



Ministry of Environment

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

K. Guraidhoo Mosque  
(Masjid-ul Sidheeeg)



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





Ministry of Environment

Strengthening Low Carbon  
Energy Island Strategies (LCEI)  
Project



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# Executive Summary

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

The purpose of this project is to support the implementation of energy efficiency and carbon improvements in the built environment in the Maldives. The project comprised the assessment and design of cost effective energy efficiency improvements in selected buildings. One of the objectives is to apply similar improvement measures to future comparative facilities. These buildings are Velaanaage Office Building, Hulhumale' Flat 110 (a residential building), K. Guraidhoo Mosque (Masjid-ul Sidheeq) and Maldives Meteorological Service's 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 K. Guraidhoo mosque (Masjid-ul Sidheeq)

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 ~27kWhrs per m<sup>2</sup> over calendar year 2017. On a typical month energy usage for the mosque was found to be very low at ~2.2 kWhrs/m<sup>2</sup>. During holy month, the energy consumption increased slightly to ~3 kWhrs/m<sup>2</sup>. The two major energy consumers are the internal fans and the external lighting, at approximately 40% of the total energy consumption each.

As the energy consumption of the mosque is very low, the opportunities for energy and carbon savings are limited. The Team do not recommend substantial measures are undertaken for the Guraidhoo Mosque and note that there are substantially greater savings potentials in the three other buildings assessed. However, the Team identified opportunities for energy improvements as improving the energy efficiency of lights and reducing operating hours for fans and lights. As thermal comfort indirectly influences fan operation and therefore energy consumption the Team also highlighted opportunities to improve thermal comfort as painting the roof with a lighter colour (when it is next painted) and increasing landscaping to reduce ambient air temperatures and to reduce direct solar radiation onto and into the Mosque.

In future developments it is recommended to focus on design for thermal comfort, considering heat transfer through the building envelope (impacted by materials, insulation, wall to window ratio and external façade colours), positioning openings to maximise cross-flow ventilation, integrated landscape design, and selecting efficient fans and lights.

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. It is recommended that the caretaker of the mosque is advised of energy consumption monthly, with comparisons to last year and last month to facilitate monitoring and identification of unusual usage.

# Section 1

## Energy Audit

## 1.1 Site Description

The Guraidhoo Mosque was visited by the Team on the 29<sup>th</sup> and 30<sup>th</sup> of March 2018.

Visits were undertaken during unoccupied and occupied periods during the day and at night to observe occupant operation of the site and the expected energy consumption in various modes of operation.

The building orientation is set by functional requirements and the building is considered fairly exposed to wind with a relatively open space immediately to the south.

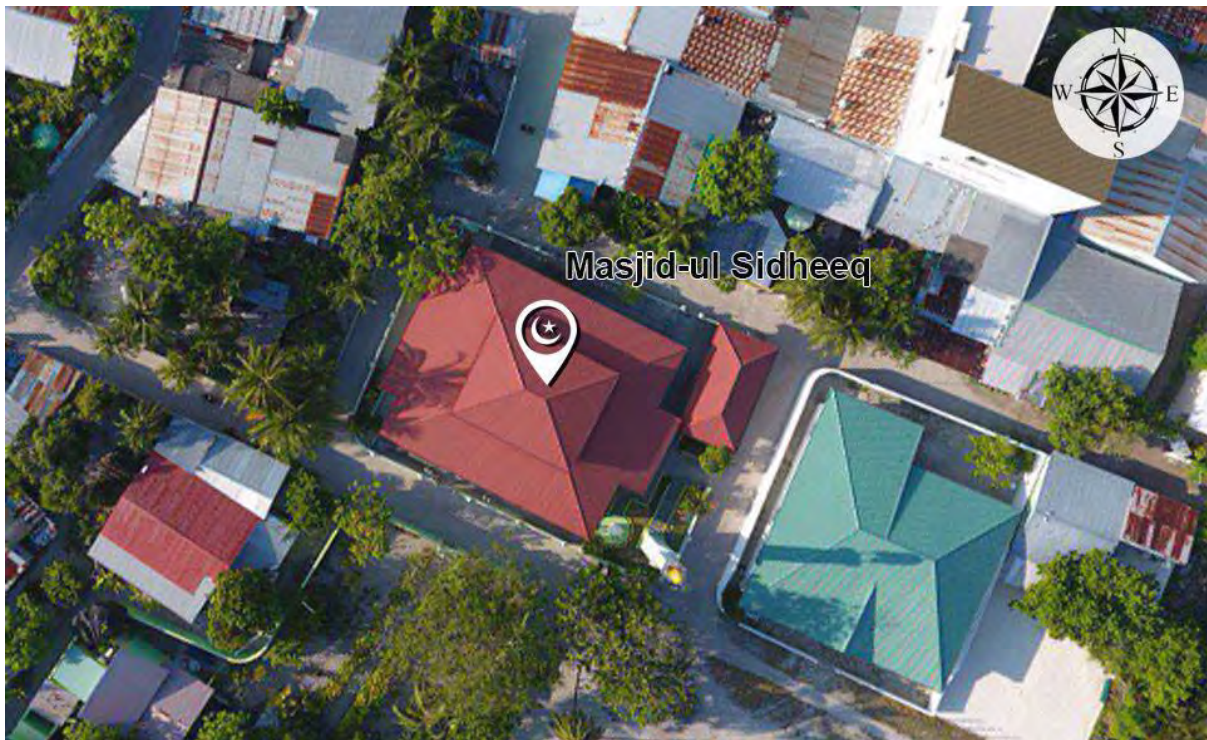


Figure 1-1 : Aerial image of Masjid-ul SidheeQ

## 1.2 Pre-Visit Analysis

Prior to visiting site, the Team reviewed historical electrical consumption data for the mosque, based on electricity bills from early 2015 until the end of 2017. The graph below shows consumption over the recorded period.

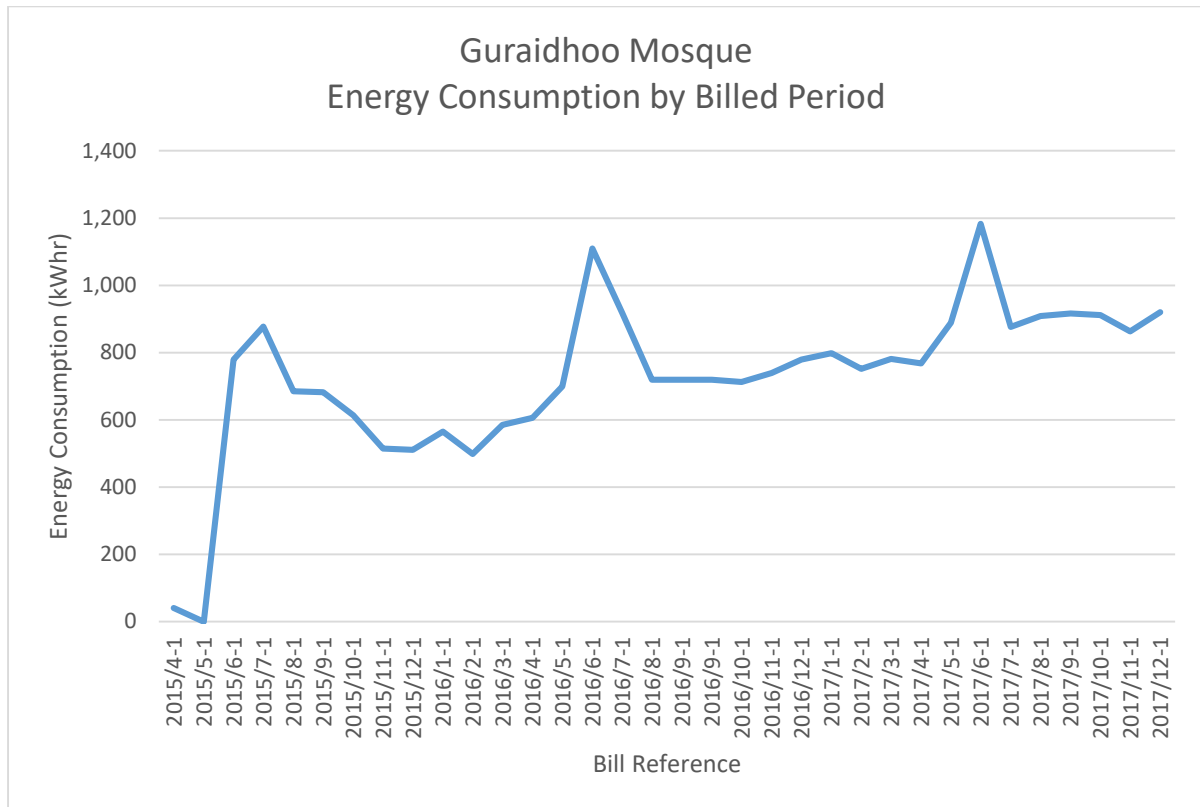


Figure 1-2: Energy consumption for Masjid-ul Sidheeq

The data shows consistent increase in energy consumption, as well as clear spikes in consumption around the fasting month in each of the past three years.

The Team believe that the increased consumption is reflective of increased use of the mosque, based on increased population of the island.



### 1.3 Data Logging Review

In addition to reviewing power consumption from bills, the Team undertook data logging on the electrical feed to the mosque. Data was collected on instantaneous power draw every 10 minutes over then monitored period, with consumption data shown below.

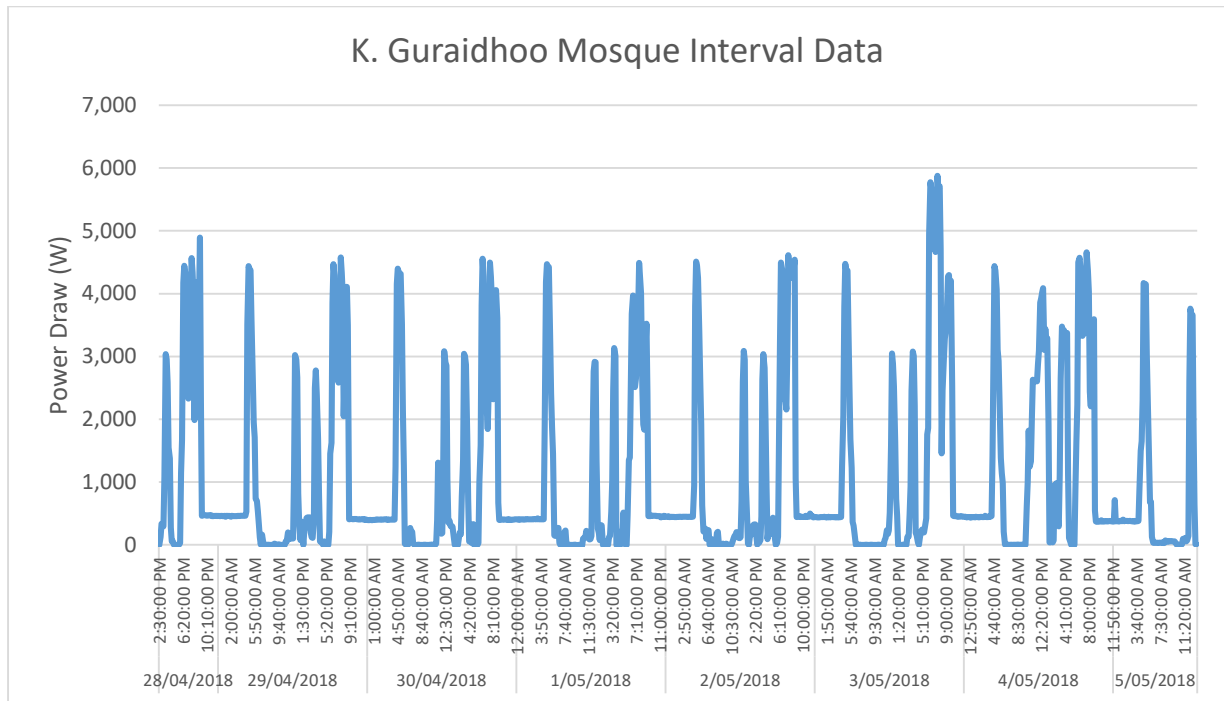


Figure 1-3: Power data log for Masjid-ul Sidheeq

The plot above shows the energy consumption over a typical week. Peak consumption on the 3<sup>rd</sup> of May (Thursday) is around 20% higher than the rest of the week, however, Friday consumption (4<sup>th</sup> of May) had the highest total – owing to longer running times, which is expected due to Friday Prayer. It is not clear why Thursday peak energy consumption was higher.

The data clearly shows external and ablution lighting consumption at ~500W overnight. Prayer times are similarly readily visible, with early morning prayers having external lighting turned off afterwards.

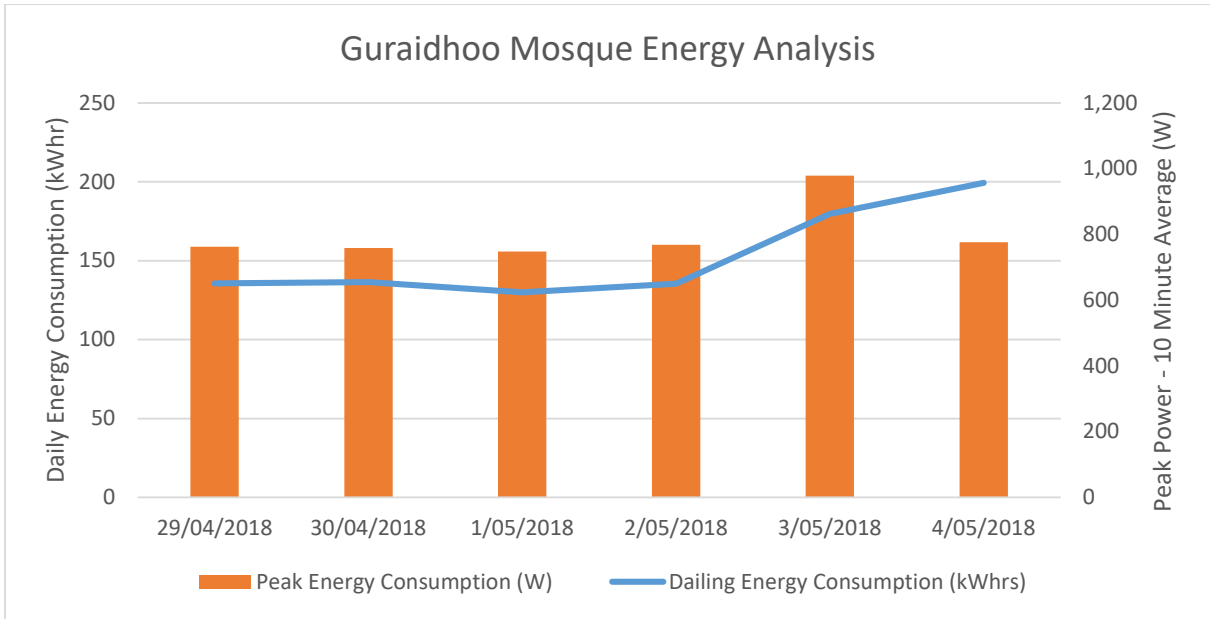


Figure 1-4: Peak energy consumption and daily energy consumption for Masjid-ul Sidheeq

## 1.4 Site Visit Observations

The Guraidhoo mosque has very limited power draw. The site has no air conditioning or hot water systems and, therefore, consumes >95% of its energy for lighting and ceiling / wall fans. AV (audio video) equipment, such as loudspeakers/mega phones externally and a Public Address system internally would also draw some power during prayer time.

Controls for all systems are manual, with lighting and air movement controls generally broken into zones of control within the mosque. This allows occupants to control areas ~1/6<sup>th</sup> of the total when they utilise the space. Switches are not labelled in detail, however, fans are provided with a numerical code which matches switches on the wall.

External lighting is also controlled from within the mosque space, there is no legend or labelling to identify which switches control which external lighting systems.

In operation, the users of the mosque seem familiar with the switching arrangements as lighting and air movement systems were observed as operational only in the occupied areas and external lighting was seen to be operational only at night. However, it is recommended to provide labels for lighting system so that users don't need identify lights by trial.

The internal connected loads were as follows:

Description	Number Off	Power Draw (W)
<b>External Lighting</b>		
Globe type Fitting	16	Est. 40W
Under Eave Exposed Luminaire	2	Est 20 W
Recessed Compact Fluorescent	11	Est 40W
Entryway Lantern	6	Est 40W
<b>Total</b>		<b>Est 1.4kW</b>
<b>Ablutions Lighting</b>		
T8 Fluorescent Tube (male area)	4	18W
T8 Fluorescent Tube (toilets)	2	18W
T8 Fluorescent Tube (cleaners store)	1	18W
T8 Fluorescent Tube (female area)	2	18W
<b>Total</b>		<b>Est 162W</b>
<b>Internal Lighting</b>		
Chandelier	1 (nominally 40 fittings)	200 W
Recessed Compact Fluorescent	39	23W
Single Tube T8 Fluorescents	15	18W
<b>Total</b>		<b>Est 1.4kW</b>
<b>Air Movement</b>		
Ceiling Fans	16	250W
Wall Fans	17	200 W
<b>Total</b>		<b>Est 7.4kW</b>
<b>Other</b>		
AV		~400W

Table 1-1: Internal energy consuming loads in for Masjid-ul Sidheeq

### 1.4.1 Air Conditioning

There is no air conditioning on site. Thermal comfort is maintained by natural ventilation – including high and low level openings to promote the stack effect – and ceiling / wall mounted fans.

Fans are controlled by occupants and have a number of speed settings available.



Figure 1-5: Existing wall fans in Masjid-ul Sidheeq

The images above show fans with local manual control. The '7' represents a zone of control from the adjacent wall switches.

### 1.4.2 Building Fabric

The building is constructed of masonry, with high numbers of openings at low level surrounding the mosque on three sides. Hot air can be relieved by openings at high level.

It is noted that the construction method, using heavy thermal mass walls and floors, leads to building structures retaining heat. The mosque is closed between 8PM – 4:30AM, apart from individual users accessing and egressing the space. This limits the ability of the space to store cool overnight and means internal temperatures are generally higher than ambient.

The building walls are white which assists in reflecting heat from direct solar penetration. The roof is red, which is considered dark in terms of solar heat gain.

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

Figure 1-6: Solar absorptance of colours

### 1.4.3 Glazing

Glazing appears to be standard, clear, single glazing in typical aluminium frames.

Windows are generally operable and left open to facilitate natural ventilation and internal air movement.



Figure 1-7: Existing glazing of the Masjid-ul Sidheeq

#### 1.4.4 Building Orientation

The building is oriented towards Mecca for functional reasons. Glazed facades face ~south west and ~ north east and are exposed to direct solar radiation for ~half of the day for ~half of the year.

Limited external shading is provided, other than to the main entry wall.



Figure 1-8: Main building entry of the Masjid-ul Sidheeq

#### 1.4.5 Building Sealing

The building is not sealed. Windows and doors are provided and generally left open to encourage natural ventilation and air movement.

#### 1.4.6 Vertical Transport

There are no vertical transportation devices on site. Occupants utilise stairs to rise ~1m to the prayer floor.

#### 1.4.7 External Lighting



Figure 1-9: External lighting to the building entry of the Masjid-ul Sidheeq

As noted above, the site has ~1.4kW of connected external lighting switched in approximately four different groups from within the mosque.

Not all lights are operated after hours, as shown in the images in **Figure 1-9** and **Figure 1-10**.



Figure 1-10: External lighting to the side of building of the Masjid-ul Sidheeq

#### 1.4.8 Internal Lighting

As noted above, the site has approximately 1.4kW of internal lighting and ~162W of lighting to the ablutions area. Internal light levels were ~250 Lux in the prayer area, which is considered reasonable for this type of space.

The largest single fitting is expected to be the chandelier, shown below:



Figure 1-11: Existing chandelier in Masjid-ul Sidheeq



### 1.4.9 Equipment



Figure 1-12: Existing AV system in Masjid-ul Sidheeq

The mosque contains very little equipment, other than the AV systems. Energy consumption for this system is estimated at 400W.

#### 1.4.10 On Site Generation

The building does not include a solar array. Energy consumption on site would indicate that an array of ~1kW would match building load at most times. Arrays larger than this would export power to the local grid, which would only be economic if the parties paying for the panels sees some benefit from reduced demand on other

#### 1.4.11 Existing Power Supply

The mosque is provided with a single-phase power supply, with meter box located on the building perimeter adjacent the main entry.

Power factor correction is not considered applicable for a single-phase power supply.



Figure 1-13: Existing single phase power board at Masjid-ul Sidheeq

#### 1.4.12 Occupant Comfort



Figure 1-14: Existing windows at Masjid-ul Sidheeq

Internal temperature within the mosque indicated conditions slightly warmer than outside. Internal conditions are heavily dependent on the operation of windows within the mosque space. Whilst the building is relatively well located for access to natural ventilation (exposed area to the south) and is taller than the surrounding sites, air movement is reliant on manual operation of windows.

The image above left shows low level operable windows with relatively small overhangs.



Figure 1-15: High level openings within the Masjid-ul Sidheeq

The overhangs provide reasonable coverage to windows facing north and south, however, the mosque has a long façade facing slightly west of south, which would receive low angle sun exposure for around half the year, as shown in the image.

The image left shows the high-level openings within the mosque which can provide relief from hot air internally when open.

Air movement within the space is assisted by wall and ceiling mounted fans. Fans are controlled by occupants by manual switches generally in proximity to the space served.



Figure 1-16: Existing wall fans in Masjid-ul Sidheeq

Lighting levels within the building were considered slightly low for reading at ~250 lux in the general praying area. However, thus lighting level is likely acceptable for the limited time occupants spend reading in the mosque.

### 1.4.13 Influence of Climate

As the Guraidhoo mosque has no air conditioning, energy consumption is not expected to have any significant correlation with weather patterns.

This is borne out through the historical weather data, provided below:

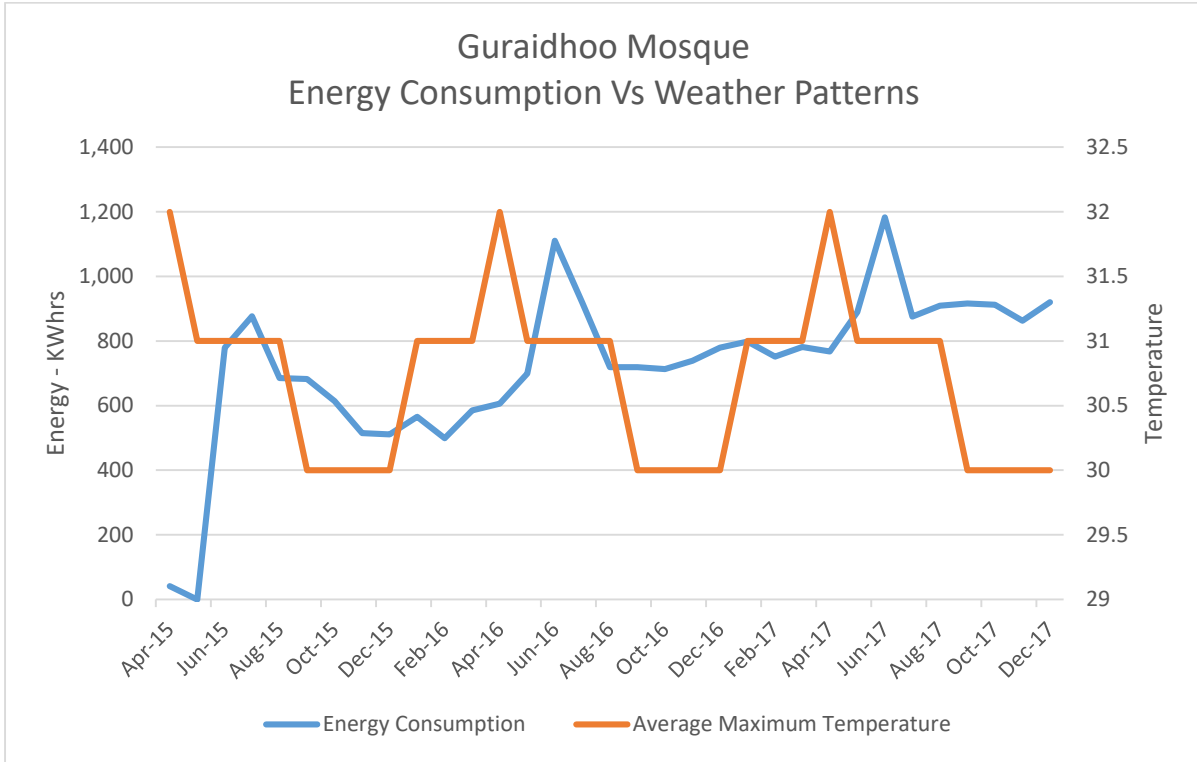


Figure 1-17: Energy Consumption versus Weather Patterns at Masjid-ul Sidheeq

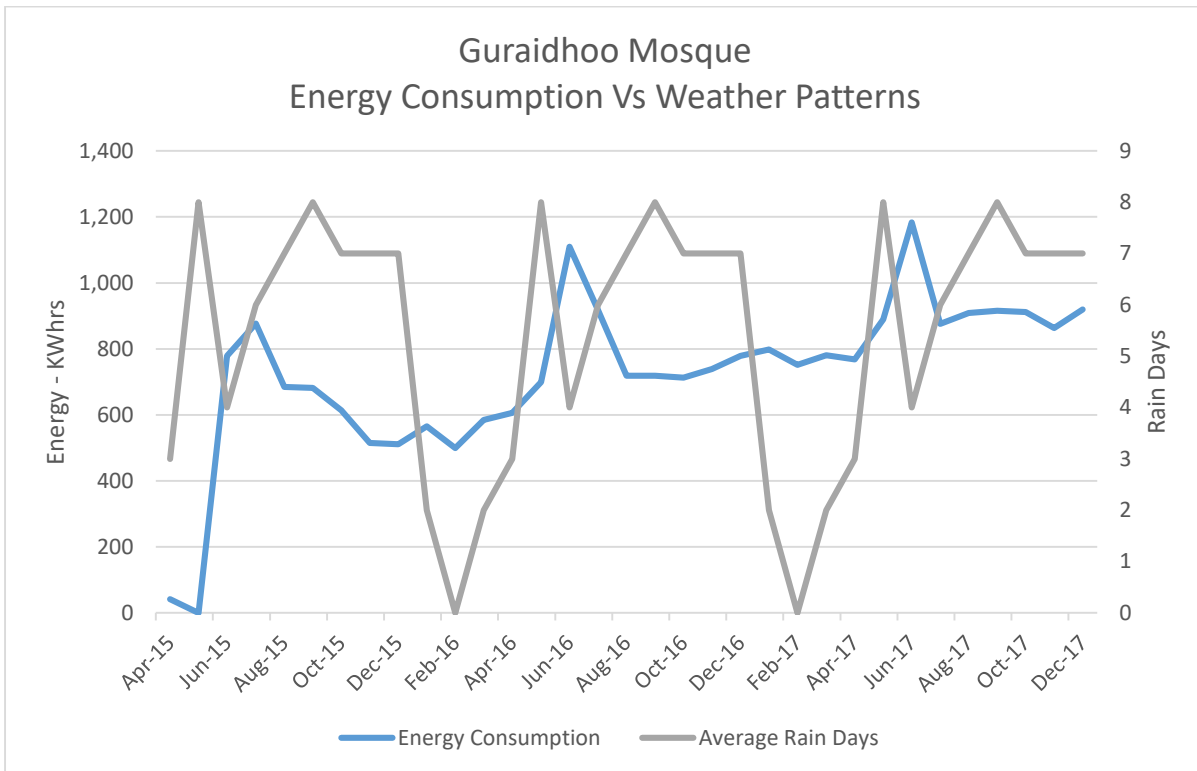


Figure 1-18: Energy Consumption versus Weather Patterns at Masjid-ul Sidheeq

### 1.4.14 Bill Payment

The team understand that bills go direct to Ministry of Islamic Affairs in Male’ and paid by the Ministry. This means that local users have no understanding of energy consumption or how their usage patterns influence energy consumption.

Consideration could be given to providing monthly feedback to users on their energy consumption, however, data would need to be compared to surrounding mosques or historical data to provide users some perspective on their consumption patterns. This opportunity is not expected to have a significant impact on consumption given the current high levels of user performance in deactivating plant when the space is not in use.

### 1.4.15 Energy Budget

The mosque energy consumption is largely dependent on hours of use. The Team estimate current consumption, as follows:

	Power	Estimated Weekly Hours of Use		Expected Weekly Energy (kWhrs)	
		Typical Month	Ramazan Month	Typical Month	Ramazan Month
<b>Internal Lights</b>	1.4	24	36	33.6	50.4
<b>Ablutions Lighting</b>	0.2	56	63	11.2	12.6
<b>External Lighting</b>	1.5	56	63	84	94.5
<b>Fans</b>	7.4	10	18	74	133.2
<b>Total</b>	10.5			<b>202.8</b>	<b>290.7</b>

Table 1-2: Estimated annual energy consumption for Masjid-ul Sidheeq

These predictions match quite well with recent consumption.

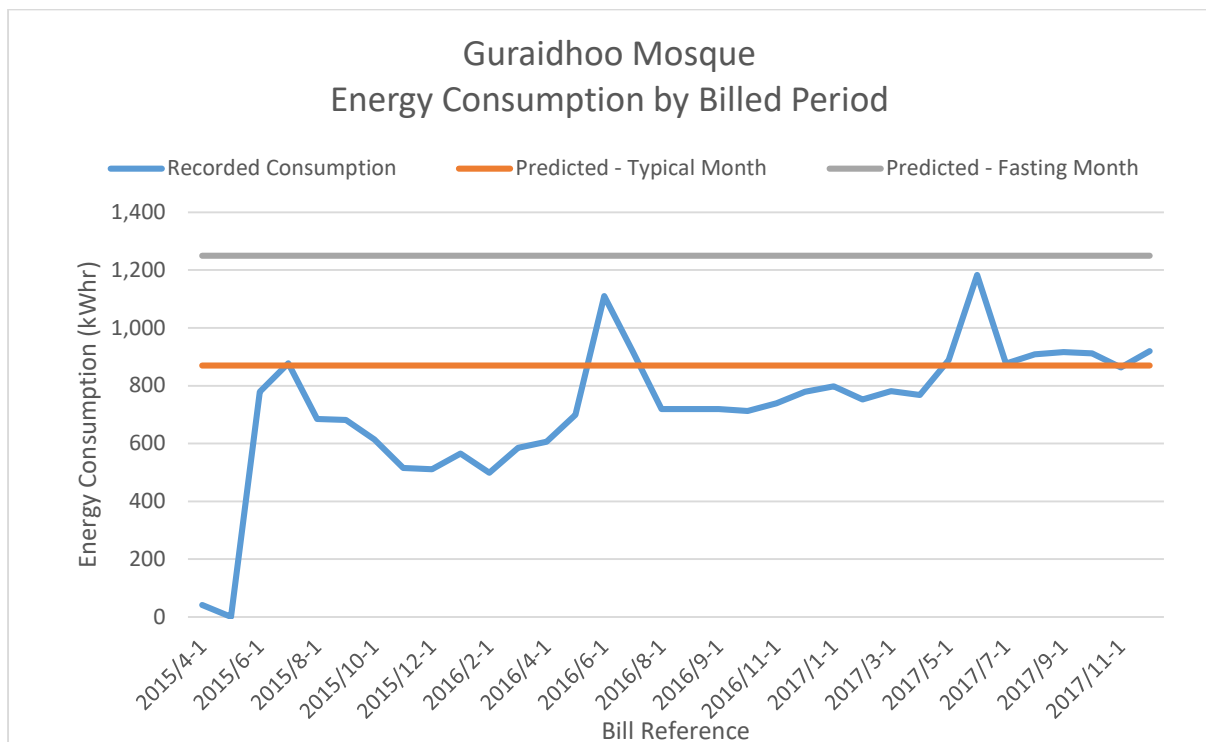


Figure 1-19: Energy consumption verses expectation for Masjid-ul Sidheeq

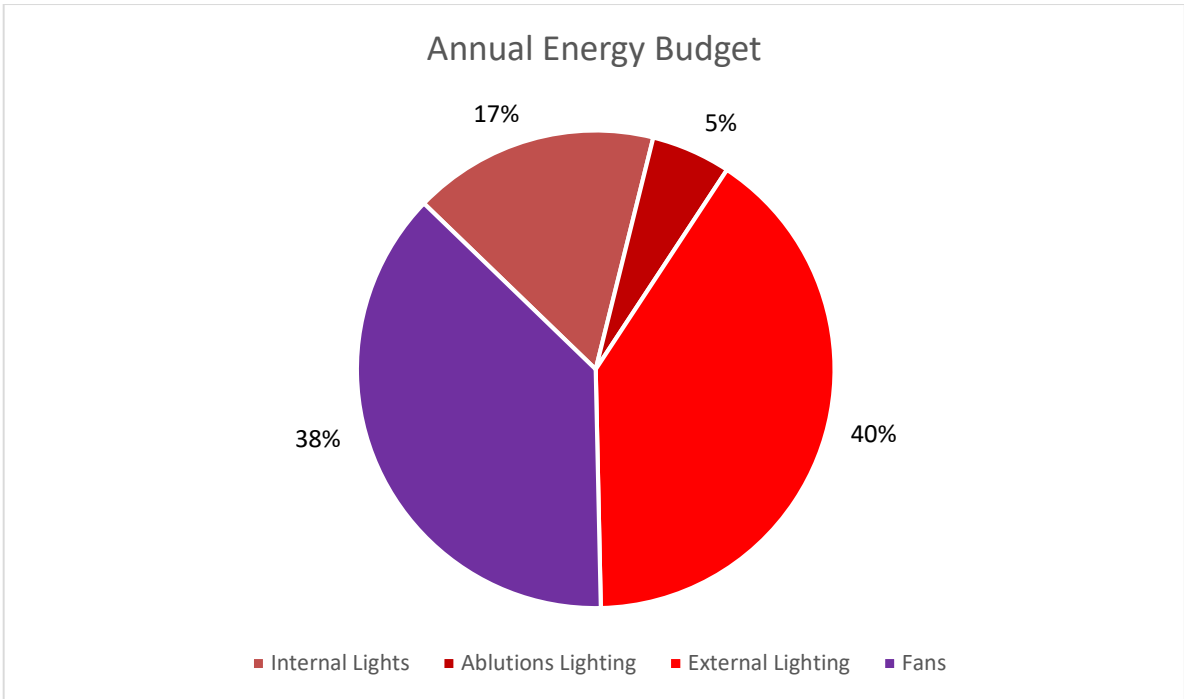


Figure 1-20: Chart showing estimated annual energy consumption by energy consuming groups for Masjid-ul Sidheeq

## 1.5 Opportunities for Improvement

The opportunities for improvement for this site will be discussed in more detail in Section 2 Design Recommendations for Masjid-ul Sidheeq, which includes:

- Lighting
- Air Movement
- Controls

# Section 2

## Design Recommendations

## 2.1 Background

As discussed in the energy audit section, the Guraidhoo Mosque draws very little energy. On a typical month, the energy usage is 2.2kWhrs/m<sup>2</sup>. During holy months the energy consumption increases slightly to 3kWhrs/m<sup>2</sup>. The two major energy consumers are the internal fans and the external lighting, at approximately 2/5<sup>th</sup> of the total energy budget each. The remaining 5<sup>th</sup> is predominantly from internal lights with a small contribution from ablution lighting.

The first part of Design Recommendations Section summarises different energy efficiency design opportunities under different areas of energy consumption. The following sub-sections details the implementation requirements, costs, savings, and recommendations for each option.

## 2.2 Air Conditioning Policy for Mosques

The government have proposed to provide air conditioning to all mosques within the next 3 years. We do not recommend this for existing Mosques.

Mosques are typically designed to be very open to the environment. The spaces do not seal well, and doors are typically left open for convenience of people to come and go as needed. Air-conditioning poorly sealed buildings is extremely inefficient and expensive.

Although the proposal states that this should be achieved through the use of solar energy, and thus has minimal associated greenhouse gas emissions, the use of solar energy still has substantial environmental costs (associated with the extraction of raw materials and the manufacture of the panels). Further, they are a significant capital cost.

We recommend that thermal comfort in Mosques is addressed through appropriate passive design solutions and is assisted by fans.

## 2.3 Design Opportunities

### 2.3.1 Lights

The power for internal and external lighting is similar. The practise is to use internal lighting only when the mosque is occupied. Observations suggest that this practise is well followed and that users switch off the lights when the Mosque is in use. In contrast, the external lights are left on overnight.

The mosque is adequately day lit during the day so there are no opportunities to reduce lighting energy consumption through daylighting. Lux levels were approximately 250 lux in the general praying area. This is slightly low for reading but given the short amount of time occupants spend reading it is considered reasonable. Further, the light levels were found to be adequate at night for occupant comfort and safety, suggesting that there are no opportunities to reduce the overall light levels. Thus, there are only two options remaining to reduce lighting energy consumption:

1. Install more efficient light bulbs
2. Reduce the hours of operation

The greatest savings from the first option would be seen by replacing external light fittings. The second option applies only to external areas as it seems that lights are not normally left on.

### 2.3.2 Fans

The high thermal mass of the building fabric, and relatively low air-movement through the space meant that the space did not feel comfortable without the use of fans. The two main opportunities to reduce fan energy consumption are:

1. Install more efficient fans
2. Reduce the hours of operation



There are two options for efficient fans. The first is to install *high speed low velocity* fans. These fans cover a much greater area than conventional fans so that fewer are needed for the same level of comfort. Moreover, they use less energy per fan than conventional fans do. The second option is to install DC motor fans. These fans use substantially less energy than AC fans.

The Team did not observe any fans being left on that weren't in use. Thus, reducing the operating hours of fans could only be achieved through improving thermal comfort.

### 2.3.3 Thermal Comfort

The internal temperature measurements showed that the temperatures inside the mosque during the day were slightly higher than external temperatures. There are several reasons for this:

1. There is limited shading on the external windows on the north-west and south-east facades, so sun penetrates the mosque directly (see **Figure 2-1**).
2. The carpeted floor provides insulation from the ground slab. Ground temperatures tend to vary little from the average annual temperature. As such, concrete slab on the ground (that does not get direct sun) can provide an element of temperature moderation, absorbing heat throughout the day and releasing it again at night.
3. Direct sun hits the building envelope and roof throughout the day (see **Figure 2-2**). Although the walls are light in colour, they still felt hot to touch, even several hours after the sun was no longer hitting them. The roof is a dark colour and thus absorbs heat.
4. Hot air rises and some of this will be expelled from the high-level vents. However, the vents are relatively small and louvres at a high angle, both of which limit rate of air exhaustion (see **Figure 2-3**).
5. The external space surrounding the mosque has a lot of grey paving which is exposed to the sun (see **Figure 2-4**). This heats up in the sun and in turn, warms the surrounding air – a phenomenon known as the Urban Heat Island effect. This means that the air that enters the mosque is already slightly warmer than ambient temperatures.
6. The surrounding buildings limit access to the prevailing winds (see **Figure 2-5**).



Figure 2-1: Sunlight directly penetrating the mosque



Figure 2-2: Sun heating the building envelope



Figure 2-3: Relatively small area for air to escape at high level



Figure 2-4: Grey paving and limited vegetation surrounding the mosque

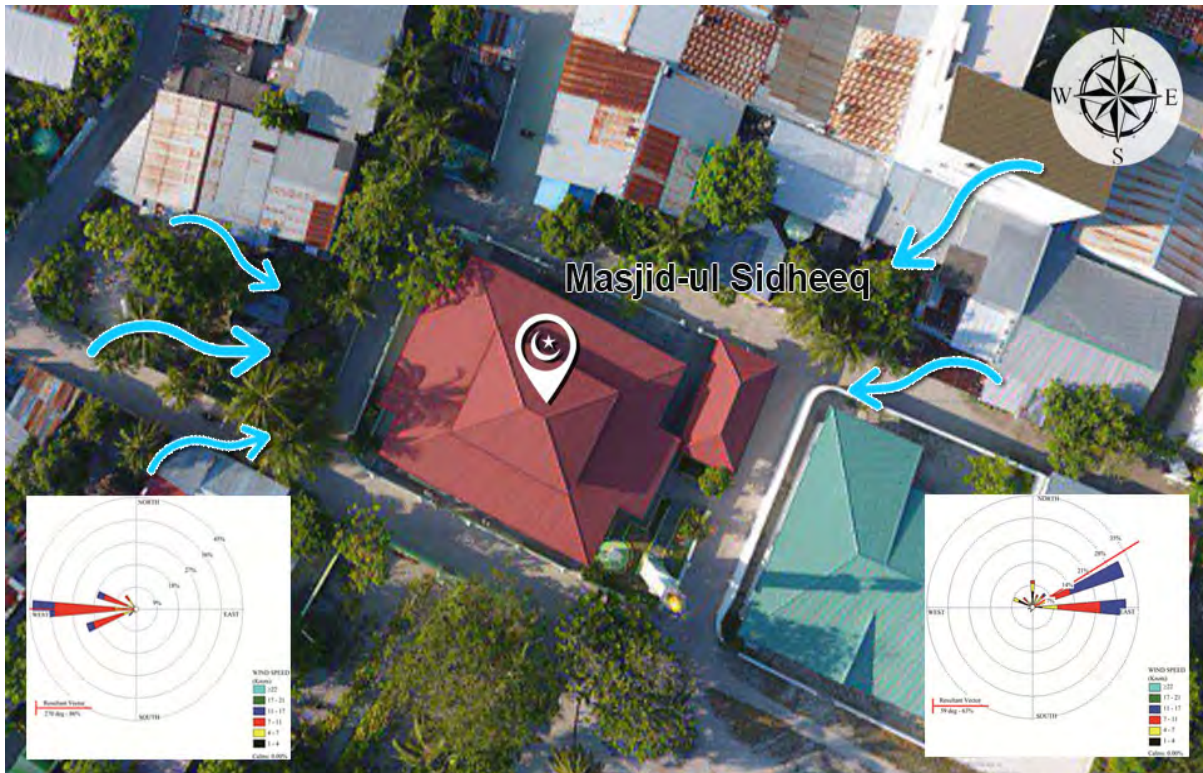


Figure 2-5: Prevailing wind directions in Guraidhoo

The most straight forward way to improve thermal comfort in the Guraidhoo Mosque would be through external planting that shades the building envelope. The extent of external paving could be reduced, and landscape could be used to shade remaining paving. This solution would improve comfort in three ways.

1. It would reduce the direct heat loads into the mosque by shading the external façade.
2. It will eliminate the Urban Heat Island effect by shading the external paving
3. Trees transpire and naturally cool their surrounds so that the air temperature surrounding the mosque would be slightly lower than ambient temperatures.

When the roof requires repainting, it would also be worth considering a lighter colour.

It should be noted that improving the thermal comfort will not necessarily reduce the use of fans and therefore electricity consumption as visitors may still turn on fans out of habit and preference. However, the landscaping would make a substantial difference to occupant comfort, in particular on days when the mosque is at capacity.

## 2.4 Detailed Design

### 2.4.1 Install more efficient light bulbs

LEDs use between one third and one half of the energy of fluorescents lights. This means that there are substantial savings opportunities in bulb upgrades. We estimate the cost to upgrade the light fittings to LEDs to be approximately 30,000MVR. Associated energy savings are estimated at 720kWhrs/year which equates to 647kgCO<sub>2(e)</sub>/year or 3000MVR/year.

The payback period is approximately 10 years for this option. This is much higher than a typical payback period for conversion to LEDs because of the relatively low hours per year of operation of most of the lights. Notwithstanding the longer payback, the Team recommend that as bulbs require replacement, they are replaced with LEDs. The lifetime of LEDs is far greater than the lifetime of fluorescents so are benefits beyond energy efficiency in the longer term.

### 2.4.2 Reduce the hours of operation

Only external lights are left on overnight. We estimate that reducing the hours of operation by 30% would equate to approximately 310 kWh/year savings, approximately 280kgCO<sub>2(e)</sub>/year or 1350MVR/year.

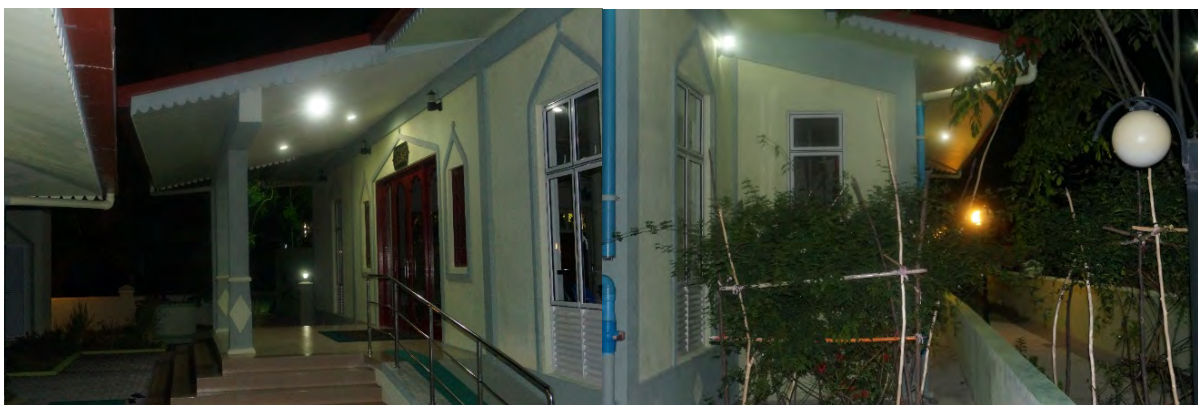


Figure 2-6: After hours lighting

It should be noted that once the bulbs are replaced with LEDs, the potential annual savings for this option reduce to approximately 155kWh, 140kgCO<sub>2(e)</sub> and 675MVR. However, there are no costs associated with this option so we recommend doing this whether or not the bulbs are replaced.

### 2.4.3 Install more efficient fans

Energy efficient fans cost approximately 1500MVR per installed fan. Replacing the 33 existing fans would therefore cost approximately 50,000MVR. The potential energy savings from such a measure are only 266KWh/year or 1150MVR/year.

Fewer high-speed low velocity fans would be needed to achieve the same level of thermal comfort. However, even with 4 fans, the costs are prohibitively high (≈24,000MVR).

Even if the existing fans were only replaced with energy efficient fans at the end of their lives, the cost differential between the energy efficient and standard fans (approximately 3 times more for the energy efficient option) means that the payback period would still be approximately 25 years. The Team estimate that the fan's useful life would be between 15-25 years.

None of the options presented are economical as the payback periods are all as long or longer than the fan lifetime. The Team do not recommend this option unless the main driver is to achieve greenhouse gas savings. Energy efficient fans would equate to annual savings of 240kgCO<sub>2(e)</sub>/year.

### 2.4.4 Reduce the hours of operation through thermal comfort measures

As discussed in the previous section the Team did not find any fans running that were not in use. As such the only way to reduce fan use would be through improvements to thermal comfort. However, as noted, even with improved thermal comfort, occupants may still opt to turn on fans out of habit, or to offset the heat they have experienced in transit to the mosque.

The two key measures that would improve thermal comfort at the mosque are:

1. Increase landscaping
2. Paint the roof a lighter colour

**Figure 2-8** gives a visual representation of the proposed landscaping. The hard scape shown on the left absorbs heat over the day and reradiates it into the night so that the air around the mosque is hotter than ambient temperatures. In contrast, greenscape can drop ambient temperatures by as much as 1°C. Further, trees planted at the perimeter can be used to shade the East and West facades from the low morning and afternoon sun. The Team estimates that this would cost approximately 30,000MVR.

Painting the roof a lighter colour would also help to reflect rather than absorb heat. We recommend an absorptivity no more than 0.5, but note that the lower the solar absorptivity of the colour selected the better (see **Figure 2-7**). We recommend that this is undertaken when the roof is next due to be painted. On this basis there is no cost for this option.

As the mosque is not air conditioned, it is not possible to translate these measures into direct energy savings. However, if we estimate that fans will be used 30% less, savings would amount to

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

**Figure 2-7: Examples of Solar Absorptance of paint colours**

265KWh/year (approximately 240kgCO<sub>2(e)</sub>/year or 1150MVR/year. On this basis, the landscaping would have a payback period of approximately 25 years. This is a relatively long payback period. However, unlike many options, the benefits would continue to increase with time. There would also be additional benefits such as improved amenity, improved aesthetics, and increases in biodiversity.

The Team therefore strongly recommend that the roof is painted in a lighter colour and recommend that the client considers landscaping options.



Figure 2-8: Current and proposed Mosque perimeter

## 2.5 Energy and Greenhouse Gas Savings

**Table 2-1** below shows the potential energy and greenhouse gas (GHG) savings of the different design options listed above. Note, the proposed changes to encourage reduced fan usage through improved thermal comfort are not included. This is because it is not possible to estimate with any accuracy the likely changed behaviour of building users.

Action	Estimated Cost (MVR)	Estimated Cost savings (MVR/yr)	Energy savings kWhrs/year	GHG savings (kgCO <sub>2</sub> (e) p.a.)	Payback Period	Recommended?	Comments
Install more efficient light bulbs	30,000	3000	720	648	10	Yes	Based on LEDs using half the energy consumption
Reduce the hours of operation for external lights – retain lights	0	1350	310	279	NA	Yes	Expect to reduce operational hours by around 30% on average
Reduce the hours of operation for external lights – energy efficient lights	0	675	150	135	NA	Yes	Expect to reduce operational hours by around 30% on average
Install more efficient fans	50,000	1150	266	240	NA	No	Based on 30% reduction in energy consumption
Increase landscaping	30,000						
Paint the roof a lighter colour	0	1150	226	240	25	Yes	Based on 30% reduction in fan use

Table 2-1: Summary of energy and GHG savings for proposed design changes

## 2.6 Future considerations

It is not recommended that substantial measures to improve comfort are undertaken in the Guraidhoo Mosque beyond the recommendations listed above. However, in future developments the following recommendations should be considered:

1. Use of lightweight building material for the building envelope.
2. A light coloured, well insulated roof.
3. Extensive landscaping and limited paving (or a light colour) surrounding the building.
4. Use of exposed concrete or tile floor



Figure 2-9: Existing (figure left) and recommended (figure right) roof colour



Figure 2-10: Recommended typical landscaping for mosques

The building form of Guraidhoo Mosque would lend itself to a highly effective passive cooling system with minor modifications. The high-level vents in the mosque sit higher than the surrounding buildings. This means that larger vents on all four sides of the building would be able to capture the prevailing winds. The wind velocity at this level would generate negative pressure helping to draw hot air out of the building. Provided the building surrounds were adequately planted, the rising hot air would in turn draw in cool air from outside (see **Figure 2-11**)



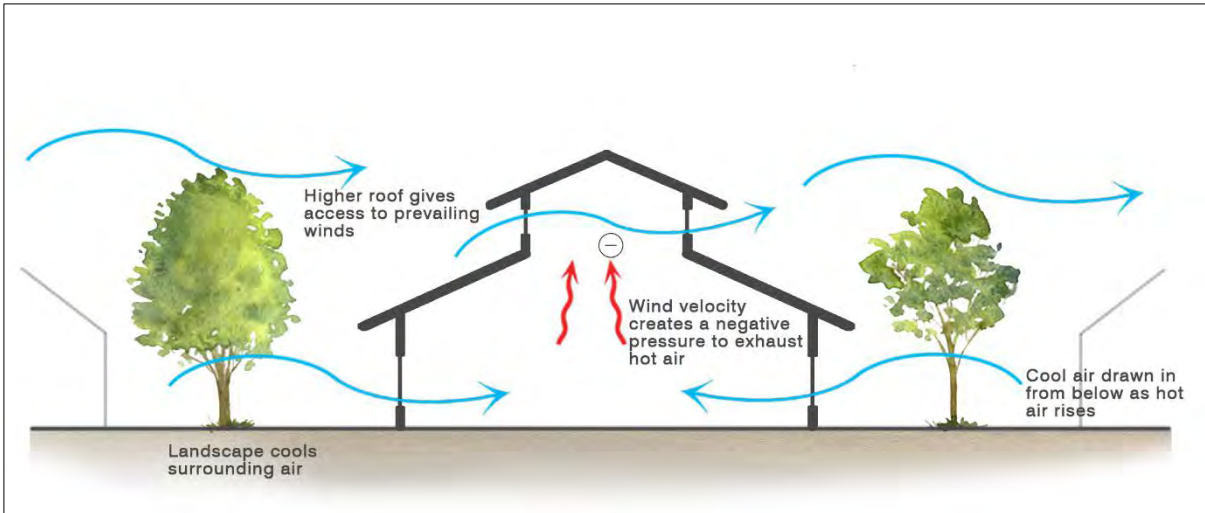


Figure 2-11: Passive cooling strategy with a raised roof

When considering passive design strategies for buildings the orientation is typically a major consideration. However, the orientation of mosques are fixed. Nonetheless, it may be worth considering the use of wing walls to capture and direct prevailing winds as the wind directions are relatively consistent during each of the monsoon periods (see Figure 2-12 and Figure 2-13).

In the Maldives these are very consistent – with easterly to north easterly winds from December to April (see Figure 2-12) and westerlies from May to November (see Figure 2-13)

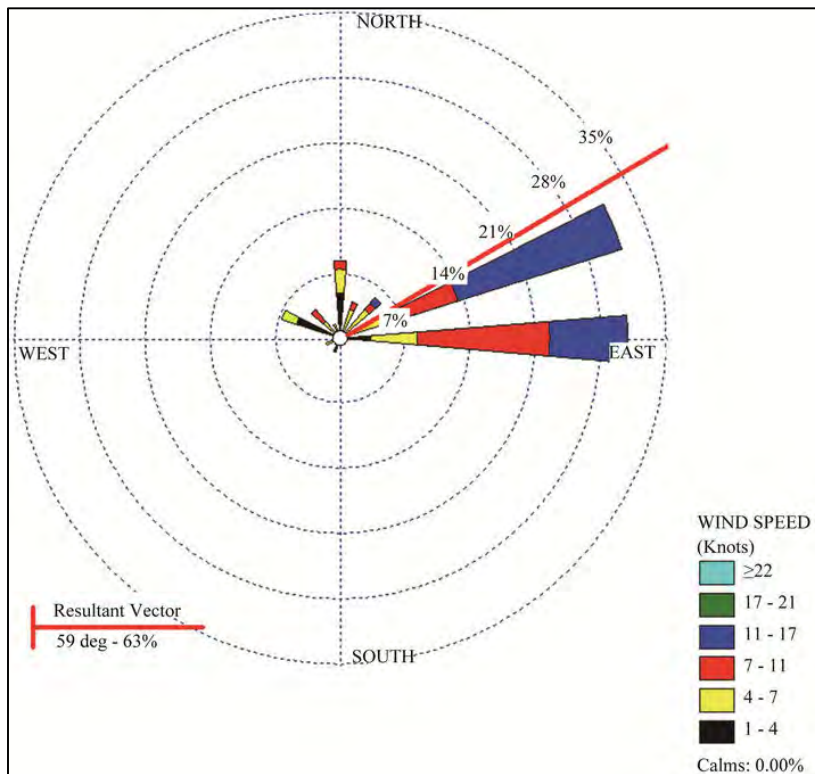


Figure 2-12: Wind rose for the northeast monsoon (Dec - Apr) for central Maldives<sup>1</sup>

<sup>1</sup> Department of Meteorology (Dom), "Severe Weather Events in 2002, 2003 and 2004," 2005. <http://www.meteorology.gov.mv/default.asp?pd=climate&id=3>

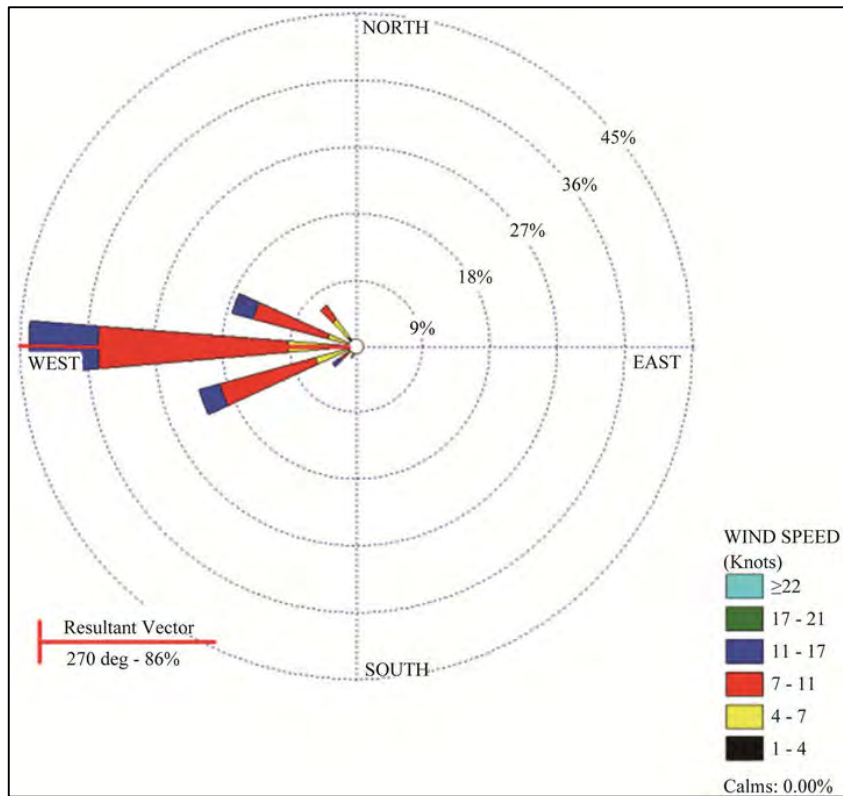


Figure 2-13: Wind rose for the southwest monsoon (May - Nov) for central Maldives<sup>1</sup>

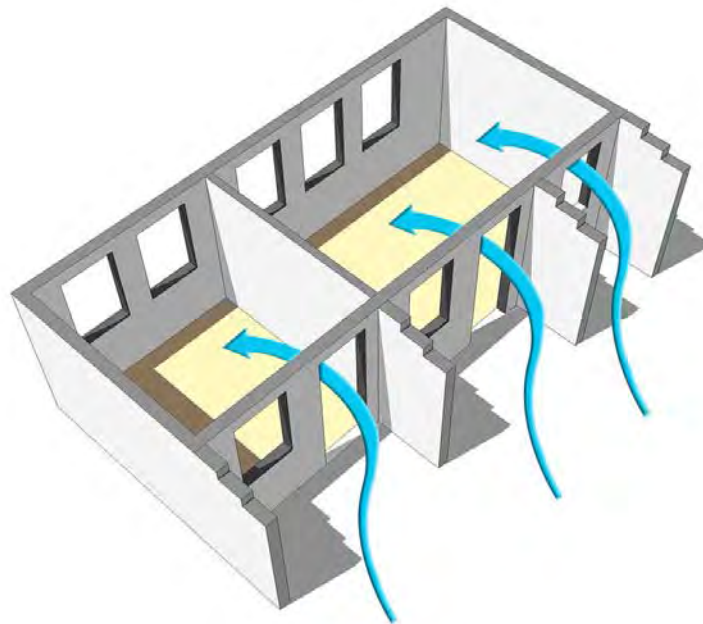


Figure 2-14: Wing walls to guide air flow

Another future consideration is the more active employment of traditional architecture practises. People living in hot climates developed many different strategies for coping with heat, many of which has been forgotten, ignored or abandoned over the centuries. These strategies are often cheaper to build, are more environmentally sustainable, and are more comfortable to live in.

Double skin on eastern and western façades are traditionally known in both India and Maldives as “Jaali”. This is prevalent in Rajasthani architecture, also used in traditional mosque designs in the Maldives. These work by creating a thermal buffer between the building and surroundings with the double skin. The outer skin is often installed approximately 4 feet from the building. The outer skin design allows diffused light to enter but substantially reduces direct solar gain. The double skin serves functions of 3 filters- air, light, and privacy.



Figure 2-15: Jaali: Traditional double skins

# Section 3

## Monitoring Plan

### 3.1 Site Boundary

The mosque is provided with a single phase power supply, with meter box located on the building perimeter adjacent the main entry as mentioned in Energy Audit **subsection 1.4.11** Existing Power Supply. The only energy flow onto the site is electricity through this meter. There is no on-site energy generation capacity.

### 3.2 Strategic Aims

The metering for this facility is primarily to allocate costs from the power generation utility to the Mosque operators.

There is limited incentive to provide additional billing for building optimisation or user engagement due to the low level of energy consumption and the lack of someone clearly responsible for energy management on site.

Best practice metering systems would provide automated reading and clear reporting for occupants and the building owner to facilitate energy management and provide alerts if individual users or systems were outside of the expected performance levels. This could be useful in identifying issues such as lights left on.

### 3.3 Major Energy Uses

As described in the energy audit report, the building has limited energy consumption on site.

The majority of building energy consumption is expected to be in external lighting and internal fans.

Estimated energy consumption is shown in **Table 1-2** and for derivation and explanation of **Table 1-2** refer to **sub-section Section 11.4** Site Visit Observations. Refer to **Figure 1-20** for annual energy budget.

### 3.4 Metering Arrangement

#### 3.4.1 Meter Reading Strategy

The current metering system is a manual read meter for the main meter. There is a secondary meter, downstream of the utility meter. It is not clear what this serve, it is expected to act as a check meter for the main supply.



Figure 3-1: Internal Check Meter

### 3.4.2 Meter Location

The main meter is located external to the building adjacent the main entry. The check meter is located internally close to the main entry door.

The sketch below shows the current metering arrangement on site:

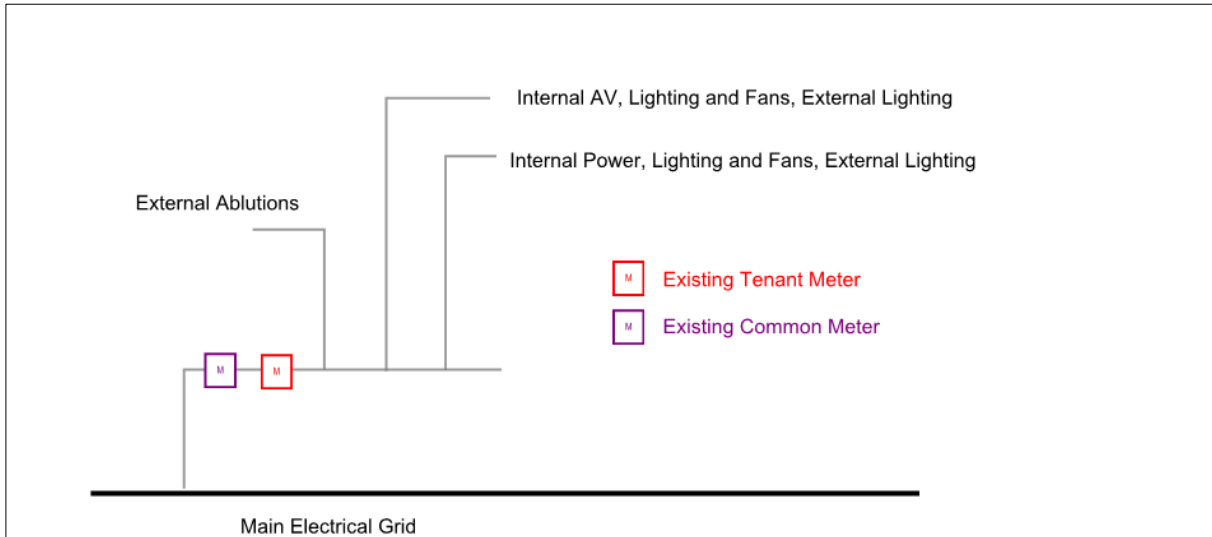


Figure 3-2: Metering Schematic

### 3.4.3 Additional Meters

There is considered to be limited benefit in providing additional meters for the site, without modifying internal wiring. As all local distribution points include multiple uses (internal lighting, power, AC and external lighting) sub-meters would not provide definitive information as to what systems are consuming consumption.



Figure 3-3: Typical Internal Electrical Distribution Centre Showing Multiple Uses Downstream

#### 3.4.4 Occupant Engagement

Energy consumption at the mosque matches well with usage. Logging shows limited excess usage overnight and, therefore, this mosque is considered well managed by engaged users. Limited benefit would be expected by providing additional metering. Refer **Figure 1-13** of **Section 1 Energy Audit** for power data log of the mosque which shows regular periods of zero energy use and consistent overnight and occupied levels of energy consumption.

It is recommended that the local agent responsible for maintenance of the mosque is advised of energy consumption monthly, with comparisons to last year and last month to facilitate monitoring and identification of unusual usage.

### 3.5 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:

Feature	Expectation	Verification	Equipment Required
<b>Install more efficient light bulbs</b>	Replacing light bulbs with more efficient fittings should reduce lighting energy by 50%.	Record average weekly energy consumption for a period of at least 4 weeks prior to change. 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 at least 12kWhrs a week less.	Nil. Utilise existing metering.
<b>Reduce the hours of operation for external lights – retain lights</b>	Reducing hours of lighting should reduce energy consumption by around 30% on average,	Record average weekly energy consumption for a period of at least 4 weeks prior to change. 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 at least 5kWhrs a week less.	Nil. Utilise existing metering.
<b>Reduce the hours of operation for external lights – energy efficient lights</b>	Reducing hours of lighting should reduce energy consumption by around 30% on average,	Record average weekly energy consumption for a period of at least 4 weeks prior to change. 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 at least 2 kWhrs a week less.	Nil. Utilise existing metering.
<b>Install more efficient fans</b>	Improving fan efficiency should reduce energy consumption	Record average weekly energy consumption for a period of at least 4 weeks prior to change. 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 at least 13kWhrs a week less.	Nil. Utilise existing metering.

Table 3-1: Design Recommendation verification



# Section 4

## Conclusion

## Conclusion

The energy consumption of the mosque is found to be quite low. Therefore, the opportunities to reduce this are limited. If all recommended measures are completed, the Team estimate that this could result in total annual savings of 4,825MVR or 4340kgCO<sub>2(e)</sub>. Total upfront costs of these options are estimated to be 60,000MVR. This is an overall payback period of approximately 12.5 years.

The Team recommends that the upgrades are undertaken in stages, according to regular maintenance needs (e.g., as lights need replacing these are replaced with LEDs). It is also recommended utilizing such energy saving measures as future considerations when developing mosques in the Maldives.

To support the recommendations and as part of the project scope, the Team has prepared Monitoring Plan which can be utilized to verify recommendations.