energy consumption in buildings:

1. External heat loads
2. Internal heat loads
3. Air-conditioning efficiency
4. External Air-conditioning maintenance

2.3.1.1 External Heat Loads

External heat loads are transmitted through infiltration (air movement), conduction (through the building envelope), and radiation (when the sun hits glazing).

The infiltration heat loads in the building are likely to be very high as the building is very poorly sealed. Tea rooms are typically ventilated by opening windows and the doors from these spaces to the air-conditioned offices are opened frequently and are poorly sealed. **Figure 1-27** in **subsection 1.4.7**: Building Sealing shows a thermal image of a tearoom door. The hot air leaking into the office space can be seen as a pink rectangle outlining the door.

Further, much of the air-conditioned lobby space was found to be open directly to the outdoors. Windows at various levels were left open into the internal courtyard and the door at the top of the stairway to the roof is left open.

The Team have identified the following measures to reduce infiltration.

- Improve seal around doors that connect air-conditioned and non-air-conditioned spaces (i.e., tearoom and balcony doors);
- Keep windows to lobby closed and manage fresh air through the HRV (heat recovery ventilation) fresh air supply system;
- Close stairwell door to roof (provided this does not pose a fire hazard)[1];
- Positively pressurise air-conditioned spaces through the provision of outdoor air.

Conductive heat transfer occurs when there is a temperature difference from one side of a wall to the other (i.e., the façade, and internal walls between air-conditioned and non-air-conditioned spaces). Glazing has higher heat conductance than walls as shown in **Figure 1-23** in **subsection 1.4.5**: Building Fabric and Glazing. Conductive heat transfer can be reduced through wall insulation and double glazing. However, there is a very low temperature differential between the external temperatures and Velaanaage office space. It is very unlikely that double glazing or increased insulation would contribute to sufficiently large energy savings to justify the cost of either of these initiatives. The Team do not recommend any measures should be taken to reduce conductive heat gain.

Radiative heat gain occurs because of direct radiation from the sun. Solar radiation can travel through glass. Reflected radiation, radiation that has bounced off internal surfaces, cannot travel through glass. As such, it becomes trapped. This is known as the greenhouse effect.

Radiative heat gain is typically an order of magnitude greater than conductive or infiltration heat gains. This is particularly so in the Maldives. There are two primary ways to reduce radiative heat gain. The first is through external shading that prevents direct radiation from hitting building glazing. The second is through glazing with a low solar coefficient. This means that only a fraction of the radiation can enter the building.

Many of the offices at Velaanaage had closed blinds as shown in **Figure 1-24** in **subsection 1.4.5**: Building Fabric and Glazing. This is most likely to manage radiation. Internal blinds are effective in managing glare from solar access. They are also effective in managing any discomfort felt when sitting in direct sunlight. However, blinds are not effective at reducing radiative heat loads. Once the radiation has come through the glass, the load on the air-conditioning system increases.

The inclusion of external, horizontal shading on the northern and southern facades at design stage such as those shown in **Figure 2-5** and **Figure 2-6** would have been very effective at reducing radiative heat gains.

The order of magnitude of retrofitted vertical shading cost is MVR 6,400 per linear meter with a width of 1.2m.

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[1] The Team have not reviewed fire safety provisions for Velaanaage. If the stairwell door to the roof is required to remain open for fire safety this should be given priority over any energy efficiency measures suggested here.

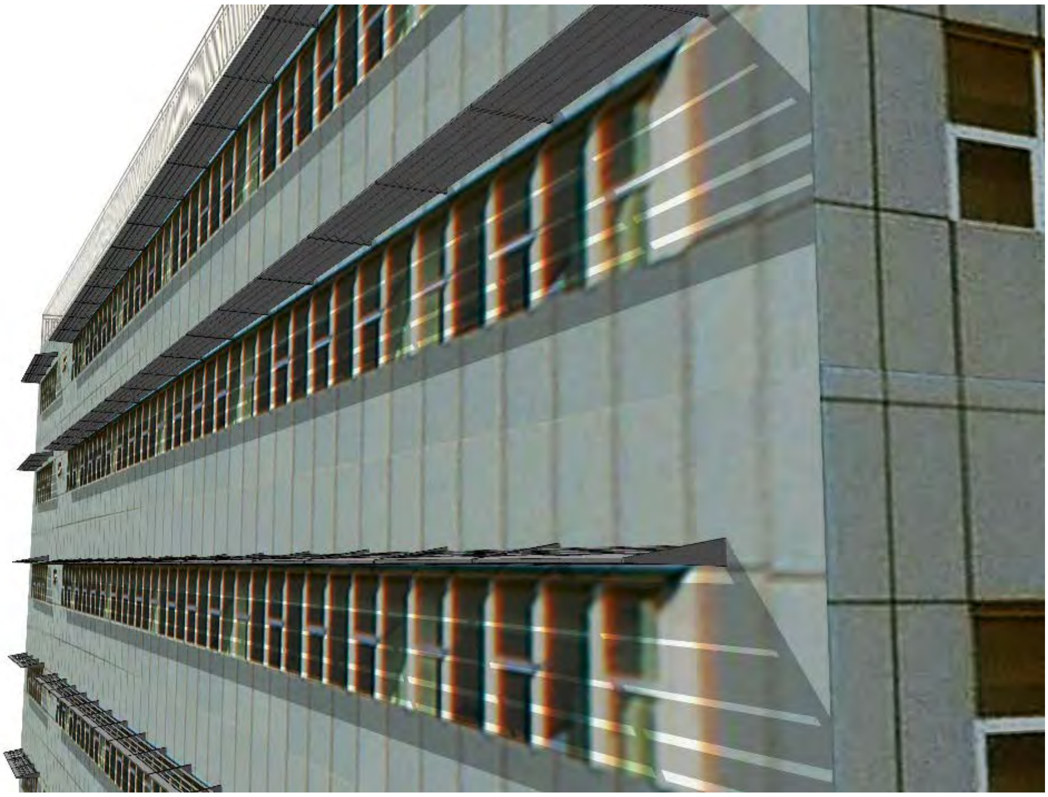

Figure 2-5 External horizontal sunshade on south facade

Figure 2-6: Horizontal shading examples

It is more difficult to manage radiation on eastern and western facades as much of this occurs when the sun is low as depicted in **Figure 2-7** and **Figure 2-8**. Even with double horizontal sunshades with an increase in sun shade width, the low sun angles still penetrate the building interior. However, this could have been addressed through the provision of perforated architectural screens such as the examples shown in **Figure 2-10** as demonstrated in

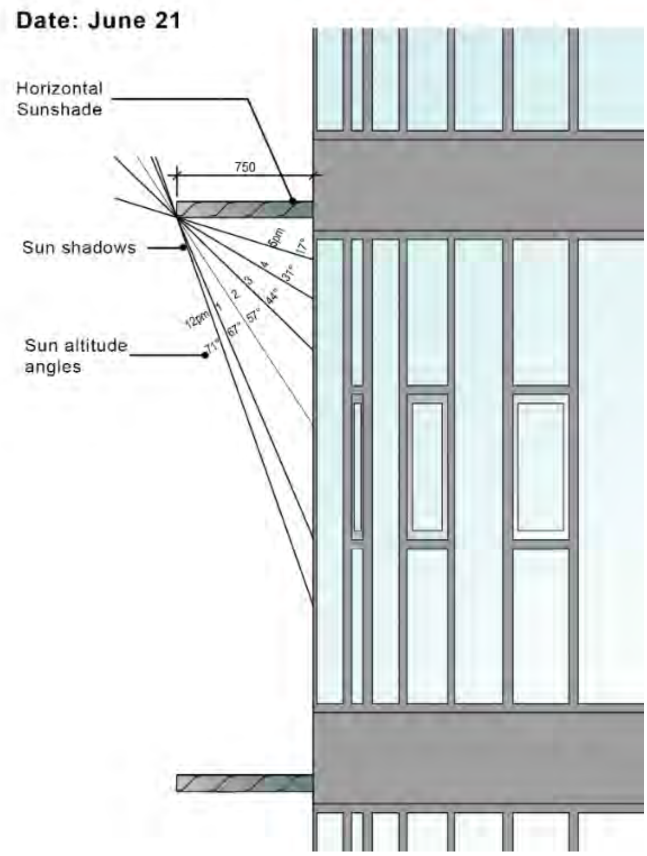

Figure 2-7 Section of west facade showing depths of shadow angles from horizontal shading installed currently at Velaanaage

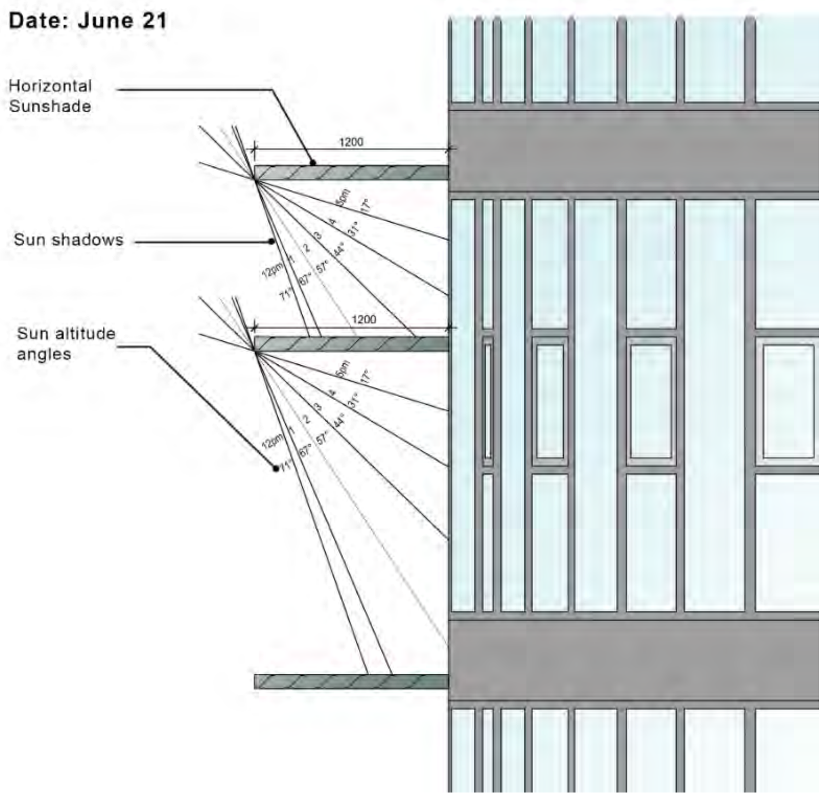

Figure 2-8 Section of west facade showing depths of shadow angles with double horizontal shading

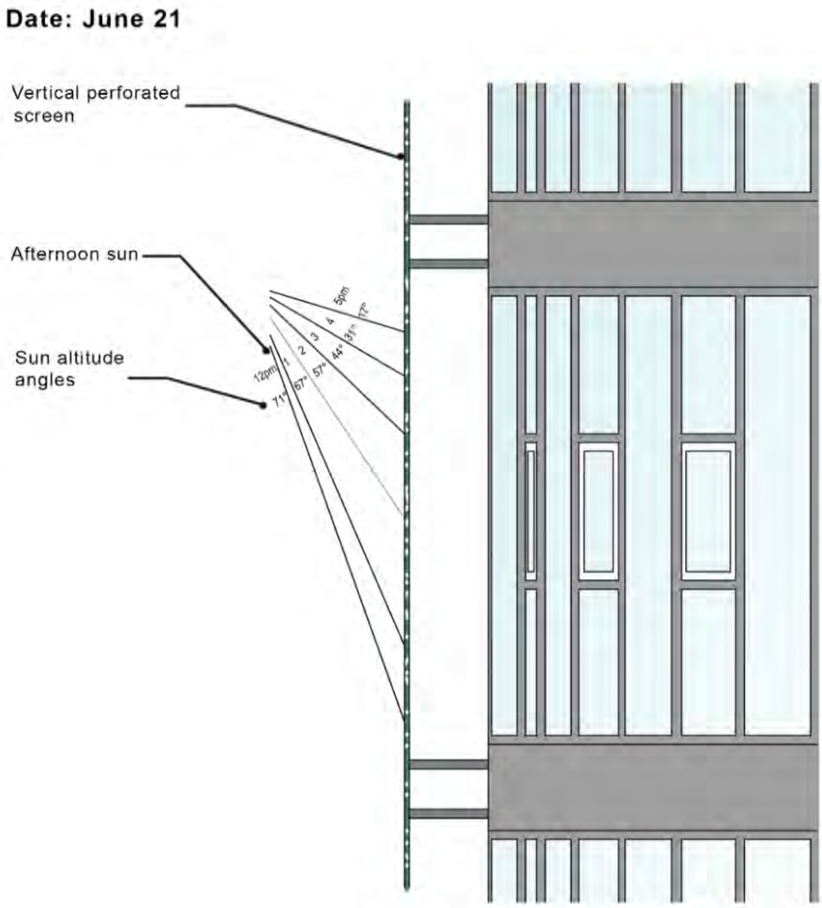

Figure 2-9 Vertical perforated sunshade fixed at west façade

Figure 2-10: Examples of perforated architectural screens

At a design stage the costs of external shading can be offset by reductions in plant size and operational costs. However, the addition of retrofitted external shading is prohibitively expensive. As such we do not consider this an option for Velaanaage. However, we recommend that external shading is actively considered on future projects.

The order of magnitude of retrofitted perforated shading costs is MVR 3,100 per square meter.

Low-emissivity (low-e) film is a thin film that can be stuck directly onto existing glazing to reduce radiant heat gain. It works by reflecting solar heat and radiation without stopping visible light from entering (see **Figure 2-11**). Low-e film is effective not only in reducing solar loads, but also in improving thermal comfort. It is also possible to select film which is tinted to help to manage glare. This means that not only will energy consumption go down, but also it is likely to encourage building occupants to keep their blinds open. Studies have shown that views, especially those that include natural elements (e.g., trees or water) can significantly improve occupant performance. Employees have been shown to be as much as 11% productive, and to take fewer sick days in buildings with high indoor environmental quality

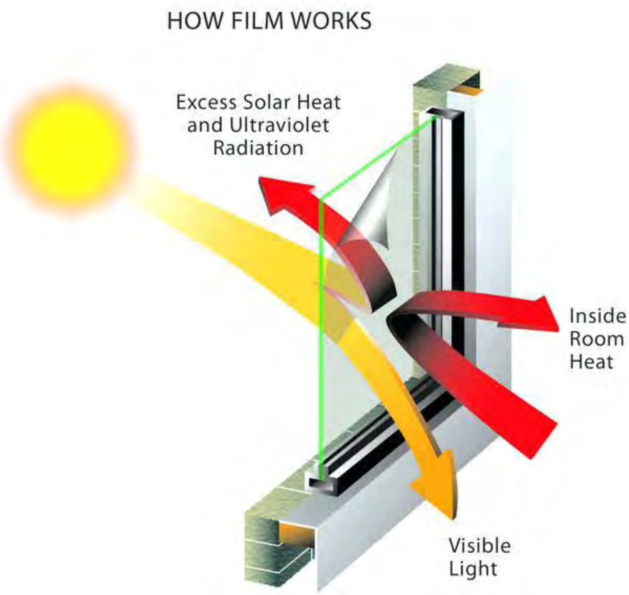

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Figure 2-11 How low-e film works

The Team have identified the installation of tinted low-e film on windows subject to direct solar radiation (i.e., upper floors) as the key strategy to reduce radiative heat loads and improve the indoor environmental quality.

2.3.1.2 Internal Heat Loads

Internal heat loads comprise the building occupants, lights, and equipment. Both lighting and equipment are major energy consumers which means improving the efficiency of these things gives not only the direct energy savings, but also indirect savings through reduced load on the air-conditioning system. The specific recommendations for improving efficiency in these areas is outlined later in the report.

2.3.1.3 Air-conditioning system efficiency

The building includes air conditioning for all occupied areas. Air conditioning systems include VRV (Variable Refrigerant Volume) type systems with cassette unit fan coil units within the occupied spaces. All condensers are mounted at roof level.

The plant varies in age from the original installation, to recent replacements and spans VRV II, VRV III and VRV IV systems, as released by Daikin. Refer **subsection 1.4.2**: Air Conditioning for further details on the air conditioning details of the building. Refer to **Figure 1-12** for a typical ceiling cassette fan coil unit which is used throughout the office building. And **Figure 1-13** shows a Daikin VRV IV HE condenser unit[2].

Based on the consistent nature of their use and the marine environment, the Team estimate VRV plant would have a useful economic life of between 7-10 years and, therefore, the VRV II plant is at or approaching the end of its economic life and should be replaced. It is also noted that the VRV II equipment utilises R22 refrigerant. R22 is no longer being produced because of its impacts on the ozone layer and thus represents a significant cost for replacement. This is further reason to replace units with R22 refrigerant (VRV II) rather than repair. New units (VRV III and VRV IV) utilise R410a refrigerant which has a lower Global Warming Potential than R22 and zero Ozone Depletion Potential

As shown in **Figure 1-14 subsection 1.4.2**: Air Conditioning, approximately half of the building air conditioning systems are at or past their useful life[3].

The graph in **Figure 1-15 subsection 1.4.2:** Air Conditioning shows the relative performance efficiency of the various types of VRV units available for the building. The higher the coefficient of performance the better. VRV II and VRV III have similar efficiency levels, however the VRV IV provides reduced energy consumption of around 20% and the VRV IV HE represents an improved efficiency of around 25%.

Performance curves are based on 24 degrees internal temperatures, 31 degrees external temperatures and published Daikin Data for a 50kW cooling only capacity condenser unit.

Replacement of existing VRV II systems with VRV IV HE would be expected to reduce mechanical air conditioning energy consumption by approximately 15%.

Further, internal layouts appear to have been designed and installed with little consideration to the air-conditioning layout. Many partition walls are located in the middle of cassette units (and lights) (see **Figure 1-33** in **subsection 1.4.8 :**Tenancy Interaction) which reduces air distribution effectiveness and increasing condensation risk. Moreover, many very small offices contain cassette units which are sized for a substantially larger and more densely occupied area, resulting in overcooling of these spaces, and insufficient cooling capacity in neighbouring open plan spaces.

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[2]Air conditioning unit shown in subsection 1.4.2 Air Conditioning Figure 1-13 is similar to the existing units which have been installed recently on site

[3] There are no existing VRV IV HE systems installed in Velaanaage at the time of the site visit

In addition to the above, the building currently has a 'phantom load' (overnight load with no or very low occupancy) of around 150kW. Based on the energy audit undertaken, it is estimated that around 100kW of this load is associated with communications rooms and associated air conditioning throughout the building.

Generally speaking, air conditioning for communications rooms is ~33% of the electrical load for the same space. Therefore, the 100kW 'phantom load' is estimated to comprise ~75kW of electronics and 25kW of air conditioning.

Electronic energy consumption is difficult to reduce without replacement of equipment with more efficient systems. However, this generally has operational implications and must be considered on a case by case basis.

Air conditioning energy consumption can, on the other hand, be reduced with plant replacement and/or correct installation without compromising operational performance of the computer systems.

The Team recommend:

- Developing a plan to upgrade the air-conditioning stock which is already past its useful life, with staged future upgrades planned to avoid repeating this inefficiency. This should include plans for system upgrades to reduce phantom loads.
- Developing tenant guidelines which include clear recommendations for how to manage internal fitout.

2.3.1.4 Air-conditioning maintenance

There are signs of poor maintenance in both the indoor units of the VRV air-conditioning units and the HRV outdoor air units.

Many of the indoor units were found to be dripping water and substantial water damage could be seen to ceiling around these units and to floor areas below. This indicates not only that the condensate pumps in the units may have failed but also that coil air flow is likely to be obstructed. This can cause lower air volumes and therefore increased condensation. It can also put more pressure on the fans which corresponds to increased power consumption. Published performance for the Heat Reclaim Ventilation (HRV) units which supply fresh air to the building is between 55-60% efficiency. However, during site visits the measured efficiency was 30% in terms of sensible heat transfer and 38% on enthalpy exchange. This means that the HRV units on site are performing 17 – 30% worse than the predicted performance.

The Team recommend regular maintenance of the building air-conditioning system to optimise performance of existing units. Further, we recommend the development of a strategy for staging regular equipment upgrades as equipment reaches the end of its useful life.

2.3.2 Equipment

Over a year, it is estimated that the tower PCs (personal computers) consume 58% of the total equipment load, which corresponds to approximately 20% of the total building energy consumption. These figures were extrapolated from the measured building energy consumption data and the number, type, estimated operating hours, and peak draw of existing PCs. Tower PCs draw approximately five times more power than laptop computers. This means that replacing PCs with laptops could equate to almost 10% total energy savings (based on 80% of PC energy).

Laptop computers have more benefits than just energy efficiency. They allow more flexible working. They can also be used to help to reduce paper consumption as staff can bring laptops home (when required) and to meetings.

However, the decision to purchase PCs or laptops typically rests with the tenants, this is not usually done at a building wide level.

The Team recommend the development of tenant guidelines which include recommendations that all upgrades and new purchases are for laptops rather than tower PCs. Tenant guidelines are discussed in more detail later in this report.

2.3.3 Lighting

The majority of the building uses T8 luminaires which are extremely energy intense compared to some of the available lighting systems. Each light draws 144W when fully lamped. The bulbs in the existing light panels could be replaced by LED T8 tubes (see **Figure 2-12**). However, the most efficient option would be to replace each panel with an LED ceiling panel. 33W LED ceiling panels have already been installed in some tenancies (see **Figure 1-37** in **subsection 1.4.11**: Internal Lighting). These LED panels perform at a higher level in terms of power consumed and in terms of lux (lighting level) provided.

Upgrading the light fittings would already save over 75% of lighting energy in most tenancies

Figure 2-12: Fluorescent vs LED T8 Fittings

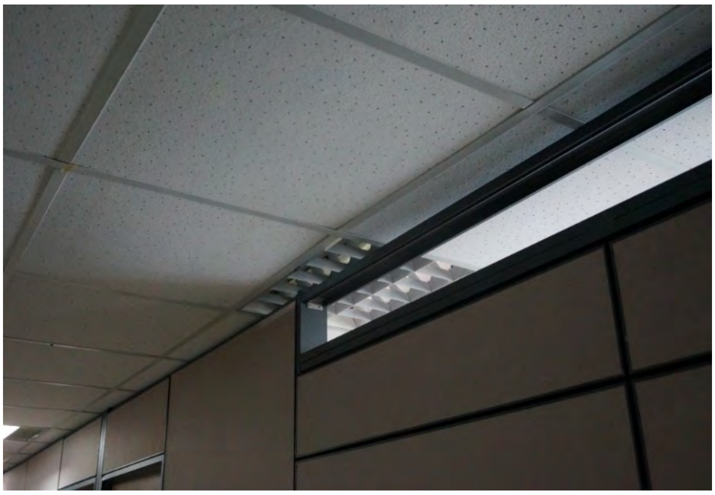

Figure 2-13: Partition wall in centre of light fitting

As discussed with respect to cassette units, the lighting design has not been integrated with internal layouts. There are partition walls which are in the middle of light fittings which results in inefficient lighting as shown in **Figure 2-13**. There are lights in some meeting rooms and offices which are on the same controls as lights in open plan areas which means some lights are operated unnecessarily.

Daylighting is typically sufficient to light the perimeter of office spaces. As such it is common practice to put perimeter lighting on a different circuit to internal lighting. The current switching arrangement does not allow perimeter lights to be off during daylight hours, so these lights are running unnecessarily (see **Figure 1-39** in **subsection 1.4.11**: Internal Lighting)

This could be achieved for a negligible cost incremental to tenants when installing LED panels or rewiring lighting to suit tenancy layouts and would achieve substantial additional energy savings.

The Team recommend:

- Upgrading light fixtures to LEDs
- Revising the control strategies for lighting so that perimeter lighting can be left off during the day.
- Developing tenancy guidelines which include recommendations for integrating lighting strategies and internal fitouts.

2.3.4 Vertical Transport

While vertical transport constitutes a relatively small fraction of the total building energy consumption, it was apparent during the site visit that the current lift operation is relatively inefficient. The lifts do not all provide access to all floors; a design feature likely to have been included for efficiency. This is a good strategy, provided it is clear to building users which lift to take. The only indication of which lifts access different floors is inside the lifts themselves. This meant that we witnessed many visitors taking the incorrect lift to an incorrect floor and subsequently catching 2-3 lifts instead of only one. Each time this occurs, energy is being consumed unnecessarily.

The open stairway is very visible and accessible on arrival into the lobby at the ground level, and also at other levels. This in itself provides good incentive to building users to take the stairs rather than using the lift. However, this could be further improved by better signage. Obvious signage directing users to take the stairs with clear indication of which offices are on each floor would help to encourage users to walk.

The Team recommend installing clear signage for the lifts and stairs at every floor.

2.3.5 Solar Panels

Solar panels work most efficiently when they are clean. As such, we recommend regular cleaning of the panels by the responsible party for maximum output. The onsite photo-voltaic array does not contribute energy into the building loads, but does effect overall greenhouse gas emissions due to energy consumption in the building.

2.3.6 Smart Buildings

The use of technology to improve access to information, security and safety, workplace productivity, building diagnostics and predictive maintenance, user interfaces and operations management is becoming increasingly common in new buildings. These solutions can range from very simple systems such as smart power strips, to live building monitoring systems (such as B-Tune – a non-vender specific building management system), to integrated smart building solutions that can include data analytics, booking integration, mobile device solutions which allow users to control building systems from their phones, facility staff dispatch (where cleaners are directed to spaces based on occupancy and odour), etc.

The cost of a fully integrated smart building is unlikely to yield reasonable paybacks in Velaanaage and so are only recommended if desired for other benefits such as operational efficiencies. However, the use of a monitored BMS to manage energy consumption should be considered. In new buildings the upfront costs to install systems such as B-Tune is relatively low and payback period is short (e.g. 1-2 years). However, the nature of the systems in Velaanaage are such that relatively expensive retrofitted monitoring and gateway to the VRV system would be required. Moreover, since there are already staffs regularly reviewing the building meters, it is difficult to predict energy savings from such a system. The significant benefits of such a system are the early detection of abnormalities that highlight maintenance and repair issues.

Smart power strips can limit energy wastage, for example when building users do not remember to hibernate their computers. However, given the larger potential savings that can be made through occupant behaviour change programmes, it is recommended that behaviour change is targeted rather than managed through the use of power strips.

2.3.7 Occupant Behaviour

Studies on the influence of occupant behaviour on building energy consumption suggest that behaviour can make anything from 10% to 100% difference. Our experience suggests that at least 10-20% savings through occupant behaviour is usually achievable.

In some respects, the occupant behaviour in Velaanaage is quite good. Few lights were found to be left on overnight. Open plan office air-conditioning was also generally switched off.

However, both the occupant interviews and during the early morning audit highlighted that computers were generally left on sleep rather than hibernated or turned off. Staff do not normally switch off their screens when going to meetings or taking a lunch break. Air-conditioning in many meeting rooms was found to be on overnight, and both lights and air-conditioning were running in most unoccupied offices and meeting rooms during the day.

The staff survey highlighted that although almost 80% of building occupants reported that they consider energy efficiency whilst at work, more than 40% of these people were unsure how they affect building energy consumption. Interviews with representatives from each tenancy highlighted that there was little guidance on energy efficiency either from building management to tenants, or from upper management to staff within each tenancy.

More than 95% of building users surveyed reported that they consider energy efficiency at home. This suggests that some guidance and training could vastly improve occupant behaviour and therefore reduce energy consumption. The Team recommend implementing a programme aimed to improved occupant behaviour.

2.3.8 Indoor Environmental Quality

Indoor environmental quality does not directly influence energy efficiency. Nonetheless, energy efficiency should not be achieved at the cost of the indoor environment.

The results of the survey suggest that the indoor environment is good, with over 50% of respondents reporting that their comfort in the office was about right most of the time and 35% of respondents reporting that they found the air quality to be really good most of the time. However, 65% of respondents reported that the air quality is sometimes stuffy, mostly poor, or poor most of the time.

During the site visit several of the staff talked to the Team about their concerns regarding the indoor environmental quality. The key concerns raised included:

- Some spaces being far too hot and others far too cold;
- A feeling of dark and dreariness due to needing to keep blinds closed most of the time to manage glare and thermal discomfort;
- Stuffy air resulting in headaches and difficulty concentrating.

The Team found the internal air quality to vary greatly from tenancy to tenancy. Many tenancies were quite stuffy and the smell of mould was present.

The key reason for the stuffiness was found to be a failure of staff to operate the outdoor air units. Without turning these on, no outdoor air is supplied to the offices other than through infiltration. A lack of outdoor air can lead quickly to very poor air quality. The smell of mould is likely due to the poorly maintained cassette units.

The Team recommend:

- Informing tenants of the importance of switching on the outdoor-air supply each day;
- Installing tinted film on glazing with direct solar access;
- Replacing mouldy ceiling panels and floor coverings and improving maintenance to the air-conditioning system.

2.3.9 Tenant Guidelines

It is common practise in many countries to provide tenant guidelines that impart detail regarding the base building provisions, and which detail the expectations for fitout procedures and building use.

The Team recommend the development of tenant guidelines which include (but are not limited to):

- An overall description of base building services;
- A guide to fitout detailing how to integrate the lighting and air-conditioning system and internal layout;

- An explanation of how tenancy air-conditioning and lighting systems should be operated – including, for example, advise that unoccupied spaces should not be air-conditioned or lit and that perimeter lighting should not be turned on unless needed;
- An overview of building wide energy efficiency strategies;
- An overview of tenancy energy efficiency expectations – this could include the expectation to provide laptops rather than tower pcs to staff;
- A guide to managing occupant behaviour – including, for example, advise to staff that computers should be hibernated or shut down each night and that screens should be switched off.

2.4 Detailed Design

The following sections provide details for each of the design options identified in the first part of this report.

2.4.1 Sealing Doors

There are 192 doors that connect air-conditioned and non-air-conditioned spaces. The most cost-effective way to seal doors is to use adhesive foam seal (**Figure 2-14**) to limit airflow around the top and sides of the doors, and door sweeps (**Figure 2-15)** to limit airflow below the door. Adhesive foam seal is available in different colours. Door sweeps can be rubber or brush. Rubber is more effective for this purpose.

Figure 2-14: Adhesive foam seal

Figure 2-15: Rubber door sweep

The installation of adhesive foam seal and rubber door sweeps is straight forward and can be undertaken by a non-specialist handy-person. However due to the high number of doors connecting AC and non-AC spaces, the estimated installed cost is relatively high at 267,000MVR. This is based on supply and install costs of 70MVR/m for form seal and 880MVR/m for door sweeps.

According to the United States Department of Energy Efficiency, properly sealed buildings can use 10-20% less air-conditioning energy than poorly sealed buildings.[4] However, in Maldives there is relatively low variation in energy consumption with outdoor temperature. Therefore estimated energy savings for this option are based on a conservative estimate of 5% of air-conditioning energy which gives savings of approximately 50,000kWh/year. This equates to 215,000 MVR/year or 45,000 $kgCO_{2(e)}$/year.

Beyond energy savings, this option would improve the indoor air quality of office space, particularly in areas in close proximity to tea rooms. Currently food smells are often transmitted from the tea rooms into office spaces.

The Team recommend this option.

2.4.2 Lobby windows, stairwell door and fresh air management

When staff were questioned about lobby windows being left open the reasons given were either that the lobby air-conditioning units were not working or that there was insufficient fresh air and the space was becoming stuffy.

[4] See http://www.cherp.net/what-importance-of-air-sealing. Other estimations are higher e.g. https://archive.airbarrier.org/conference/Steve%20Tratt%20-%20Air%20Sealing%20Existing%20Bldgs%20for%20Energy%20Savings.pdf

The solutions to the first problem, i.e., system upgrades and system maintenance are discussed in a later section. The solution to the second problem is twofold:

> During the sight visit it was found that switches to the HRV fresh air system were inaccessible due to furniture layout, i.e., some switches were behind cupboards or filing cabinets. Switch locations will need to be reviewed and where necessary furniture may need to be relocated.
>
> Further, most staff were unaware of the HRV fresh air system and therefore even when switches were accessible, the HRV system was often not running. Staff were aware of the lack of fresh air, but not aware of the availability of a solution. Staff education will be required so that key people know how to operate both the air-conditioning and the fresh air systems. Staff were not overly concerned about the increase in energy consumption caused by having the windows open. Again, this should be addressed through staff education.

We propose that switch accessibility is confirmed in each lobby and that key staff are made aware of how to use the fresh air system, who to contact if lobby air-conditioning is not working, and the implications of keeping lobby windows and stairwell door to roof open (provided closing this door does not pose a fire hazard)[5]. We estimate that this will cost 1200MVR the first year and 600MVR each subsequent year. This estimate is based on two staff days at a rate of 600MVR in the first year, and one staff day per year in subsequent years to review and re-educate staff.

Based on the monthly variations in air-conditioning energy consumption – likely due to window management, the Team estimates that energy savings for this option would be approximately 3,000KWhrs/year which equates to approximately 2700 $kgCO_{2(e)}$/year or 13,050MVR/yr. This equates to an initial payback period of one month for the upfront costs, and net annual savings of 12,450MVR thereafter. We therefore strongly recommend this option.

2.4.3 Positively pressurise air-conditioned spaces through the provision of outdoor air

The solution to this problem is simply to run the HRV fresh air system. As discussed in the previous section many staff are unaware of the HRV system. Further, many of the switches are not accessible. As for lobby management, we propose that switch accessibility is confirmed in each tenancy and that key staff are made aware of how to use the fresh air system. We estimate that this will cost 2400MVR the first year and 1200MVR each subsequent year. This estimate is based on four staff days in the first year, and two staff days per year in subsequent years to review and re-educate staff.

This option will result in slightly increased energy consumption. However, due to the low temperature differential between the external temperatures and internal set point it is unlikely to be a significant increase. We estimate increased energy consumption of 50,000kWh/year which equates to 215,000 MVR/year or 45,000 $kgCO_{2(e)}$/year. This is based on 5% of air-conditioning energy on a similar basis of assumption to the savings estimations for building sealing. The annual staff costs are estimated at 1,200 MVR, and thus net annual costs 217,200 MVR/year.

Although there are no direct cost savings, the purpose of this suggestion is to ensure spaces meet minimum fresh air requirements. When fresh air requirements are not met it is difficult for staff to perform as they typically feel lethargic, headachy and take more sick days. Studies have shown that healthy offices can increase staff productivity by more than 10%. There is an opportunity to assess the increase in staff productivity in Velaanaage from this change. This can be done through a comparison of staff absence over the year preceding and the year following the change. Even if the resulting increase in productivity was only a tenth of that estimated in studies, i.e., 1%, this would equate to significant cost savings overall. On this basis we strongly recommend this option.

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[5] The Team have not reviewed fire safety provisions for Velaanaage. If the stairwell door to the roof is required to remain open for fire safety this should be given priority over any energy efficiency measures suggested here.

2.4.4 Installing low-e film on windows with direct solar access

Several buildings in Male' have already installed low-e film to manage heat loads and glare with good success. **Figure 2-16** provides an example of the effectiveness of low-e glazing – showing heat gains through glazing before and after installation.

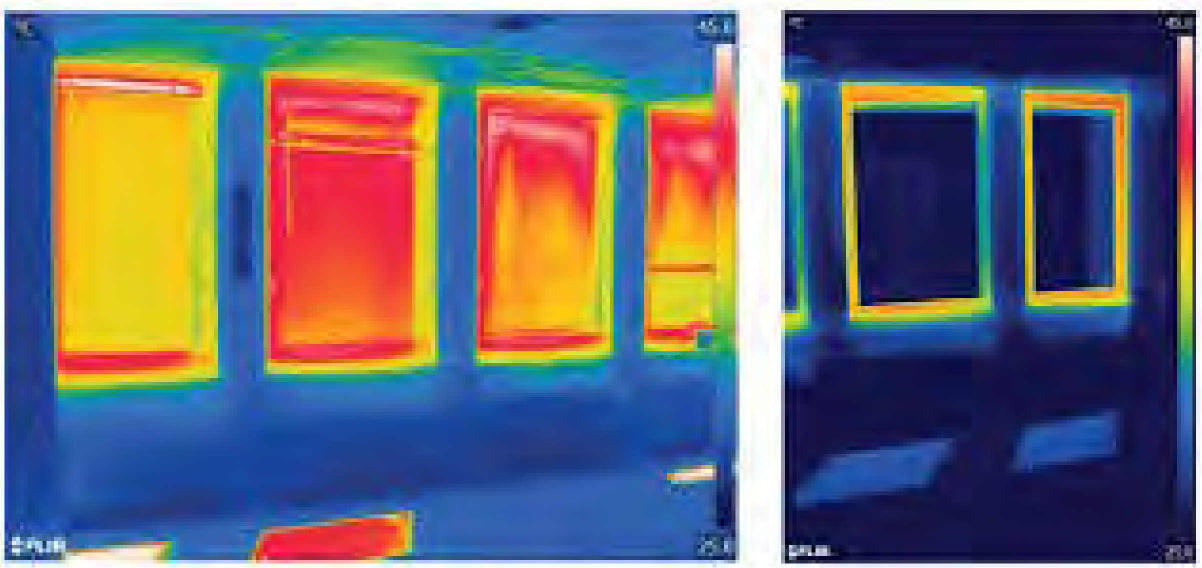

Figure 2-16 Heat loads through glazing before and after installation of low-e film

Installation of low-e film must be done by experienced trades people. Once installed, there are no ongoing costs associated with this option. However, cleaners should be educated to follow care instructions in order to optimise the life of the film.

The installed cost of film is estimated at 2 million MVR if locally sourced. This is based on a total glass area of just under 2,200 and a supply and install cost of 900MVR/m^2. However, our research suggests that if material is imported from China for the project, installed costs can be reduced to approximately 435,000MVR. This figure is based on a direct import plus installation cost of 200MVR/m^2 including 20% import duty.

We recommend low-e film with a shading coefficient (SC) of ≤0.7 (the lower the better) and a visual light transmission as high as possible (no less than 50%). With a visual light transmission of 50% or more, daylight levels should be substantially improved compared to the status quo where blinds are typically drawn to manage glare and thermal comfort. Energy savings are estimated to be 30,000 kWhrs/year – on the basis that this would provide a 30% reduction in façade loads which are currently estimated at approximately 100,000kWhrs/year. This equates to savings of 27,000 $kgCO_{2(e)}$/year or 130,500MVR/year; a payback period of less than 7 years (15 if locally sourced).

The benefits of installing low-e film are greater than energy savings. It will improve thermal comfort, daylighting (as blinds will not need to be kept closed to the same extent) and staff wellbeing (and therefore productivity) due to better connectivity to the environment.

We strongly recommend this option.

2.4.5 Positive Replacement of VRV II systems with VRV IV HE

There are 22 VRV II units that are more than 7-10 years old which should be replaced immediately. When the units are replaced, this is likely to result in energy savings of 125,000 kWhrs/year (saving calculated using the energy consumption difference between existing systems and proposed units) which equates to 112,500 $kgCO_{2(e)}$ /year or 550,000MVR/year. The capital cost to replace the equipment is estimated at 16 million MVR. There is no cost increment that can be attributed to energy efficiency. The savings are based on replacement of old systems with current day good practise systems. Less efficient units equivalent to the ones currently used are no longer available on the market. As such, the energy and greenhouse gas savings will be realised upon replacement of the units. Further, as discussed previously, the refrigerant used in these older units (R22) is no longer available, maintenance of these becomes prohibitively expensive.

A plan should then be developed to ensure that VRV units are upgraded as they reach the end of their useful life. The useful life can be extended with regular maintenance. As such, provided a regular maintenance contract is commenced, the useful life for these units can be assumed to be at the upper end of the range, i.e. 10 years.

In order to address the phantom load, air-conditioning equipment serving communications rooms should be specifically considered. Based on the review of the plant and installation conditions, upgrading to modern units and installing condensers with appropriate air flow would be expected to reduce energy consumption in communications room air conditioning by an average of ~25%. This is expected to equate to ~50MWHrs per year.

The works to achieve these savings would include the replacement of 18 communications room air conditioning units. Units should be selected with at least 20% spare capacity over the current operating air conditioning capacity. The capital cost to replace this equipment would be approximately 12 million MVR. The payback period for this initiative would be well over 20 years and thus not worthwhile from a purely efficiency point of view. As such, we recommend replacing these units only as they near the end of their useful life.

2.4.6 Guidelines for integrating internal fitouts and air-conditioning

A tenant guideline should be developed that explains to tenants how best to use the building and building systems. Within this document, tenancy fitout guidelines should be included. These should include the following instructions with respect to the air-conditioning system:

- Avoid placing internal partitions underneath or very close (<0.5m) to ceiling cassette units as this prevents them from operating properly.
- In the instance that cassette units are located where partitions are required, the cassette units should be relocated.
- There should be a fresh air supply and a cassette unit in every occupied space (i.e., this is not necessary for storerooms etc).
- There should be no more than one cassette unit in small offices or meeting rooms. Larger board rooms with high occupancy may require more than one.
- Cassette units should be distributed as evenly as possible within open plan office areas. They should be located as centrally as possible in meeting rooms and offices.

2.4.7 Guidelines for integrating internal fitouts and lighting

A tenant guideline should be developed that explains to tenants how best to use the building and building systems. Within this document, tenancy fitout guidelines should be included. These should include the following instructions with respect to the lighting system:

- Internal partitions should not be located below lights as this blocks the light.
- In the instance that cassette units are located where partitions are required, the cassette units should be relocated.
- Light zoning should be considered in tenancy fitout design. Lights should be rewired as required so that all lights on a given switch are in the same space and/or serve the same purpose. For example, a single switch should not be connected to lights on different sides of a partition.
- Where possible lights should be evenly distributed within each space.

The cost of developing tenancy guidelines is estimated at 185,000MVR. Estimated savings are 50,000KWh/year. This is based on the Team's experience that suggests 5-10% of airconditioning energy consumption can be saved with proper fitout – a conservative estimate of 5% has been used here. This equates to 45,000 kgCO_2/year or approximately 215,00MVR per year, i.e., a payback period of less than 1 year.

2.4.8 Regular maintenance of air-conditioning system (including outdoor air supply)

Maintaining the air-conditioning system not only improves energy efficiency, it also improves indoor air-quality. A maintenance contract has been estimated at 400,000 MVR/year (for each unit to be serviced once a year). This should include, at a minimum, the cleaning/changing of filters on every unit. Routinely serviced air conditioners can reduce energy consumption by 5-15%. Using an conservative estimate of 5% energy saving for servicing air conditioning system regularly, the expected increases in energy efficiency translate into savings of 50,000KWhr/year or 220,000MVR/year.

2.4.9 Replacement of tower PCs with laptops

The replacement of tower PCs with laptops is costly. We estimate that the cost differential between tower PCs and equivalent performance laptops is USD$500. However, they use significantly less energy.

We do not recommend upgrading the fleet of tower PCs to laptops solely as an energy efficiency measure. However, we recommend that tenant guidelines include recommendations to purchase laptops instead of tower PCs when computers are being upgraded. The following points should be included in the tenant guidelines.

- Laptop computers use approximately 45% less power than tower PCs
- Laptop computers encourage more efficient working styles – for example they can be brought to meetings which eliminates the need to transfer written notes to typed notes.
- Laptops also encourage flexible working, which has been demonstrated to improve worker satisfaction and worker output.

2.4.10 Replacement of T8 lights with LEDs

T8 lights are significantly less efficient than LEDs and have significantly shorter lifetimes. The costs to replace existing T8s with LED panels similar to those already used in two of the existing panels is estimated at 770,000 MVR for the 700 lights. This is based on 920 MVR per light supplied and 171 MVR per light for installation. Energy savings are estimated at 125,000 KWh/year which equates to approximately 540,000 MVR/year (i.e., a payback period of approximately 1.5 years). This calculation is based on existing wattage of 10.2W/m^2 and an assumed LED wattage of 4.5W/m^2. Operational hours are assumed to be 9 hours a day and 245 days per year, with a floor area of approximately 10,000m^2.

To avoid unnecessary waste of existing lights, we recommend replacing all the T8s in the building with LEDs at the end of their life.

We propose that LED panels similar to those which are already installed in some of the tenancies are installed throughout Velaanaage. The LED panels should have the following minimum specifications:

- Power ≤ 36 Watts
- Luminous flux ≥ 3600 lumens

2.4.11 Rewiring of lights

When the existing T8s are replaced by LEDs and/or when lighting systems are rewired for different tenancy layouts it is recommended that the existing circuits are revised such that switching zones are parallel to the façade rather than perpendicular (see **Figure 1-39** in **subsection 1.4.11:** Internal Lighting). This will allow perimeter lighting to remain off during daylight hours for the majority of the year, providing up to a further 50MWhrs per annum of savings. This estimation is based on savings for an LED system with a perimeter zone of approximately 4m, and operational hours of 9 hours per day and 245 days per year. The actual savings will vary depending on the position of lights, and how many rows of lights left off in practise which will depend on occupant preferences and behaviours.

The costs of implementing this solution in tandem with other lighting upgrades is negligible.

2.4.12 Provision of signage for vertical transport

We estimate that signage explaining which lift to take to different floors and encouraging building occupants to use the stairs could save one in five trips, an energy saving of 5,400kWh/year (one fifth of current vertical transport energy usage) which equates to approximately 4860 $kgCO_{2(e)}$ /year or 23,500MVR/year.

Signage has been estimated at 30,000MVR based on two signs per floor – one for the lifts and one at the stairs. This gives a payback period of a little over one year. We strongly recommend this option. Elevator signage should include clear information about which departments can be accessed by each lift. Stair signage should be designed to encourage people to walk if their trip is less than three floors down or two floors up.

2.4.13 Regular solar panel maintenance

Solar panels must be regularly cleaned to avoid efficiency losses. In the Male' environment there is a lot of salt in the air which deposits on the panel surfaces. We recommend that the solar panels are cleaned twice a year. This can be done by a non-skilled labourer. We estimate that this will cost 2,000MVR/year (based on 5 man days per year). Energy savings (increased energy output) is estimated at 3,000kWh/year which equates to 13,050MVR or 2,700 $kgCO_{2(e)}$ /year.

2.4.14 Smart Buildings

A Building Management System (BMS), sometimes called a Building Automation System (BAS), is a computer-based system installed to control and monitor a building's electrical equipment such as ventilation, lighting, energy, fire systems, and security systems.

Flexibility and function of such systems vary from system to system. The Team recommends the B-Tune or similar system for a building like Velaanaage. A suitable BMS can control timed shutdown of electrical equipment and lighting saving energy and related costs.

The costs of such a building tuning system such as B-Tune cannot be directly estimated as they range significantly with building performance and corresponding works needed. However, for a building such as Velaanaage, we estimate a payback period of 3-5 years.

2.4.15 Occupant behaviour strategies

The Team recommend the following strategies to improve occupant behaviour:

- Develop a building-users guide with recommendations for best practise behaviours including:
  - hibernating or switching off computers each night,
  - switching off monitors and hibernating computers for meetings and lunch breaks,
  - not switching lights or air-conditioning on in unoccupied spaces and turning them off when vacating spaces.
- Provide annual training to tenant representatives who will take responsibility for tenancy energy consumption.
- Share tenant energy consumption with tenants. When this is higher than average, communicate this to tenants.
- Run intermittent energy efficiency competitions between tenancies with prizes to encourage participation and awareness. For example, tenancies could compete for the greatest percentage reductions in energy consumption over a month compared to the past year's consumption for the same month. Rewards could include a financial contribution towards a

staff function such as a morning tea. The winners could also be displayed in the lift lobbies for all to see. Live monitoring or a daily updated leader board displayed in the lobby could be used to encourage active participation over the month.

Older computers can draw between 50 – 100 Watts/hour while idling. Sleep mode typically reduces this by a third and hibernating or switching off computers drop the draw to 0 – 3-4Watts/hour. As most computers were found to be on when not in use, this means that simply educating building users to hibernate or shutdown their computers could save as much as 250,000kWh/year, which equates to 1 million MVR/year or 225,000 $kgCO_{2(e)}$ /year (assuming an 80% success rate).

Many studies have shown that occupant behaviour strategies can result in reductions in energy consumption of as much as 10-20%. This means 332,000 – 664,000 kWhrs /year, or 300,000 – 600,000 $kgCO_{2(e)}$ /year, which equates to savings of 1.4 million to 2.8 million MVR/year.

There are a number of ways to encourage pro-environmental behaviour change for building users. In general, the prerequisites for behaviour change are that the person:

1. Wants to behave in the desired way;
2. Has the skills and knowledge that allows them to behave in the desired way
3. Has the tools required to behave in the desired way
4. Does not have any obstacles preventing them to behave in the desired way.

In general, people do want to behave in a way that is best for the environment. Typical barriers that prevent this are a lack of knowledge of how their behaviour effects the environment, inconvenience caused by certain behaviours, or lack of skills/knowledge of how to perform the behaviour.

At Velaanaage we have found all of these barriers to be true. While most staff feel that they have the power to influence energy consumption and sustainability in their homes, significantly fewer feel that they are able to influence these factors in the office. Moreover, most tenants have a poor understanding of how the air-conditioning systems work (e.g., they do not realise that the outdoor air system needs to be switched on), and the systems provide obstacles to efficient use (poor access to switches, poor zoning meaning that lights are on in unoccupied areas in order to light occupied areas).

To address this, we recommend the development of a building user guide that explains how best to use the building systems, and to hold training for select staff from each tenancy, to teach them to change the behaviour of their staff. These key staff members could then hold internal training sessions for the respective tenancies. There will be ongoing costs to implement these strategies. A detailed building users guide could be developed alongside the tenancy fitout guidelines for approximately 90,000MVR. Initial staff training could be carried out for approximately 120,000MVR. This is based on a 2-day workshop for up to 30 staff from facilities management and each tenancy.

Implementation of ongoing measures such as competitions could be done as part of facilities management (FM) duties in coordination with key staff members. A day a fortnight of FM time towards driving occupant behaviour would make a substantial difference. The ongoing costs are therefore estimated at 30,000MVR/year.

Assuming total upfront costs of 210,000MVR and a conservative estimate of net savings of 1.35 million MVR/year, this gives a payback period of less than 2 months.

2.5 Energy and Greenhouse Gas Savings

The table below shows the estimated costs, and potential energy greenhouse gas (GHG) and cost savings of the different design options listed above.

Action	Estimated Cost (MVR)	Estimated Cost savings (MVR/yr)	Energy savings kWhrs/year	GHG savings (kgCO2(e) /year)	Payback Period	Recommended?	Comments
Improve seal around doors that connect air-conditioned and non-air-conditioned spaces	267,000	215,000	50,000	45,000	1.2	Yes	5% of air conditioning energy.
Positively pressurise air-conditioned spaces through the provision of outdoor air	1,200	-215,000	-50,000	-45,000	NA	Yes	Expected to increase energy consumption but provide improved indoor environment quality and therefore increase staff productivity.
Keep windows to lobby and stairwell door to roof closed	1,200	12,450	3,000	2,700	1 month	Yes	Based on monthly variations in lobby air conditioning power consumption

Action	Estimated Cost (MVR)	Estimated Cost savings (MVR/yr)	Energy savings kWhrs/year	GHG savings ($kgCO_2(e)$ /year)	Payback Period	Recommended?	Comments
Installing tinted low-e film on windows subject to direct solar radiation	2,000,000	130,500	30,000	27,000	<7	Yes	Based on 30% reduction in façade loading
Replacement of VRV Units	NA	550,000	125,000	112,500	NA	Yes	Capital cost based on replacement as equipment reaches end of life. Savings based on energy consumption of existing vs new units.
Replacement of Communications Rooms AC Units	NA	220,000	50,000	44,000	NA	Yes	Capital cost based on replacement as equipment reaches end of life. Savings based on 25% reductions in Communications Rooms AC loads.

Action	Estimated Cost (MVR)	Estimated Cost savings (MVR/yr)	Energy savings kWhrs/year	GHG savings ($kgCO2(e)$ /year)	Payback Period	Recommended?	Comments
Guidelines for integrating internal fitouts and air-conditioning and lighting	185,000	215,000	50,000	45,000	<1	Yes	5% of air conditioning energy. Not expected to have any significant energy saving, rather improved indoor environment quality.
Regular maintenance of air-conditioning system (including outdoor air supply)	0	-180,000	50,000	45,000	NA	Yes	5% of air conditioning energy
Replacement of tower PCs with laptops	7,500,000	87,000	20,000 kWhrs/year	18,000 $kgCO_{2(e)}$ p.a.	NA	Yes	Performance may be slightly better than this as new computers will reduce wait times and increase occupants preparedness to shutdown when not in use.

Action	Estimated Cost (MVR)	Estimated Cost savings (MVR/yr)	Energy savings kWhrs/year	GHG savings (kgCO2(e) /year)	Payback Period	Recommended?	Comments
Replacement of T8 lights with LEDs	770,000	540,000	125,000	112,500	≈1	Yes	
Rewiring of lights so that control circuits run in parallel to the façade	NA	220,000	50,000	46,000	NA	Yes	It is assumed that this change occurs when lighting upgrades are already planned so that costs are negligible.
Provision of signage for vertical transport	24,000	23,500	5,400	4860	1	Yes	Based on one in five trips saved
Regular solar panel maintenance		11,050	3,000	2,700	<1	Yes	Based on ~5% improvement in outcome
Building Tuning System	NA	NA	NA	NA	3-5 years	Yes	Costs vary substantially depending on building performance and necessary works.
Occupant Behaviour	210,000	1,350,000	310,000	280,000	<1	Yes	Based on savings of 10% energy consumption.

Table 2-1 Estimated energy and GHG savings for proposed energy saving options

Section 3
Monitoring Plan

3.1 Site Boundary

The Velaanaage office building is powered from a three-phase feed located within the undercroft level.

Power is fed through the building from distribution boards, with the largest of which located on ground floor and containing all tenant sub-meters.

The building includes a large solar photovoltaic array at roof level. Power from this array is fed directly back into the grid and does not influence energy consumption within the building.

The building also includes a diesel generator which is tested regularly and has the capacity to satisfy some electrical demand on site.

The energy flows across the boundary are therefore:

- Diesel fuel in
- Electricity flow in (main building)
- Electricity flow out (solar array)

3.2 Strategic Aims

The metering for these facilities is to allocate costs from the power generation utility to the department responsible for their operation.

Metering is also provided for common area services to facilitate their optimisation and management.

Data is provided to the onsite building management team monthly, in accordance with billing periods. High level analysis of total energy consumption is completed on monthly data, with the primary metric being consumption differential from previous months. It is up to the site team to investigate and make allowances for changing usage patterns on site.

Limited data is provided to tenants for review of their energy consumption.

Energy generation data for the solar array is displayed (kWhrs generated per day) in the main lobby as part of a user education and engagement system:

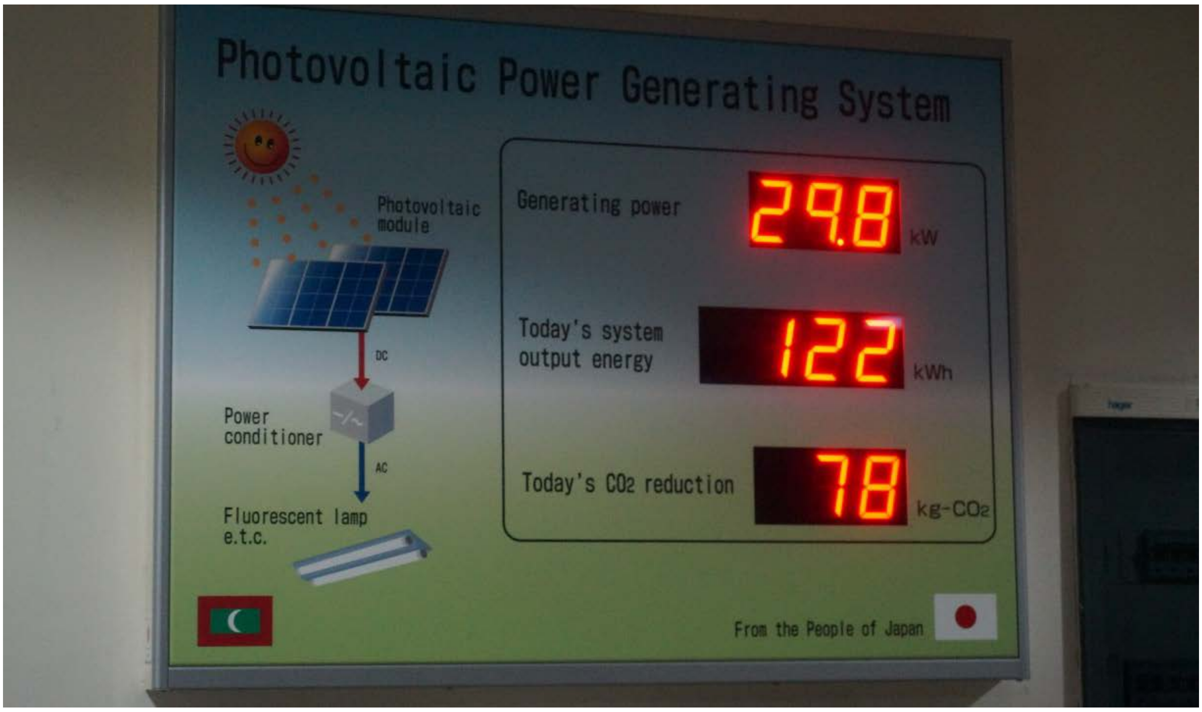

Figure 3-1: Expected annual energy usage by equipment groups for the accommodation unit

3.3 Metering System Arrangement

3.3.1 Current System

Currently, the building includes meters for each half floor (north and south each level) and major building energy uses, as follows:

Meter Reference	Allocated Area	Meter Reference	Allocated Area
36094	1B	**36077**	10A
36056	1A	**36074**	11B
36092	2B	**36075**	11A
36093	2A	**36072**	12B
36090	3B	**36073**	12A
36091	3A	**36063**	Roof Comms Room
36088	4B	**36064**	Water Pumping
36089	4A	**36065**	Fire Pump
36086	5B	**36066**	Lifts
36087	5A	**36067**	Reception
36084	6B	**36068**	Lobby Power
36085	6A	**36069**	Lobby Lighting
36082	7B	**36062**	Lobby AC
36083	7A	**36070**	Ground Floor?
36080	8B	**39864**	Basement
36081	8A	**51890**	Car Park Ventilation
36078	9B	**36071**	Canteen
36079	9A	**37210**	GF Bank
36076	10B	**40227**	Pik Post

Table 3-1: Meter details for the Velaanaage office building

Meters are manually read monthly or as determined by site maintenance staff.

The solar panels on the roof have a digital meter reading system which provides daily usage to a display board in the building foyer.

3.3.2 Best Practice System

Best practice metering systems would provide increased quanta of meters and improved dissemination of data. Generally, metering should be provided as follows for office buildings:

- For each tenancy (i.e. two off per floor)
    - Separate Lighting Consumption
    - Separate General Power Consumption
    - Separate Air Conditioning and Ventilation Consumption
    - Communications or Server Rooms and Associated Air Conditioning
- Common Area Lighting

- External Lighting
- Car Park Lighting and Ventilation
- Building Security
- Café Tenancy
- In-Building food service area
- Lifts

In addition, metering should be automatically read at least once per hour with data logged and available for review and analysis.

Meter data should be readily available to tenants, as a minimum, tenant consumption should be reported monthly. Tenants should also be provided with how their consumption compares to other tenants (per m^2) and previous performance (last month and same month 1 year and 2 years ago).

Note that the method of meter reading and data presentation is dependent on the metering system used. Best practice systems would not require interaction or action by the tenant. Meter data would be automatically collected and emailed directly to tenant representatives.

If manual meter readings are required, tenants should maintain a spreadsheet with regular reads of meter face values and times/dates of reading maintained. Consumption between two readings is calculated by subtracting the first face reading from the second.

3.4 Major Energy Uses

The major energy consumers of the building are on server rooms, air conditioning and building equipment. Based on site observations and calculations energy budget for the building is given in subsection 1.6: Energy Budget. Refer to the subsection for more details and derivations.

3.5 Metering Arrangement

3.5.1 Meter Reading Strategy

Currently, meters are read manually every month. With data tabulated and sent to relevant parties for bill payment.

There is no clearly documented strategy for dissemination of information and most tenancy managers were unaware of their energy consumption patterns. Similarly, there is relatively limited understanding of how energy was consumed within each tenancy, or how tenant activity influenced power consumption.

3.5.2 Meter Location

All tenant meters are located in the main building distribution room at ground level. There are some additional meters within the basement level where the generator connects into the building.

Figure 3-2 shows the existing building electrical schematic.

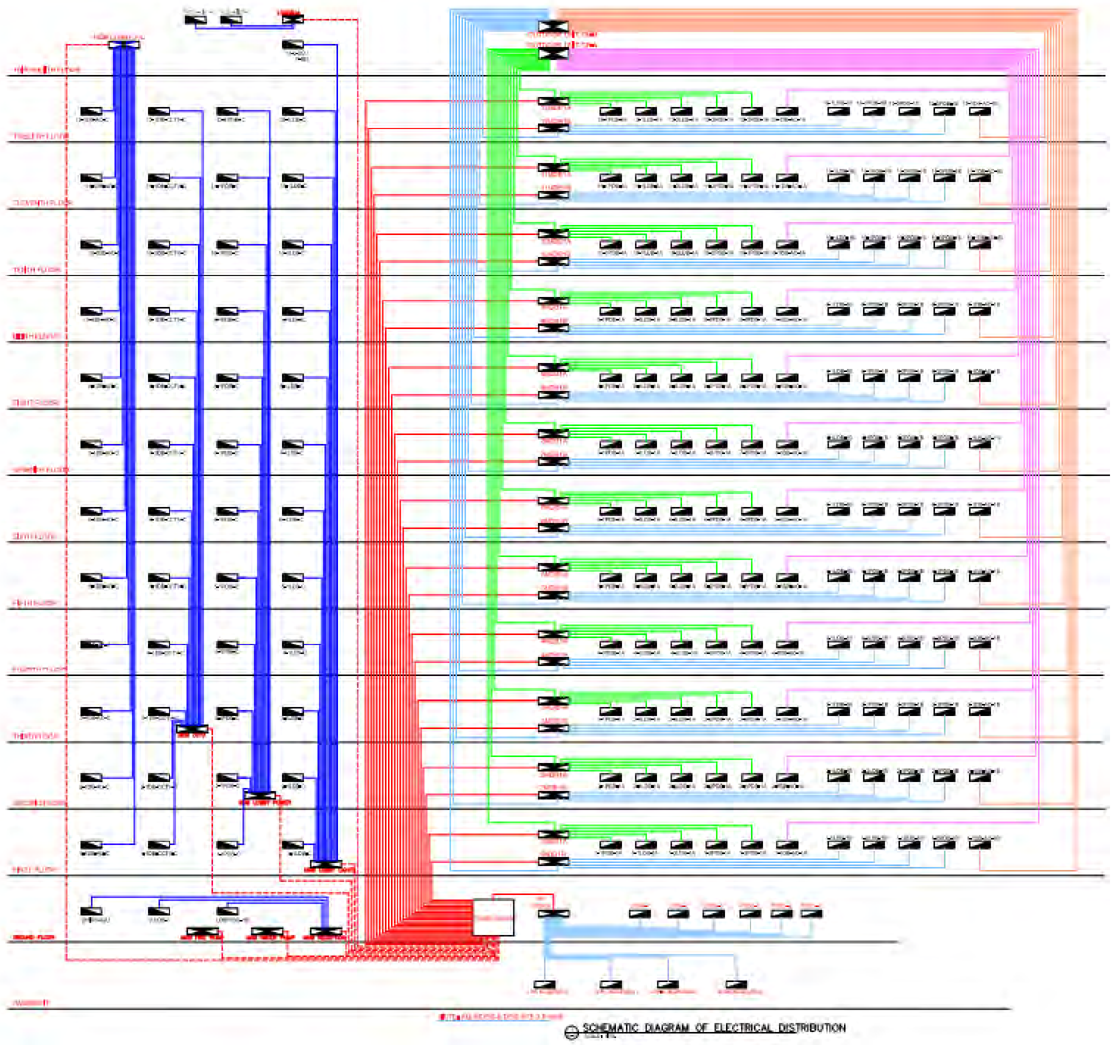

Figure 3-2: Existing Electrical Meter Locations

All building energy consumption is electric. Sub meters are used to allocate consumption within the building. Addition meters, with automated reading systems are recommended to properly track electrical consumption within the building.

The existing meters which are read monthly are shown in **Table 3-2**.

Meter Type	Proposed Designation	Account Number	Meter Number	Owner	Usage
Base Building	BE-01	0000036063	4982048	MINISTRY OF FINANCE & TREASURY	**Roof Comms Room**
Base Building	BE-02	0000036064	4982053	MINISTRY OF FINANCE & TREASURY	**Water Pumping**
Base Building	BE-03	0000036065	9133166	MINISTRY OF FINANCE & TREASURY	**Fire Pump**
Base Building	BE-04	0000036066	9133172	MINISTRY OF FINANCE & TREASURY	**Lifts**
Base Building	BE-05	0000036067	3565709	MINISTRY OF FINANCE & TREASURY	**Reception**
Base Building	BE-06	0000036068	3565711	MINISTRY OF FINANCE & TREASURY	**Lobby Power**
Base Building	BE-07	0000036069	3565716	MINISTRY OF FINANCE & TREASURY	**Lobby Lighting**
Base Building	BE-08	0000036062	9133188	MINISTRY OF FINANCE & TREASURY	**Lobby Air Conditioning**
Base Building	BE-09	0000036070	911150087	MINISTRY OF FINANCE & TREASURY	**Ground Floor Security**
Base Building	BE-10	0000039864	11214985	MINISTRY OF FINANCE AND TREASURY	**Basement**
Base Building	BE-11	0000051890	215383523	PUBLIC WORKS SERVICES	**Car Park Ventilation**
Tenant	TE-G01	0000036071	911140897	MINISTRY OF FINANCE & TREASURY	**Canteen**

Meter Type	Proposed Designation	Account Number	Meter Number	Owner	Usage
Tenant	TE-G02	0000037210	905160008	MINISTRY OF FINANCE & TREASURY	**GF Bank**
Tenant	TE-G03	0000040227	1107112032309	MINISTRY OF FINANCE AND TREASURY	**Pik Post**
Tenant	TE-01B	0000036094	911150067	MINISTRY OF FINANCE & TREASURY	**1B**
Tenant	TE-01A	0000036056	911150089	MINISTRY OF FINANCE & TREASURY	**1A**
Tenant	TE-02B	0000036092	911150084	MINISTRY OF FINANCE & TREASURY	**2B**
Tenant	TE-02A	0000036093	911150070	MINISTRY OF FINANCE & TREASURY	**2A**
Tenant	TE-03B	0000036090	911150066	MINISTRY OF FINANCE & TREASURY	**3B**
Tenant	TE-03A	0000036091	911150077	MINISTRY OF FINANCE & TREASURY	**3A**
Tenant	TE-04B	0000036088	911150079	MINISTRY OF FINANCE & TREASURY	**4B**
Tenant	TE-04A	0000036089	911150091	MINISTRY OF FINANCE & TREASURY	**4A**
Tenant	TE-05B	0000036086	911150073	MINISTRY OF FINANCE & TREASURY	**5B**
Tenant	TE-05A	0000036087	911150088	MINISTRY OF FINANCE & TREASURY	**5A**
Tenant	TE-06B	0000036084	9111500082	MINISTRY OF FINANCE & TREASURY	**6B**
Tenant	TE-06A	0000036085	9111500092	MINISTRY OF FINANCE & TREASURY	**6A**
Tenant	TE-07B	0000036082	911150086	MINISTRY OF FINANCE & TREASURY	**7B**
Tenant	TE-07A	0000036083	905160006	MINISTRY OF FINANCE & TREASURY	**7A**
Tenant	TE-08B	0000036080	911150090	MINISTRY OF FINANCE & TREASURY	**8B**
Tenant	TE-08A	0000036081	911150075	MINISTRY OF FINANCE & TREASURY	**8A**
Tenant	TE-09B	0000036078	911150085	MINISTRY OF FINANCE & TREASURY	**9B**
Tenant	TE-09A	0000036079	911150094	MINISTRY OF FINANCE & TREASURY	**9A**
Tenant	TE-010B	0000036076	911150071	MINISTRY OF FINANCE & TREASURY	**10B**
Tenant	TE-010A	0000036077	911150076	MINISTRY OF FINANCE & TREASURY	**10A**
Tenant	TE-011B	0000036074	911150080	MINISTRY OF FINANCE & TREASURY	**11B**
Tenant	TE-011A	0000036075	911150074	MINISTRY OF FINANCE & TREASURY	**11A**
Tenant	TE-012B	0000036072	911150081	MINISTRY OF FINANCE & TREASURY	**12B**
Tenant	TE-012A	0000036073	911150083	MINISTRY OF FINANCE & TREASURY	**12A**

Table 3-2: Estimated annual energy consumption for the Velaanaage office building

Figure 3-3 shows the current power supply for a typical floor on site, with recommended additional meters shown dashed

3.5.3 Additional Meters

Additional meters are recommended for major uses on each floor and within each tenancy, as shown in **Figure 3-3.** This allows for four separate tenancies on each floor, with two dedicated communications rooms, or other major usage – e.g. café.

Meters should be connected to data harvesting devices to allow detailed logging and analysis beyond simple month to month total energy comparison.

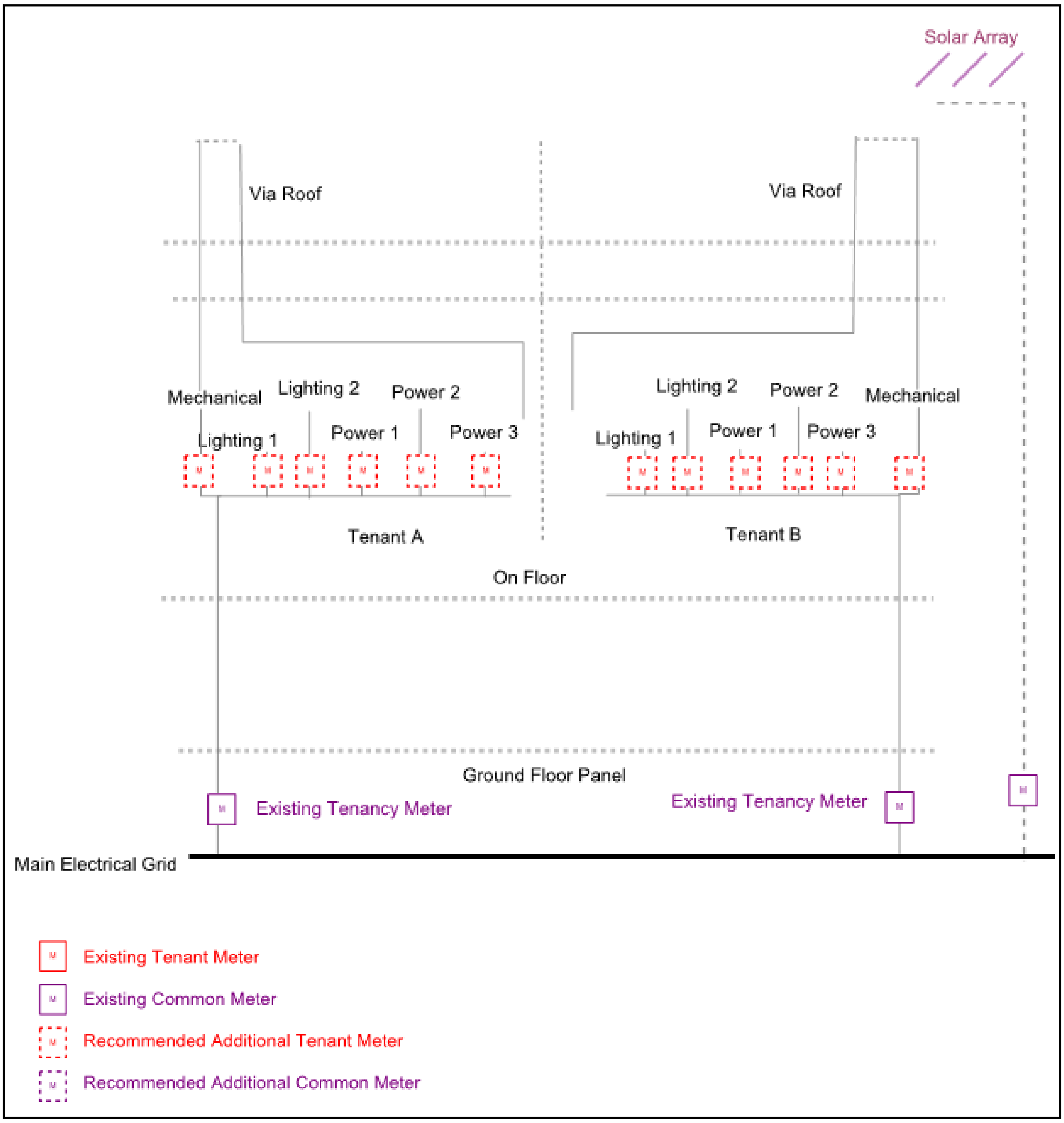

Figure 3-3: Metering Schematic

3.5.4 Occupant Engagement

Provision of sub-meter data as per **Table 3-2** is considered highly desirable to promote energy efficiency on site and provide additional data to allow occupant review and management intervention.

Metrics such as peak power consumption, after hours power consumption and consumption relative to ambient conditions will provide valuable information into determining elements which influence power consumption and assist in ongoing management and power reduction.

Detailed data also assists in educating and engaging users with respect to how their actions influence building operation and energy efficiency.

3.5.5 Tenant Roles and Responsibilities

Tenants should play an active role in managing their energy consumption, however, as meters are located in common areas and plant rooms, data collection is best undertaken by others.

Tenants therefore should:

- Confirm hours of occupancy to building management monthly
- Alert building management for any changes in tenancy, including refits or refurbishments or changes in occupant levels or hours.
- Provide sub-meters for major energy uses such as communications rooms or tenant installed air conditioning systems
- Receive and review their own electricity consumption – review should entail comparison to previous month and the same month in the past two years. Changes in energy consumption of more than 5% should be investigated.

3.6 Design Recommendation Verification

The Team have made a number of recommendations with regards improving performance. Monitoring plans to verify performance for these features are as follows:

Design Recommendation	Expectation	Verification	Equipment Required
Improve seal around doors that connect air-conditioned and non-air-conditioned spaces	Improved door seals should reduce air leakage into occupied space.	Take thermal image of door before and after seal installation. Photo after should show a <2 degree difference in air temperature between door edge and adjacent wall – external temperature should be >10 degrees warmer than internal temperature.	Thermal imaging camera, FLIR TG165 or equivalent.
Keep windows to lobby closed and manage fresh air through the HRV fresh air supply system and Close stairwell door to roof (provided this does not pose a fire hazard)	Reduced building leakage should improve pressurization and reduce energy consumption.	Log temperatures within lobby spaces on all floors and compare to adjacent office space and ambient conditions. Temperature within lobbies during office hours should be closer to adjacent office temperature than ambient. Install temperature loggers within lobbies (adjacent lift), within office space on the same floor (away from windows) and in external condition.	Temperature loggers – minimum 5 off (to allow two floors to be tested simultaneously). Temperature loggers to be +/- 0.5K and to log temperature in 15 minute intervals for a minimum 48 hour period.
Positively pressurise air-conditioned spaces through the provision of outdoor air	Positive pressurization should reduce air leakage to the building.	Take thermal image of door (without new seals) to staff kitchen area before and after use of air conditioning system. Photo after should show a <1 degree difference in air	Thermal imaging camera, FLIR TG165 or equivalent.

Design Recommendation	Expectation	Verification	Equipment Required
		temperature between door edge and adjacent wall – external temperature should be >10 degrees warmer than internal temperature.	
Installing tinted low-e film on windows subject to direct solar radiation	Improved glass performance should reduce energy consumption.	Compare energy consumption for tenancy with tinting installed before and after installation. Measure and record weekly energy consumption for a period of at least 4 weeks after change and compare data. Energy consumption post change should be less than prior – depending on period of year and performance of tinting.	Nil, utilise existing meters.
Replacement of VRV II systems with VRV IV HE	Improved efficiency of air conditioning systems should reduce energy consumption.	Compare energy consumption for tenancy with tinting installed before and after installation. Measure and record weekly energy consumption for a period of at least 4 weeks before and after change and compare data. Energy consumption post change should be less than prior – depending on period of year and performance of tinting.	Nil, utilise existing meters. Visual inspection of installed condenser units.
Guidelines for integrating internal fitouts and air-conditioning	Correctly installed and operating tenancies should result in lower energy consumption.	Visual inspection of completed tenancies.	Nil, trained staff to complete audit.
Guidelines for integrating internal fitouts and lighting	Correctly installed and operating tenancies should result in lower energy consumption.	Visual inspection of completed tenancies.	Nil, trained staff to complete audit.
Regular maintenance of air-conditioning system (including outdoor air supply)	Appropriately maintained units should provide lower energy consumption and improved air quality.	Maintenance logs by contractors.	Nil.

Design Recommendation	Expectation	Verification	Equipment Required
Replacement of tower PCs with laptops	Laptops use significantly less energy than desk top PC's.	Visual inspection. Measure and record peak consumption and average weekly energy consumption for a period of at least 4 weeks before and after change and compare data. Peak energy consumption post change should be ~5W/m2 lower after the change. Average weekly energy should be 0.7kWhrs/m2 lower after the change.	Energy logger as used by The Team.
Replacement of T8 lights with LEDs	LED fittings would be expected to significantly reduce energy consumption within the space.	Visual inspection. Note that the existing control strategy and poor lighting design quality does not allow for monitoring verification of this initiative.	Nil, trained staff to complete audit.
Provision of signage for vertical transport	Reduced use of lifts should result in lower energy consumption.	People counter on stairs, data from lift energy meter. Install people counter on stairs between each level and record people using stairs daily for a 4 week period before and after signage installation. Record lift energy consumption each day over a 4 week period.	Utilise existing lift meter with manual read by trained staff at the same time each day. Digital infrared automatic retail traffic people counter, MPN, LA5197 or equivalent.
Regular solar panel maintenance	Cleaned solar panels should produce more energy than prior to cleaning.	Install data logger on energy generation from solar cells and compare peak energy output over a one week period before and after cleaning.	Energy logger as used by The Team
Occupant behaviour strategies	Engaged and educated tenants should reduce energy consumption.	Compare monthly and annual energy consumption prior to implementation of actions. Complete annual employee survey on energy efficiency performance of their tenancy and the building. Compare performance over time.	Nil, utilise existing metering.

Table 3-3: Design Recommendation verification

Section 4
Energy Efficiency Policy

4.1 Background

The Maldives imports 100% of its fossil fuels for electricity generation which is understood to represent approximately 20% of national GDP [Energy Policy Overview – Ahmed Ali, MoE] and costs for electricity range between 0.3 to 0.7 USD/kWh.

The extensive use of electricity, created by fossil fuels, presents numerous problems for the Maldives including:

- Significant cost
- Limited energy security
- Increased CO_2 emissions

The last of the above is of particular concern for the Maldives which has a far higher exposure to the risk of ocean level rises and increased storm activity due to climate change than most nations.

It is therefore imperative that the Maldivian government actively seeks to reduce reliance on fossil fuel generated electricity through both the inclusion of renewable generation and also the improvement of energy efficiency outcomes within its assets.

This policy directly targets the improvement of energy efficiency and intended to address parts of Policy 02 of the Guiding Principles of Maldives Energy Policy, as per MoE, 2016: Maldives Energy Policy and Strategy.

4.2 Energy Policy

4.2.1 Policy

The Maldivian Government is committed to delivering energy efficiency as a key part of our response to the risks of climate change, energy security and operational cost. Whilst we are committed to meeting any and all legal or other requirements with regards energy use, consumption and efficiency, our policy is to measure our performance, identify opportunities for improvement and actively seek continual improvement in energy performance.

All members of the Maldivian Government are to seek to create an environment which enables energy efficiency and energy conservation. This includes ensuring that information pertinent to energy efficiency and performance analysis is made readily available for auditors and the general population of the Maldivian Government.

Departments and individuals should act to increase awareness on energy efficiency and energy conservation and should adopt implementation of energy management practices. Management will provide all necessary resources, including skills and equipment necessary to meet our objectives and targets.

The policy to improve energy efficiency is to extend to cover not only occupant operational patterns, but also the energy efficient design of our accommodation and the procurement of energy-efficient products and services.

As part of this policy the Maldivian government has produced this Energy Management Policy which is to be implemented within all agencies. This includes the presentation and display of this policy at all levels within the organisation.

This policy applies to all government agencies and, at this stage, the energy associated with their office accommodation and operations. Office accommodation and associated operations are understood to represent a significant proportion of the energy consumption of the Maldivian Government and, importantly, offers potentially cost positive opportunities for improvement which provide significant environmental and economic advantages for the Government.

We are committed to regular review and update of this policy and the associated energy management system used to achieve its targets. Individual departments and accommodation units will be responsible for their own analysis and actions to improve performance, however, the policy will also include biannual review and comparison across departments to facilitate review and resetting of targets and objectives.

4.2.2 Purpose

This policy is intended to follow the general outline of an Energy Management System, as per ISO 15001, to provide the basis for ongoing continual performance improvement in the management and minimisation of energy consumption.

4.2.3 Outcomes

The Maldivian Government is committed to establishing, documenting, implementing, maintaining and improving an Energy Management System, in accordance with the requirements of the ISO 15001 standard for Energy Management Systems.

The Energy Management System is expected to include customised plans for each of the major government departments and, subsequently, each of major asset and accommodation utilised by each department. At this stage, the scope of the Energy Management System covered by this document is for all government office accommodation and operations.

The Energy Management System will include a requirement for monthly performance review, quarterly reporting and annual auditing to identify areas for improvement and measure their effectiveness. Targets and benchmarks will be updated annually as a result of the aggregated reporting across Government.

4.2.4 Objectives and Targets

The following are set as the current objectives and targets with regards delivering performance improvement for energy management and efficiency optimisation:

- Transparency
    - All departments and accommodation units are to be aware of and report their own energy efficiency performance.
    - As a minimum, this will include reporting of monthly energy consumption against targets, previous performance and peers in prominent displays and/or email correspondence to all occupants and users of the space.
- Performance Improvement
    - All departments and accommodation units are to target year on year reductions of 5% of total energy consumption and are to report against these targets annually.
- Performance Review
    - All departments and accommodation units are to undertake energy audits as documented within this policy and whenever situations materially effecting energy consumption change.
- Procurement
    - All procurement shall consider energy efficiency and performance improvement and any tender evaluations shall include energy efficiency as a measure – including advising tenderers as such.
- Engagement
    - Staff training and awareness exercises shall be carried out as needed, but no less than 12 monthly on topics identified during staff surveys.
    - Staff surveys to confirm areas needed for training and engagement shall be completed no less frequently than annually.

    - New staff inductions shall include training on energy efficiency issues and the implications of staff actions.
- Policies and Procedures
    - Start up / shut down procedures and responsibilities shall be developed for each space confirming requirements for all staff to optimise energy efficiency in their areas.

4.3 Management Responsibilities

Delivery of energy efficiency outcomes will require commitment and engagement from all levels. The following section of the policy outlines the expectation of management figures within each department and the overall Maldivian Government.

4.3.1 Top Management

Top management will be required to overtly demonstrate commitment and support to Energy Management and the Energy Management system. They shall also be required to assist with continually improving energy management and energy efficiency by:

- Contributing to the development and customisation of this energy policy
- Appointing management representative(s) to be a part of an energy management team and, where required actively building that team.
- Provide resources to establish, implement, maintain and improve the Energy Management System
- Provide resources, including specialised skills, equipment, time etc - to improve energy efficiency outcomes, where they are available
- Continually review the scope and boundaries to be addressed by the Energy Management System
- Consistently communicating the importance of energy management within the organisation and making decisions to support energy management as a priority
- Reviewing and assisting in developing energy objectives and targets
- Reviewing and assisting in developing Energy Performance Indicators and, where appropriate, customising them to suit their area of influence
- Include energy efficiency in long term and strategic planning
- Ensuring energy data is measured, reported and analysed at regular intervals
- Undertake management reviews of policy, system and performance regularly and transparently

4.3.2 Management Representative

Top management shall appoint representative(s) with the necessary skills, competence and interest who has the time allocation, responsibility and authority to:

- Champion the Environmental Management System and ensure that it is established, implemented, maintained and continually improved in accordance with ISO 15001 2011.
- Identify other person(s) to work with the management team to support energy management and optimisation activities
- Report to top management on energy performance and the operation of the Energy Management System.
- Ensure that planning, strategy and energy management activities support the Maldivian Government's energy policy.
- Define, allocate and communicate responsibilities to relevant parties and authorities to facilitate effective energy management.
- Determine criteria and methods to maintain effective operation and control of the Energy Management System.

- Promote awareness of and engagement with the Energy Policy at all levels within the organisation.

4.4 Energy Planning

Energy policy requires planning as to how to minimise energy consumption and deliver ongoing continual performance improvement. The following section provides the intended policy for energy planning activities:

4.4.1 General

The Maldivian Government, through MoE and each department, shall undertake energy planning to lead to activities and interventions that continually improve energy performance. This planning shall include:

- Initial audit of key building and office accommodation sites, representative of typical operational models for departments
- Extended audit of a wider range of sites, comparison of similarities and differences which influence energy efficiency outcomes by usage type
- Presentation of findings from reports and provision of advice for all government departments to complete detailed internal audits and initial energy efficiency and management plans.

It is the intention that accommodation sites shall report vertically through their departments to allow opportunities for improvement and investment to be identified, with analysis and feedback provided from management in accordance with the plan and this policy.

4.4.2 Legal Requirements

The Maldivian Government has the following legal requirements with regards its energy use, consumption and efficiency:

These requirements and their implications as to ongoing energy management and efficiency planning shall be reviewed biannually or where legal obligations change.

4.4.3 Energy Review

Energy consumption reviews shall be undertaken monthly, with reporting quarterly, unless unusual consumption patterns indicate a need to investigate and report sooner.

All sites shall undertake a detailed energy audit over the initial five years of the adoption of this policy and energy management system, with follow up audits and reviews to be undertaken as follows:

- For accommodation units which consume more than 5% of a departments energy consumption, reviews and audits shall be completed annually.
- For units which consume more than 2% of a departments energy consumption, reviews and audits shall be completed on a three-year basis
- Accommodation units representing no less than 80% of all departmental energy consumption shall be audited every three years.
- Accommodation units representing no less than 99% of all departmental energy consumption shall be audited every five years.
- Any accommodation unit with energy consumption which increases annually or fails to achieve an average 2% annual reduction over any three-year period shall be audited no less than annually until they no longer meet the criteria.
- Any accommodation unit with a significant modification in operational parameters such as staff, hours of use, equipment or refurbishment shall be audited between 3 and 9 months after the modification.

Audits shall generally follow the format provided for the initial audit of key facilities – attached as appendix – and shall:

- Identify all current energy sources
- Review past and present energy consumption for a period of no less than two years and with data collected and presented at least monthly.
- Identify any area of significant (>5% of building consumption) energy use
- Identify individuals, processes and equipment which influence energy consumption significantly
- Estimate expected energy consumption and the impact of various interventions on predicted consumption levels.
- Identify and prioritise energy efficiency interventions.

The energy review documentation shall be updated whenever a new audit is completed and no less frequently than annually, based on the previous twelve months operation.

4.4.4 Energy Baseline and Performance Indicators

Energy baselines for typical office accommodation usages have been identified in the initial energy audit of the Velaanaage Office building and the Gan Metrology office tenancy. Energy consumption for other accommodation units shall be assessed on these baselines, normalised for:

- Hours of use
- Number of staff
- Occupied area
- Provision of air conditioning

Energy consumption reporting shall be reported separately for air conditioned and non-conditioned areas in kWhrs/m^2. Consumption shall be normalised as follows:

- Occupant density varying from 1 person per 10m^2 shall utilise the following adjustment factors
    - 1 person per 5m^2 – Energy consumption multiplied by 75%
    - 1 person per 10m^2 – Energy consumption unchanged
    - 1 person per 20m^2 – Energy consumption multiplied by 133%
    - Scaling shall be linear between these points. Densities outside of these ranges shall use the closest figure (75% or 133%) accordingly.

  For a occupant to be counted, they must have a dedicated work setting within the accommodation unit which is occupied at least 70% of the operational hours of the department.

- Weekly hours of use varying from 35 hours/week shall utilise the following adjustment factors:
    - 28 hours per week – Energy consumption multiplied by 115%
    - 35 hours per week – Energy consumption unchanged
    - 42 hours per week – Energy consumption multiplied by 87%
    - Scaling shall be linear between these points. Hours of use outside of these ranges shall use the closest figure (155% or 87%) accordingly.

  Hours of use are the hours, per week, where at least 20% of an operational group are present and undertaking typical work tasks.

All units shall report their:

- Total energy consumption (kWhrs)
- Energy Density (kWhrs/m^2)
- Weekly Hours of Use (hrs per week)
- Occupant Density (pax/m^2)

- Normalised Energy Density (as calculated from above) (kWhrs/m^2)

4.4.5 Energy Objectives, Targets and Energy Management Action Plans

The Maldivian Government shall establish, implement and maintain documented energy objectives and targets for all functions and facilities within the organisation.

Objectives and targets are to be set by June 2019 and shall include specific time frames for achievement and action items.

Targets and objectives will be set with the intention of:

- Creation of an enabling environment for energy efficiency and conservation
- Actively increasing engagement and awareness of energy efficiency and energy conservation
- Adoption and implementation of energy management practices

Targets will consider legal requirements, performance trends, significant energy uses and opportunities. Consideration of financial, operational, technological and business consideration will be completed. Consultation will be undertaken with interested parties.

All departments will be responsible for delivering on the adopted targets and shall be required to establish, implement and maintain action plans in support of achieving the outcomes. Action plans are to include:

- Allocation of responsibility
- The means and timescale for targets to be implemented
- The means and timescale for interventions in support of targets
- The intended method for verification and review of intervention effectiveness
- Review of the outcomes of previous interventions

4.5 Implementation and Operation

4.5.1 General

The organization shall use the action plans and other outputs resulting from the planning process for implementation and operation of processes and interventions to manage and reduce energy consumption.

4.5.2 Competence Training and Awareness

Managing and monitoring energy consumption, the Energy Policy and any Energy Management Systems requires certain specific training and analytical skills. The Maldives Government, and their constituent departments shall invest in training and/or allocate appropriately skilled individuals to relevant positions to support and develop the appropriate materials and analysis required to effectively monitor and manage energy consumption.

In addition, the energy management process is expected to identify needs for training and skills within the operational departments of the Maldives Government and, where relevant, Energy Management Systems and energy audits shall identify training and human resources as strategies to reduce energy consumption.

Records of training required and provided are to be maintained as part of each Energy Management plan.

4.5.3 Education and Engagement

As part of its strategy of energy management and optimisation, the Maldives Government shall make sure that anyone working for or on its behalf is aware of:

- The need to comply with the energy policy

- The need to comply with the relevant procedures and documentation identified within any energy management plan or the Energy Management System.
- Their roles and influences – including responsibilities and authorities – to achieve the requirements of the Energy Management System.
- Their specific impacts and potential benefits associated with their activities, including how their behaviour contributes to the achievement of energy consumption targets.
- The benefits associated with improved energy performance.
- The potential consequences of departure from procedures.

4.5.4 Communication

Ongoing communication to staff and stakeholders will be critical to effective implementation of Energy Management Systems and Policies.

- The Government shall communicate internally with regards energy performance locally and as a whole. Communications should include information as to operation of local groups in as much detail as possible, as well as an overall view of departments covered by the party.
- Part of the communication will include opportunities for stakeholders to provide comments or suggest improvements to the Environmental Management System or to suggest opportunities for investigation to reduce energy consumption.
- The Government shall determine whether or not to communicate publicly about its energy management policy and shall document this decision.
    - External communication policies may be required to manage external communication, if relevant.

4.6 Documentation

4.6.1 Documentation Requirements

The Energy Management System will require relevant documentation to support its maintenance and implementation. Documentation shall be established, implemented and maintained to support and describe the functions of the management system.

Within the Energy Management System, the documentation shall include:

- Scope and boundaries of the Energy Management System
- The Energy Policy
- The Energy Objectives, targets and action plans
- Documents and records, as required by IS 15001.
- Any other documentation required

4.6.2 Control of Documents

Documentation, as per the above, are required to be controlled. This will include:

- Procedures to approve documents
- Procedure to review and update documentation as necessary
- Procedure to energy changes and current revision status are identified
- Ensuring relevant versions of documents are available for use
- Ensure documents are legible and readily identified
- Ensure documents that are generated externally are identified and are also controlled
- Preventing the use of obsolete documents.
- Identification of documents to be retained.

4.6.3 Operational Control

The Maldivian Government will plan operations and activities which are related to its significant energy uses. Ongoing reviews and audits shall identify opportunities for improvement and key operational controls required to effect reduction in use and/or continued efficient operation.

Plans will include:

- Criteria for effective operation and maintenance of significant energy consuming elements eg: Lighting or computers,
- Operation and maintenance of facilities, processes, systems and equipment
- Communication of operational controls to personnel

For example, this is likely to manifest its self in:

- Procurement guides which include energy efficiency as a review point for all new equipment
- Policies on operation and maintenance of air conditioning and lighting systems
- Procedures for 'end of day' and 'start of day' activities in offices or other facilities, customised for specific sites
- Operational questionnaires for occupants to be revisited regularly.

4.6.4 Design

Design of spaces, systems and functions will have a significant impact on energy performance and operational control.

Design stages shall consider energy efficiency and energy efficiency improvement opportunities for any new, modified or renovated facilities. Similar considerations shall apply for equipment, systems and processes which will significantly influence energy performance.

Where design has considered energy performance, the results of the evaluation shall be included in the specification, design and procurement activities for the project.

All design activities shall have the energy efficiency results and analysis documented and recorded.

4.6.5 Procurement of Energy Services, Products, Equipment and Energy

Part of any procurement of Energy Services, products or equipment shall include consideration of efficiency and any tender documentation shall include notification to suppliers that the procurement is partly evaluated on the basis of energy performance.

Energy efficiency criteria shall be clearly documented and shall include consumption and efficiency over the lifetime of the products being procured.

4.7 Checking

4.7.1 Monitoring Measurement and Analysis

Ongoing monitoring, measuring and analysis of operational energy consumption is critical to enable effective energy management. Therefore, all sites shall ensure that key characteristics and features which influence energy performance are monitored and measured, with analysis as per the requirements earlier within this document.

As a minimum, the following characteristics shall be identified:

- Significant energy uses
- Variables which effect the significant energy uses
- Energy Performance Indicators – as per previous
- Effectiveness of current and previous action plans
- Review of actual energy consumption against expected energy consumption.

The results of these analyses shall be documented and recorded.

Energy measurement plans shall be generated for all sites and new sites shall include measurement plans to CIBSE TM 39 or equivalent.

Monitoring systems shall include utility meters as a minimum and, for new accommodation, shall include separate metering for:

- Lighting
- Power
- Air conditioning and mechanical plant
- Renewable generation
- Server rooms
- Any unusual energy consumption, more than 5% of the total power or energy consumption on site.

All metering systems – including automatic reading and recording systems - shall be validated by independent, calibrated check meters over a period of at least 168 hours or 500 times the reported accuracy of the meter. Recalibration shall be undertaken every 5 years, or change in tenant – whichever is more frequent.

Records of calibration shall be retained.

Where there is unusual month to month variation of energy consumption the relevant department / local manager shall review, investigate, respond and report to the wider group to allow learnings to be effectively shared and preventative actions undertaken where possible.

Results of these activities shall be maintained.

4.7.2 Evaluation of Compliance with Legal and Other Requirements

At planned intervals, the organization shall evaluate compliance with legal requirements and other requirements to which it subscribes related to its energy use and consumption. Records of the results of the evaluations of compliance shall be maintained.

4.7.3 Internal Audit of the Energy Management System

The Maldivian Government shall undertake regular internal audits, in accordance with their own quality and document control policies.

As a minimum, an audit plan and schedule shall be developed which considers the importance of the spaces to be audited and the results of previous audits and analysis. For example, the best and worst 5 performing sites, as measured by the performance indicators identified earlier should be audited no less than annually.

The selection of auditors and conduct of audits shall ensure objectivity and impartiality of the audit process.

Records of the audit results shall be maintained and reported to top management.

4.7.4 Nonconformities, Correction, Corrective Action and Preventative Action

Where non-conformities are identified, actions shall be taken to correct them and ensure, as much as possible, systems and procedures are modified to avoid their repetition. Actions will include:

- reviewing nonconformities or potential nonconformities;
- determining the causes of nonconformities or potential nonconformities;
- evaluating the need for action to ensure that nonconformities do not occur or recur;
- determining and implementing the appropriate action needed;
- maintaining records of corrective actions and preventive actions;

- reviewing the effectiveness of the corrective action or preventive action taken.

Corrective actions and preventive actions shall be appropriate to the magnitude of the actual or potential problems and the energy performance consequences encountered.

The organization shall ensure that any necessary changes are made to the Energy Management plans and systems at various sites.

4.7.5 Control of Records

Each facility and department shall establish and maintain their own records, as well as contributing to the reporting and documentation of the records of the group. Each department shall implement document control procedures to support the identification, retrieval and retention of all relevant records.

Records shall be and shall remain legible, identifiable and traceable to the relevant activity.

4.8 Management Review

4.8.1 General

As nominated earlier, top management shall review the organization's Energy Management System to ensure its continuing suitability, adequacy and effectiveness. This will include site and department specific Performance Indicators and audit findings.

Records of management review shall be maintained.

4.8.2 Input to Management Review

Part of the management review will include:

- Follow-ups and actions from previous reviews
- Review of the energy policy, targets and objectives
- Review of energy performance and Performance Indicators
- Results of compliance with legal requirements
- Changes in legal requirements
- Performance against objectives and targets
- Audit results
- Proposed interventions and recommendations for improvement.
- Status of current interventions and their relative success.
- Expected energy performance

4.8.3 Output from Management Review

As part of the management review, the following outputs shall be generated:

- Updated (if needed) energy policy
- Decisions or actions related to changes in the energy performance of the Maldivian Government
- Changes to Energy Performance Indicators
- Changes to other objectives or targets
- Identification resources required and, where relevant, changes to how resources are allocated

Section 5
Energy Management Plan

5.1 Background

The site is an office building, which has a high energy demand to achieve its functional requirement of computer based, administrative tasks. There are additional support systems for this function which also consume energy. Indicative energy budgets are provided in **subsection 1.6**: Energy Budget.

Currently, building occupants and stakeholders have a relatively high level of interest in energy efficiency and conservation, but limited understanding of the factors that influence consumption or their current rate of energy use.

Energy consumption is currently tracked on a tenancy basis, with meters manually read monthly. Data is collated and reviewed by building management, with limited discussion or engagement with tenants, particularly if energy consumption is remaining constant.

The Team visited site and undertook energy audits and identified means by which energy efficiency could be improved.

Currently, building stakeholders have limited access to energy consumption data and limited understanding of the data provided. In addition, occupants do not have the technical expertise to compare energy consumption between tenancies, rather relying on previous energy consumption as the only means to identify unusual practices. Without trained individuals undertaking analysis and review and/or with more detailed automated metering systems and alerts, significant improvements in energy efficiency or operation are unlikely to be made.

In addition, improving building thermal and visual comfort is likely to increase building energy consumption and, although recommended by the Team, does not achieve the aims of this study.

5.2 Energy Management Policy & Best Practices

The Maldivian Government have identified energy efficiency and resource consumption as being of key strategic importance. Please refer to the energy management policy for additional details.

Part of this strategy includes:

- Ongoing and targeted training of key individuals and general staff to improve awareness of energy efficiency and the impact that they can have on building performance.
- Ongoing improvement of building metering technology and analysis to allow better identification of energy efficiency opportunities.
- Regular review and reporting on energy consumption and efficiency initiatives.
- Engagement with senior leaders in all tenancies to improve energy efficiency outcomes.
- Implementation of energy efficiency projects in the short, medium and long-term.
- Procuring equipment and office design which favours reduced energy consumption.

5.2.1 Key Stakeholders

The key stakeholders for energy management within the Velaanaage office building are:

- Facility Manager
    - o The facility management team have access to all energy data as well as undertaking site inspections to ensure systems are operating correctly and not left running unnecessarily.
    - o In the absence of additional trained technical staff, the building management team should maintain the leadership role in the energy management plan.
- Tenancy Champions
    - o Each tenancy has variable hours of use, equipment and lighting. Tenancy champions are the main point of contact with the building facility manager and each individual

tenancy within the Velaanaage building. These champions are to receive information on tenancy energy consumption from the facility manager and, where relevant:

  - Provide feedback as to changes in tenancy operation or occupancy which would explain or contribute to changed energy consumption
  - Provide feedback to staff members within the tenancy as to energy efficiency performance and actively seek their assistance in performance improvement.

- External Management

The Team strongly recommend a group of tenancy management representatives are formed as an energy committee who review energy consumption reports quarterly and act to provide leadership within tenancies seeking to improve performance.

5.3 Energy Baseline

The following table shows the existing meters and the 12 months of energy consumption, calendar year 2017:

The existing meters which are read monthly are shown in **Table 5-1**:

Meter Type	Account Number	Meter Number	Owner	Usage	2017 Consumption	2017 kHrs/m²
Base Building	0000036063	4982048	MINISTRY OF FINANCE & TREASURY	**Roof Comms Room**	9590	
Base Building	0000036064	4982053	MINISTRY OF FINANCE & TREASURY	**Water Pumping**	2830	
Base Building	0000036065	9133166	MINISTRY OF FINANCE & TREASURY	**Fire Pump**	610	
Base Building	0000036066	9133172	MINISTRY OF FINANCE & TREASURY	**Lifts**	27250	
Base Building	0000036067	3565709	MINISTRY OF FINANCE & TREASURY	**Reception**	25392	
Base Building	0000036068	3565711	MINISTRY OF FINANCE & TREASURY	**Lobby Power**	71405	
Base Building	0000036069	3565716	MINISTRY OF FINANCE & TREASURY	**Lobby Lighting**	69912	
Base Building	0000036062	9133188	MINISTRY OF FINANCE & TREASURY	**Lobby Air Conditioning**	89470	
Base Building	0000036070	911150087	MINISTRY OF FINANCE & TREASURY	**Ground Floor Security**	52710	
Base Building	0000039864	11214985	MINISTRY OF FINANCE & TREASURY	**Basement**	5471	
Base Building	0000051890	215383523	PUBLIC WORKS SERVICES	**Car Park Ventilation**	485	
Tenant	0000036071	911140897	MINISTRY OF FINANCE & TREASURY	**Canteen**	15465	
Tenant	0000037210	905160008	MINISTRY OF FINANCE & TREASURY	**GF Bank**	4020	
Tenant	0000040227	1107112032309	MINISTRY OF FINANCE & TREASURY	**Pik Post**	2891	
Tenant	0000036094	911150067	MINISTRY OF FINANCE & TREASURY	**1B – Immigration**	22680	103.6
Tenant	0000036056	911150089	MINISTRY OF FINANCE & TREASURY	**1A – Immigration**	120780	274.5
Tenant	0000036092	911150084	MINISTRY OF FINANCE & TREASURY	**2B – MQA**	29340	146.7
Tenant	0000036093	911150070	MINISTRY OF FINANCE & TREASURY	**2A – DHE and Clemency Board**	30780	66.9
Tenant	0000036090	911150066	MINISTRY OF FINANCE & TREASURY	**3B – Ministry of Youth**	48840	138.0
Tenant	0000036091	911150077	MINISTRY OF FINANCE & TREASURY	**3A – Ministry of Youth**	64590	137.4
Tenant	0000036088	911150079	MINISTRY OF FINANCE & TREASURY	**4B – SEZ and MMPRC**	64590	180.7
Tenant	0000036089	911150091	MINISTRY OF FINANCE & TREASURY	**4A – DNR**	121200	257.9
Tenant	0000036086	911150073	MINISTRY OF FINANCE & TREASURY	**5B – MITDC and Ministry of Tourism Bureau**	74010	183.6

Meter Type	Account Number	Meter Number	Owner	Usage	2017 Consumption	2017 kHrs/m²
Tenant	0000036087	911150088	MINISTRY OF FINANCE & TREASURY	**5A – Ministry of Tourism Bureau**	25620	54.5
Tenant	0000036084	9111500082	MINISTRY OF FINANCE & TREASURY	**6B – Attorney General**	74550	186.4
Tenant	0000036085	9111500092	MINISTRY OF FINANCE & TREASURY	**6A – Attorney General**	99420	211.5
Tenant	0000036082	911150086	MINISTRY OF FINANCE & TREASURY	**7B – Ministry of Fisheries**	70860	177.2
Tenant	0000036083	905160006	MINISTRY OF FINANCE & TREASURY	**7A – Mistry of Fisheries**	68280	145.3
Tenant	0000036080	911150090	MINISTRY OF FINANCE & TREASURY	**8B – Ministry of Education**	120780	198.8
Tenant	0000036081	911150075	MINISTRY OF FINANCE & TREASURY	**8A – Ministry of Education**	54240	115.4
Tenant	0000036078	911150085	MINISTRY OF FINANCE & TREASURY	**9B – Ministry of Education**	53730	134.3
Tenant	0000036079	911150094	MINISTRY OF FINANCE & TREASURY	**9A – Ministry of Education**	60630	123.7
Tenant	0000036076	911150071	MINISTRY OF FINANCE & TREASURY	**10B – Home Affairs**	69420	173.6
Tenant	0000036077	911150076	MINISTRY OF FINANCE & TREASURY	**10A – Home Affairs**	83460	177.6
Tenant	0000036074	911150080	MINISTRY OF FINANCE & TREASURY	**11B – Ministry of Economic Development**	43920	109.8
Tenant	0000036075	911150074	MINISTRY OF FINANCE & TREASURY	**11A – Civil Aviation and Regional Airports**	74190	161.3
Tenant	0000036072	911150081	MINISTRY OF FINANCE & TREASURY	**12B – Civil Services**	43920	27.5
Tenant	0000036073	911150083	MINISTRY OF FINANCE & TREASURY	**12A – Civil Services**	65640	164.1

Table 5-1: Meter List

The data in **Table 5-1** - tenancies, area and energy consumption - should be updated at least quarterly.

5.4 Identified Conservation Capital Projects

The projects in **Table 2-1** in **subsection 2.5:** Energy and Greenhouse Gas Savings have been identified as having a good basis for reduction of energy consumption within the building. Refer to that subsection for additional information.

5.5 Action Plan

In order to manage and reduce energy consumption within the building, in addition to the capital intensive projects nominated within section Identified Conservation Capital Projects it is critical that improved understanding of energy consumption is obtained.

The monitoring plan, produced as a part of this project, has identified recommended upgrades to the metering system as a means to improve data visibility, however, if the capital works are not complemented by an employee training program which educates key individuals and/or if the data is not provided to people who can influence outcomes, the investment will not be worthwhile.

Table 5-2 below identifies recommended, ongoing, energy management practices which should be implemented within the Velaanaage office building:

Phase	Task	Person Responsible	Frequency	Description
Data Collection	Basic Meter Reading	Building Management	Monthly	Building management is to collate all electricity meter data monthly and tabulate.

Phase	Task	Person Responsible	Frequency	Description
	Occupancy Information	Stakeholders	Monthly	Office stakeholders are to provide commentary to Building Management regarding office occupancy over the previous month. Information should include: • Hours of tenancy operation, per week. • Number of occupants with permanent work setting within the tenancy.

<table>
<tr><th>Phase</th><th>Task</th><th>Person Responsible</th><th>Frequency</th><th>Description</th></tr>
<tr><td rowspan="2">Analysis</td><td>Meter Normalisation</td><td>Building Management</td><td>Monthly</td><td>Building management is to compare consumption between floors, using the following formula:

N = M x O x H / A

Where:

N = Normalised Energy

M = Metered Energy Consumption

O = Occupant Density Factor

H = Hours of Use Factor

A = Area – in m^2

O is calculated as follows:
<table>
<tr><td>Occupant Density – p Pax/m^2</td><td>O</td></tr>
<tr><td>> 0.2</td><td>0.75</td></tr>
<tr><td><0.2, >0.1</td><td>(0.1-p)x2.5+1</td></tr>
<tr><td>0.1</td><td>1</td></tr>
<tr><td><0.1, >0.05</td><td>(0.1-p)x6.6+1</td></tr>
<tr><td><0.05</td><td>1.33</td></tr>
</table>
H is calculated as follows:
<table>
<tr><td>Weekly Hours of Use - w</td><td>O</td></tr>
<tr><td>>42</td><td>0.87</td></tr>
<tr><td><42, >35</td><td>(35-w)x0.186+1</td></tr>
<tr><td>35</td><td>1</td></tr>
<tr><td><35, >28</td><td>(35-w)x0.214+1</td></tr>
<tr><td><28</td><td>1.15</td></tr>
</table>
</td></tr>
<tr><td>Reporting</td><td>Building Management</td><td>Monthly</td><td>Tenants are to be provided with normalised meter data and standard meter data.

Data is to be compared to previous months and consumption</td></tr>
</table>

Phase	Task	Person Responsible	Frequency	Description
				information is to be provided to individual tenants. Data to tenants is to be presented in a graphical form, including previous 24 months usage.
Improvement	Target Identification	Building Management	Quarterly	Building Management is to review both normalised data and metered consumption to determine areas for additional investigation. Triggers for further investigation include: • Energy consumption change by more than 5% against previous month and same month last year. • Normalised consumption change by more than 5% against previous month and same month last year. Building management is to identify tenancies which meet either of these criteria over a quarterly period and request formal justification from the tenant as to why the change has occurred. Building management is to undertake the same review on base building energy consumption meters, without normalisation factors.
	Energy Audit Response	Tenant Stakeholders and Building Management	As required	Where tenancies are identified as having variable energy consumption, they are to undertake a review of operation and provide feedback to the building management staff and their manager as to causes, effects and proposed actions – either to retain performance improvement measures or to reverse actions which have resulted in energy increase.

Phase	Task	Person Responsible	Frequency	Description
				Elements to be considered are: • Operation of plant or equipment over night • Change of internal equipment – lights, computers etc. Tenants are to be supported by building management taking energy consumption readings for their meter daily for a period of two weeks, whilst the tenants review tenancy operation and make modifications to suit. The trigger, review process and elements changed are to be summarised in a formal report
	Tenant Education	Building Management and Tenant Stakeholders	As Required	The findings of the reviews for each tenancy are to be distributed amongst all stakeholders for review and education of staff.
	Celebration	Building Management	Monthly	All tenancies are to be ranked according to their normalised consumption, with performance displayed in a prominent location within each tenancy and within the main building lobby.

Table 5-2: recommended, ongoing, energy management practices which should be implemented within the Velaanaage office *building*

If additional information is able to be gathered, say by increased frequency of meter readings, or by improved metering systems, the following additional measures should be used to identify tenancy operation changes and areas for improvement:

- Overnight consumption
  - Energy consumption outside of office hours should reduced by 15% or less per hour than energy consumption within hours
- Peak to minimum
  - Minimum energy consumption should be 10% or less of peak energy consumption on any day.
- Match to occupancy
  - Hours where energy consumption is >25% of peak should match with hours of occupancy as advised by stakeholder.
- Air Conditioning
  - Air conditioning energy consumption should be ~60% of power and lighting energy consumption for the tenancy served.

Tenancies which deviate significantly from these targets should be reviewed to determine the cause and, if possible, undertake design or operational changes to improve performance.

Table 5-3 below shows the Energy Conservatives Projects Tracking form to be used by tenancies to track progress.

Energy Conservation Projects Tracking

Project Description	Fuel Type	Project Stage	Energy Savings	Dollar Savings	Responsible Person	Percent Complete	Completion Date	Comments on Progress and Barriers etc.

Table 5-3: recommended, ongoing, energy management practices which should be implemented within the Velaanaage office building

Section 6
Conclusion

Conclusions

The total upfront costs of all recommended options is just under 11 million MVR with an average payback period of just under 5 years (and annual savings of just over 2 million MVR thereafter). This gives total energy savings of approximately 600,000KWh per year and annual greenhouse gas emission savings of 540 tonnes of $CO_{2(e)}$/year. Note these figures do not include the additional savings from business as usual VRV equipment upgrades. These will contribute to a further 175,000KWh per year energy savings, approximately 150,000kgCO_2e.

It is unlikely to be economically viable to roll out all of these options concurrently. We therefore recommend the prioritisation of options with a payback period of up to one year. The total upfront costs of these options are just under 1 million MVR. Annual savings are estimated at 2 million MVR/year. The resultant energy savings are estimated to be 520,000KWh/year, i.e., 85% of potential overall savings. This gives greenhouse gas emission savings of approximately 470 tonnes of $CO_{2(e)}$/year.

By prioritising these options, savings can thus be directed towards the implementation of ongoing improvements.

To support the recommendations and as part of the project scope, the Team has prepared Monitoring Plan which can be utilized to verify recommendations. Energy Management Plan and an Energy Efficiency Policy was developed to actively seek continuous improvement in energy for the Government sector to support the Maldives Government's energy sustainability target. To achieve this, we recommend an engaged and informed workforce and applying systems that meet international standards.

The Team strongly recommend that the key stakeholders for this project communicate the strategy and expected influence on all staff within the building as part of the improvement process.

ANNEXES

Annex 1 - Velaanaage Office Equipment List