



**Ministry of Environment , Climate
Change and Technology**

Assessment of Local Conditions and Building Systems

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





Ministry of Environment, Climate
Change and Technology

Strengthening Low Carbon
Energy Island Strategies (LCEI)
Project



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1. Introduction

Energy Security is crucial for nation such as Maldives which is completely depended on the fuel imports to meet all its energy demand thereby making it vulnerable to global oil shocks. The Government realizes energy efficiency & conservation measures are very crucial to achieve this energy security. It is observed that the buildings in Maldives consumes 30% of the total energy consumption in the region. Therefore, it becomes necessary to reduce the energy use in the buildings and related carbon emissions more so **to achieve country's commitment to reduce** greenhouse gas (GHG) emissions by 10 percent before 2030.

As the energy demand is expected to continue to grow at more than 8.5% per annum in Maldives with building sector being the major contributor, the Government of Maldives have initiated several steps towards achieving energy efficiency in the sector for the existing and new buildings such as developing energy efficiency building guidelines & standards-labelling programs for the appliances. The energy performance index (EPI) of existing building stock in Male and Hulhumale is higher than that of the modern buildings, which adopt best practices in building design and energy efficiency. Opportunities to improve the building design of Maldivian building stock to reduce their EPI can therefore be identified, by identifying the design features that affect energy performance and comparing the characteristics of existing buildings to the best practices.

In view of the above, the energy efficiency building guidelines sets minimum requirement for energy efficiency & use of resources in buildings. It considers the local climatic condition, the building materials available, building technologies used in the region. All the factors are corelated to carryout retrofits in the existing buildings and design of new buildings to achieve energy efficiency. For instance, the climatic condition & building materials used in an existing building can be analyzed & with minor changes such as insulation on the walls or roofs or changing the glazing that allows specific amount of solar heat gain can bring about significant reduction in the energy consumption from air conditioners in the building. Likewise, for a new development, huge amount of energy can be achieved by considering local climatic conditions at the design stage like orientation of the buildings that uses natural daylight & ventilation. Therefore, in view of developing an effective energy efficiency building guidelines that results in significant energy efficiency in the buildings in Maldives, it is important to study the local condition and existing building systems of the region.

1.1. Objective of the Report

Pursuant to the inception report that was aimed at setting the methodology for developing energy efficiency building guidelines & the role of various stakeholders, the next step was to study the local condition and building systems of the region. This report studies & analyses the following:

1. Real Estate Growth in Maldives
2. Climate Analysis of Maldives,
3. Existing Construction sector - building typologies, common building materials used
4. Energy & water consumption pattern of existing buildings in Male and Hulhumale
5. Regulatory framework of the construction, energy & water sector,

The study of existing regulatory framework of the building and other related sectors helps in understanding the existing regulations and the various stakeholders involved, so as to develop energy efficiency guidelines that can be seamlessly integrated with existing regulations & easily implemented. The analysis of other local factors will help in setting the current energy performance baselines which would in turn result in formulation of a simple, realistic & efficacious energy efficiency measures that will bring about greater energy efficiency in buildings by incorporating the local conditions.

Additionally, the details of stakeholder consultation, the detailed energy assessment and occupancy survey carried out during 20-31 January, 2020 with the results and outcomes are provided in this report.

1.2. Approach & Methodology

The approach and methodology adopted to prepare this report on local condition assessment is explained in Figure 1.

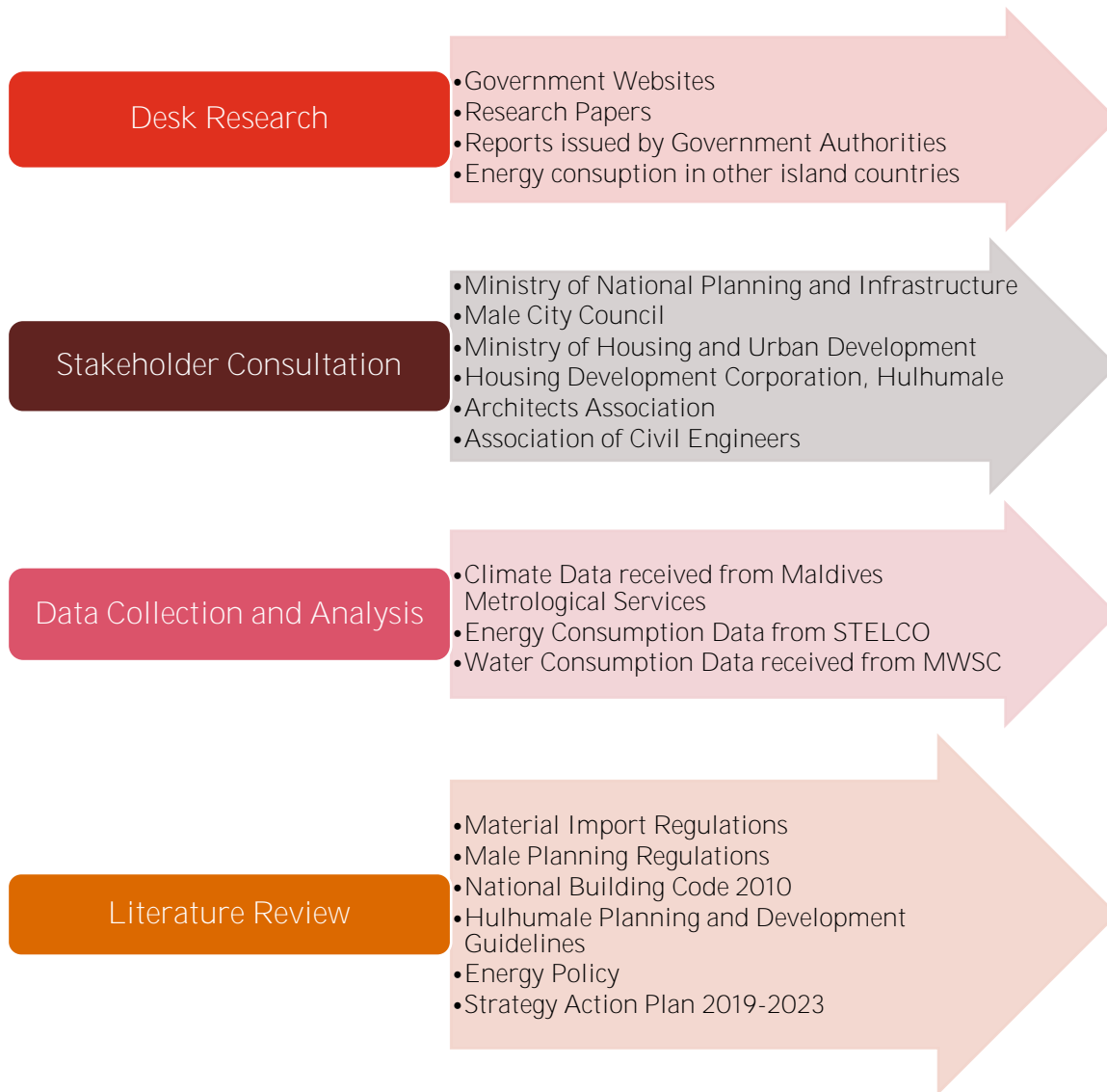


Figure 1: Approach and Methodology

The approach and methodology adopted for the detailed energy assessment and occupancy survey is provided in the respective section later in this report.

2. Construction Sector of Maldives

The construction sector plays a vital role in the economic growth of the Maldives. It is one of the biggest contributors in the GDP growth and fulfils the need of basic infrastructure for socio-economic expansion of the Maldives. Construction segment includes construction of civil works like roads, highways, bridges, buildings for residential, commercial, institutes and Hotels etc. Apart from the direct contribution of the construction business, segment also contributes secondarily through its associations to other segments of the Maldivian economy extending from the suppliers of construction materials, real estate services and architectural services etc. In addition to the positive impact on Maldivian economy, it is also imperative to note that construction segment has disproportionate dependence on imports and its adverse **influence on the country's** fiscal deficit.

The construction sector of Maldives is rapidly emerging. According to economic bulletin of Maldives Monetary Authority (MMA) in 2018, the construction industry has progressively contributed to the country's GDP along with the construction related imports which has drastically increased. The construction sector of the Maldives is dependent on the imports of country since almost all building materials such as cement and aggregates, base metals and wood is imported. The Figure 2 shows the Real Estate share to GDP from 2013-2018. Construction sector related imports achieved the growth rate of 35% in 2018 from 24% in 2017. In addition, credits provided by commercial banks to the construction sector documented an annual growth of 21% in 2018 and provided 52% of entire private sector credit in 2018. The main reason of achieving high construction sector growth was due to rise in low interest loans provided to the residential and housing project construction, in combination of credit lent for the development of new resorts and restoration of the resort projects.

In 2018, the private sector investments in tourism and real estate provided impetus for the construction sector growth. The sector also received a boost from additional development projects such as the establishment of water and sewage systems in the atolls and social housing projects. Major projects carried out during the year includes construction of hotels, Dharumavantha Hospital in Male & residential units in Hulhumale.

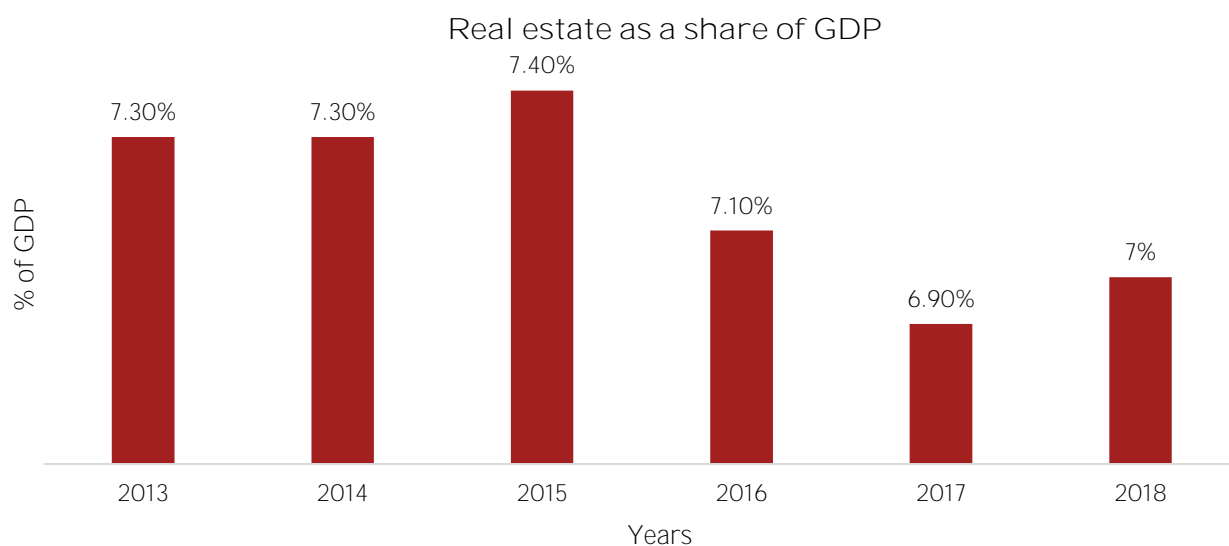


Figure 2: Real estate sector share in GDP growth of the Maldives
(Source –Maldives Monetary Authority – Monthly Statistics 2019)

Maldives has mixed infrastructure development, which consist of residential sector with different income groups, commercial, hotels and luxury apartments, light industrial and government buildings. The Real estate development in Maldives has about 86% of residential area and remaining 14% of commercial development. The tourism sector with hotels and guesthouses has highest share of 37% of non-residential infrastructure development in Maldives followed by educational infrastructure comprising about 35%. The share of different types of buildings is presented in the Figure 3.

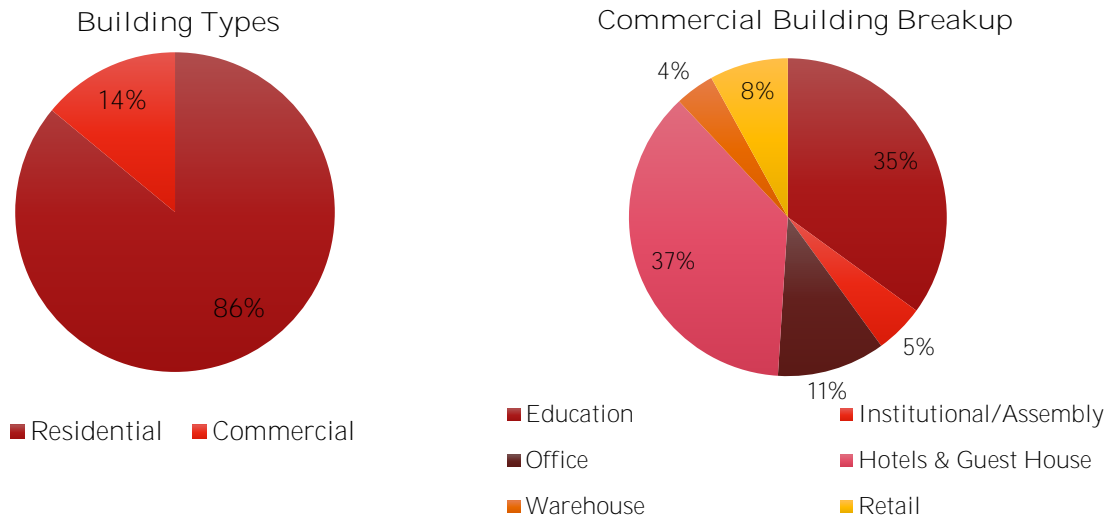


Figure 3: Buildings distribution in Maldives
(Source: Green buildings market intelligence-IFC World Bank Report)

2.1. Built-up area growth

The capital Male is main commercial hub of the country that has employment opportunities, better health, and educational services so migration from outer islands has increased. This rapid urbanization has increased the demand of residential and commercial buildings. Before 2006 Tsunami, the region had up to 6 storey high buildings but after the Tsunami, Male has witnessed a rapid increase in 10 to 25 storey high buildings. The Figure 4 indicates the built-up area of authorized buildings construction and completed buildings in Male. Almost 476 buildings were authorized in 2017 for the construction with total floor area of 413,633 sqm. Construction work of nearly 279 buildings was completed in 2017.

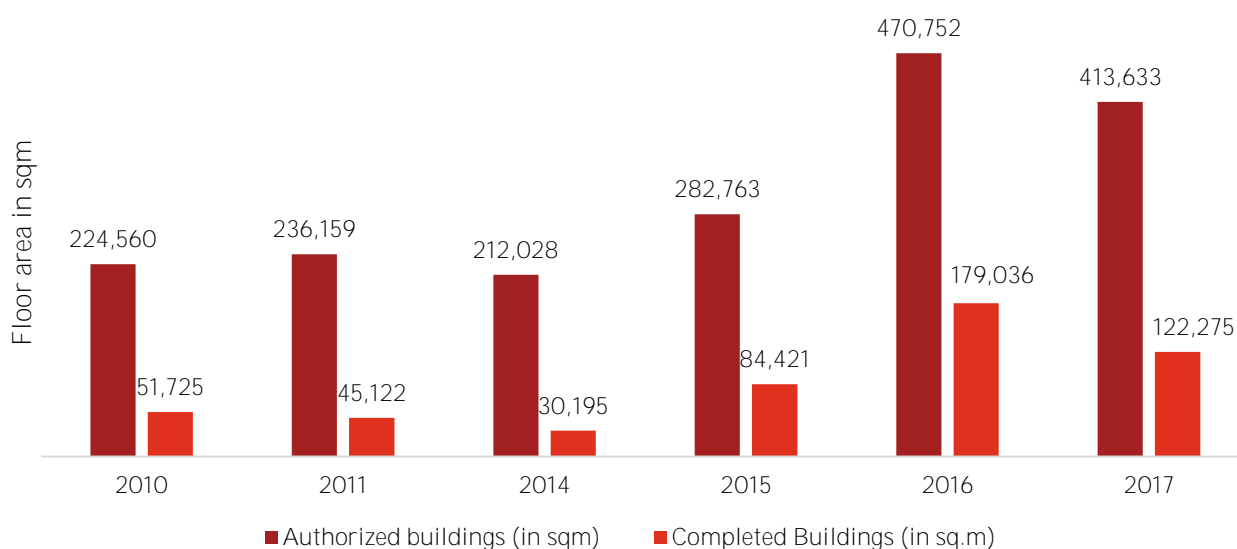


Figure 4: Buildings authorized for construction and buildings completed by floor area in Male from 2010-2017 (Source – Ministry of Housing and Infrastructure)

2.2. Planned initiatives in Male and Hulhumale in next 5-10 years

Government of Maldives has announced three integrated urban development zones- The Greater Male zone, Northern development zone, Southern development zone. The Greater Male region will be developed as main hub of national development consisting of Male', Hulhumale', Vilimale' and Villimale' II and Fushi Dhiggaru Falhu which will emerge as the integrated pivot that drives the country's economy. The northern development zones consist of two atolls Haa Alif & Haa Dhaal while the southern development zone consists of four atolls Gaafu Alif, Gaafu Dhaal, Gnaviyani & Seenu that will feature international airport, hospital, retails & hotels to making them a tourism hub. The government has also planned to develop international transshipment with special economic zones, international bunker facilities in northern & southern development zones respectively to boost economy.

Development in Hulhumale:

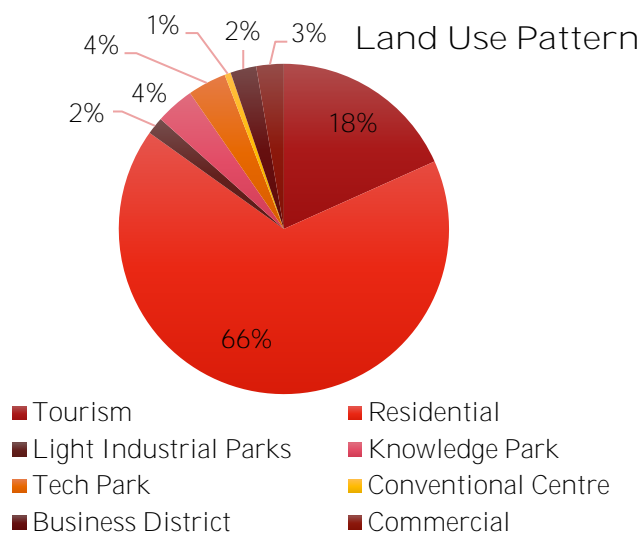
The Hulhumale' development project was initiated by the government to alleviate the acute housing congestion problem in the capital region Male'. Housing Development Corporation (HDC), a state-owned enterprise, was established in 2001 to undertake and manage the overall planning and building of the reclaimed city. The city is developed in two phases having area of 188 Ha and 244 Ha respectively to accommodate approximately 240,000 population. Phase I development targeted 80,000 population & involved construction of sports complex, school, malls, hospitals & community center, government housing, private mixed residential units & private housing complexes in which some of residents have built guest houses for commercial purpose. At present, 80% of the phase is complete with 50,000 population. The Phase II of the development started in 2015 & involved construction of government housing complex with 7000 units, luxury villas, water parks, universities, business & IT parks, industrial area, ports & tourism islands in Hulhumale city, referred as Youth city, is ongoing. The plan is to complete the Phase II of the development by 2030 (Source: HDC).

The Figure 5 indicates the development of projects in Youth City.



Figure 5: Development Plan of Hulhumale
 (Source – Housing Development Corporation, Hulhumale)

The Youth city has mixed land use pattern with range of residential development, hotels and commercial sector. The land distribution of Youth city is as indicated in Figure 6.



Land Use	Total Area (sq. Km)
Tourism	214,720
Residential development	781,463
Light Industrial Park	20,000
Knowledge Park	44,496
Tech Park	44,380
Conventional Centre	7200
Business District	29,760
Commercial	31,588

Figure 6: Land Use Pattern in Hulhumale
(Source – Housing Development Corporation, Hulhumale)



Figure 7: Phase 1 Developments in Hulhumale
(Source – Housing Development Corporation)

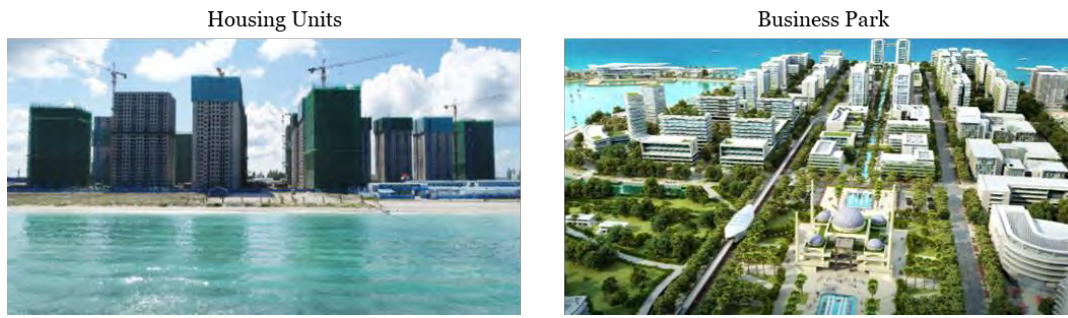


Figure 8: Phase 2 Ongoing & Upcoming Developments in Hulhumale
(Source – Housing Development Corporation)

2.3. Regulatory Framework of the Building Construction sector

Ministry of National Planning & Infrastructure (MNPI) is the ministry involved in the construction sector. The regulatory framework of the sector is given in Figure 9.

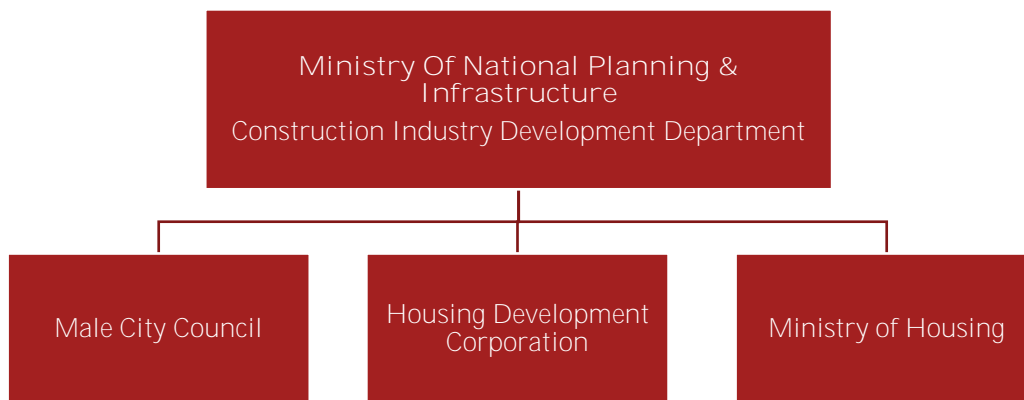


Figure 9: Regulatory Framework of the building construction sector

The construction sector in Maldives is regulated by Construction Industry Development Department (CIDD) under the purview of Ministry of National Planning & Infrastructure (MNPI) while Male City Council, Housing Development Corporation and Ministry of Housing are the local authorities responsible to grant approvals/permissions to the contractors for designs & construction of buildings.

Roles & Responsibilities of Departments

- 1) The Construction Industry Development Department (CIDD) under the purview of Ministry of National Planning & Infrastructure is the regulatory body that performs following function
 - a) Formulating Building regulations, codes and standards for the Maldivian construction sector.
 - b) Formulate regulations for safe built environment.
 - c) Ensure development of the Construction Industry by establishing the relevant regulatory framework, strategies and monitor accordingly with the policies set within the ministry.

- d) Responsible for monitoring the work of all the local authorities such as Male city council, FDC & HDC, whether they function in compliance all the regulations
- e) Responsible for creating awareness amongst all stakeholders regarding best construction practices for example including good design practices subjects in the universities.

CIDD is also working towards developing new building & infrastructure code. The gazette regulations in the construction sector is listed in the next section.

2) Local Authorities

The local authorities are responsible to grant approvals/permissions to the contractors for design & construction of buildings. The local authorities only grant permission to construct any building if it is compliant to

- Planning guidelines that governs the height of the structures & land use,
- Fire safety guidelines and
- Electrical (MEP) guidelines
- Environment Impact Assessment is also applicable for some projects

There are three main local authorities that are responsible for different regions of Maldives, Male City Council are responsible for Male region, Fahi Dhiriulhun Corporation Limited (FDC) & Housing Development Corporation (HDC) for Hulhumale & Ministry of Housing (MHUD) for the islands.

a) Male City Council

Male City Council which was founded in 2011 is the local government body responsible for the governance of the city of Male. They are responsible for providing clearance to the building projects in Male region if the buildings follow all the regulations. All the contractors must take two mandatory approvals from the city council for any construction of building. First is the approval on the drawings to start construction at Site. This approval is valid for 6 years. If the building does not commence construction within 6 years, the approval becomes invalid and re approval will be required. The second approval is post construction completion to obtain Occupancy permit. The occupancy permit is granted if the building is constructed as per the drawings approved by city council. A physical inspection of the building is carried out by representatives of the city council before awarding the permit.

b) Fahi Dhiriulhun Corporation Limited (FDC) & Housing Development Corporation (HDC):

Housing Development Corporation: It is a state-owned enterprise that was established in 2001. HDC undertakes & manages the overall planning & building in Hulhumale. The company undertakes hospitality, industrial, recreational, commercial & residential projects.

c) Ministry of Housing (MHUD)

They are responsible for providing housing solutions mainly project management work only in the islands. They do not make any regulations. They are currently involved in various government housing projects such as 100 row houses (design and Build model) & 100 high rise apartments in various islands in Maldives.

2.4. Regulations in Construction Sector in the country

The major regulations/codes related to the building sector are

1) Construction Act:

There are 13 regulation gazettes under this act along with some additional regulations for development in islands. It focuses on building permits before, during & after the construction.

2) Maldives National Building Code:

Government of Maldives has recognized the importance of ensuring safety of built environment and made mandatory to **produce the ‘Maldives National Building Codes’ that are recommended as best construction practices**. The building code sets the performance standards that ensures the safety and physical well-being of the building users. The designing, construction of the building is carried to ensure sustainable development. The code covers general clauses outlining classified building uses and interpretations and 35 technical clauses that cover aspects such as structural stability and durability, fire, safety, access, moisture control, safety of users, services and facilities and energy efficiency.

In energy efficiency clause, the code briefly stipulates that the buildings, throughout their lives, shall have provisions in controlling indoor temperature. To satisfy this requirement the building elements to be constructed considering:

1. Thermal resistance to heat loss through the building envelope
2. Heat gains (including solar radiation) through the building envelope
3. Air tightness
4. Control systems for cooling and ventilating.

The above-mentioned performance is not applicable to Housing, Outbuildings, Ancillary buildings, or buildings with a floor area of less than 50 m².

3) Male Planning Regulation:

Male Planning Regulations includes the amended regulations that were released by the Ministry of Housing and Infrastructure. The Male city council permits the construction of building only if the drawing submitted for approval are according to the regulations. The Table 1 below indicates regulations that are pertaining to building design.

Table 1: Male Planning Regulations

Criteria	Regulations												
Height of Buildings	<p>Building height based on the width of the road, if Building height is ≤ 30.48m</p> <table border="1"> <thead> <tr> <th>Width of Road(m)</th> <th>Maximum height of buildings (m)</th> </tr> </thead> <tbody> <tr> <td>< 1.219</td> <td>< 6 or single storey</td> </tr> <tr> <td>1.219 ≤ width < 1.524</td> <td>≤ 9 or three storey</td> </tr> <tr> <td>1.524 ≤ width < 1.829</td> <td>≤19.20 or six storey</td> </tr> <tr> <td>1.829 ≤ width < 13.048</td> <td>≤ 25.20 or eight storey</td> </tr> <tr> <td>1.219 ≥ width < 1.524</td> <td>≤ 30.48</td> </tr> </tbody> </table>	Width of Road(m)	Maximum height of buildings (m)	< 1.219	< 6 or single storey	1.219 ≤ width < 1.524	≤ 9 or three storey	1.524 ≤ width < 1.829	≤19.20 or six storey	1.829 ≤ width < 13.048	≤ 25.20 or eight storey	1.219 ≥ width < 1.524	≤ 30.48
Width of Road(m)	Maximum height of buildings (m)												
< 1.219	< 6 or single storey												
1.219 ≤ width < 1.524	≤ 9 or three storey												
1.524 ≤ width < 1.829	≤19.20 or six storey												
1.829 ≤ width < 13.048	≤ 25.20 or eight storey												
1.219 ≥ width < 1.524	≤ 30.48												
Cantilevering to the street	<p>Making a part of the building cantilever on to the road above the height of 30.48m is not permitted. It is permitted only if there is no adjacent building</p> <p>Above the height of 30.48m, roofs, concrete bricks, Sun shading devices, balconies and space to keep materials used for building services such as air conditioning must not extend on to the street beyond more than 0.457m</p>												
Ventilation and Lighting	<p>Each floor of the building must have a minimum space of 10% left as void/opening. This does not include spaces that are left after the glass blocks, sliding doors, windows and glass windows that cannot be opened.</p>												

	<p>If the first 2 floors are to be used for other purposes other than as a living area (for example as a commercial area) and if the two floors have sufficient mechanical ventilation, then the following points would not apply to this scenario:</p> <p>The void of minimum 600x600mm in size. If the void is to be taken from the boundary of another house, then the void must be minimum 750x600mm in size.</p> <p>Each floor of the building must have a minimum space of 10% left as void/opening.</p>
Buildings that are 100fts extended to the road	<p>Any area from the building that is below the height of 2.743M (9ft) is not to be extended beyond the boundary of the house to the sidewalk.</p> <p>Beyond 2.743M (9ft) up to 6.09M (20ft), a building's roof, concrete masonry or any other parts of the building can be extended to the road side only to 0.457M (18 inch) beyond the boundary.</p> <p>Building any part of the building between 2.743M (9ft) and 6.096M (20ft) of height as permanent elements is prohibited.</p>

4) Material Regulations:

The regulation ensures that minimum level of standards is maintained in the quality of the building materials both imported & locally manufactured. Regulation has 4 parts- material standard, material testing laboratory requirements, import requirements and other control requirements.

The regulation stipulates that all the building material that is imported or locally manufactured should comply to any one of the following standards

- ISO (international organization for standardization)
- BS (British standard)
- IS (Indian standard)
- EN (Euro Code)
- ASTM (American society for testing materials) standard

However, any material that are imported or locally manufactured for building construction purpose does not follow any standards mentioned above, documents related to the specification of the materials & material test report needs to be submitted to the ministry which would indicate that these materials have an equivalent standard from any of the above standards mentioned.

The regulation also specifies monetary fines for non-compliance to regulation.

5) Health & Safety

States protections required & procedures to be followed to ensure health & safety at construction sites throughout Maldives. The regulation ensures that minimum safety standards are followed for the construction workers & general public and fines for any violation of the regulation.

6) National Contractor Registration:

Under this, all the contractors who wishes to carryout building project should be registered with CIDD. It specifies mandatory requisites who wish to be registered with the registry. The contractor must demonstrate his relevant experience, financial, technical & management capabilities for the registration.

7) Hulhumale Planning & Development Guideline

Housing Development Corporation (HDC) is the local authority that regulates all the construction developments in the Hulhumale region. HDC has laid out rules in the Hulhumale Planning & Development Guidelines for building typologies - commercial buildings, mix residential buildings (commercial & residential use) & green buildings with mix office use (commercial & office use) that covers the following aspects

- Height & FSI of the Buildings
- Boundary Wall
- Access and Circulation with respect to vehicular motion & pedestrian
- Other general requirements such as parking space, services, ergonomics for people with disability, public & private open spaces, fire safety, foundation depth & more

It is observed that the guidelines do not have any provisions for energy efficiency measures for the above said building typologies. However, HDC has a separate set of design standards for all the building typologies. This design standards mandates certain international standards to be followed in the construction of the buildings & encourages to adopt energy measures. Some of the provisions that are mentioned under sustainability & MEP criteria of the design standard guidelines that encourages energy efficiency measures & green building designs are as given in Table 2

Table 2: Some provisions in the design standards for construction in Hulhumale

Criteria	Provisions
Bio Climatic Design & Building materials	<ul style="list-style-type: none"> • Encouraging energy efficiency both at construction stage and during the lifetime of the building e.g. By climate sensitive design which takes account of the orientation and surrounding features to control wind effects while optimizing sunlight, daylight and solar gain benefits • Use of resource efficient buildings that utilize, to the extent practical, recycled, renewable, and/or reused construction materials.
Air-conditioning and mechanical ventilation	<ul style="list-style-type: none"> • Encourages the use of energy efficient AC systems & equipment • Design of AC & mechanical systems shall follow the latest version of following standards <ol style="list-style-type: none"> i) Indoor Air Quality (IAQ) ii) ASHRAE 62 “Ventilation for Acceptable Indoor Air Quality” iii) Latest Edition of SMACNA, ASHRAE and ARI standards. iv) National Environmental Bureau (NEB) v) CIBSE guidelines • Use of VRV systems for typical office building, • The ventilation system must be provided with automatic controls to turn on and off on demand
Lighting systems	<ul style="list-style-type: none"> • Use of LEDs • The illumination levels must be generally in accordance with the IES Code of Practice, CIBSE Code for Interior Lighting and Lighting Guide 3 (LG3) and current practices. • Daylight harvesting system must also be incorporated in to the design to maximize the use of sunlight while minimizing the energy consumption • All external lights shall be controlled by digital timer with provision of manual control switches

Integrating energy efficiency guideline in the existing regulatory framework

Building approvals are limited to compliance of planning, fire safety, MEP guidelines in Maldives. Although, some provisions for energy efficiency are given in the design standards for new constructions in Hulhumale but these

measures are not comprehensive & do not consider local factors thereby reducing the efficacy of such measures. Therefore, a separate energy efficiency guideline that covers the all the aspects in the buildings must be developed & since authority to grant approval lies with the local authorities, this energy efficiency guidelines should be mandated by the central authority CIDD & then should be adopted by the local authorities in Male & Hulhumale as a fourth compliance parameter for grant of approval to construct any new building.

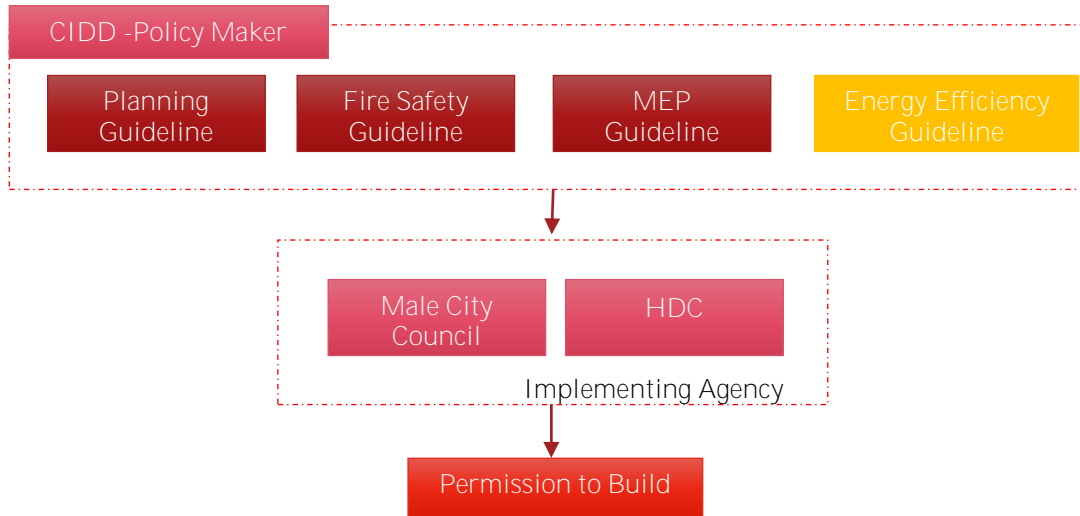


Figure 10: Integration of energy efficiency guideline in the building approval process

2.5. Building typology in Male

The typical building typologies in Male is given below.

Residential buildings:

In Male and Hulhumale, mostly residential apartments have mixed use-building pattern. Many buildings are having commercial stores on lower floors and residential blocks on the floor above. Multi dwelling residential buildings with apartments on each floor represent the most common type of residential building. Each apartment is rented by a family, except the top floor, which is mainly occupied by the building owner and family. The urban residential buildings are surrounded by buildings on three sides and exposed only on the side facing the road. Images of typical residential buildings are given in Figure 11.



Figure 11: Images of residential buildings

Government Buildings:

There are individual government buildings in Male and Hulhumale. Some of the government buildings are tall multi-storey complexes while some are detached small buildings. Images of typical government buildings are given in Figure 12.



Figure 12: Images of government buildings

Commercial Buildings:

There are many commercial buildings such as office buildings, shopping malls, banks, hospital buildings, central business complexes. These are high-rise multi-storey buildings. Images of typical commercial buildings are given in Figure 13.



Figure 13: Images of Commercial buildings

Hotels and Guest Houses:

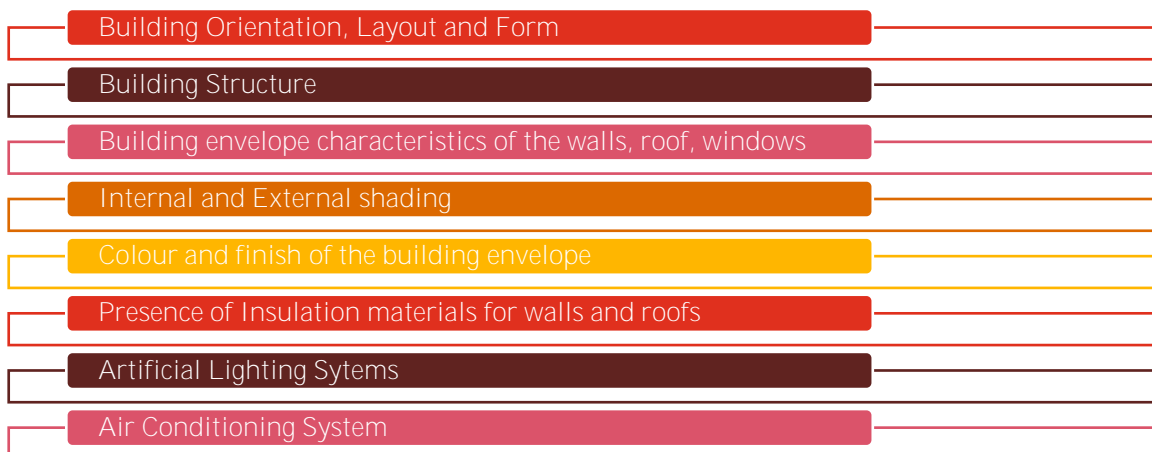
Hotels and guesthouses mostly have restaurants, cafes or commercial shops on the lower 2-3 floors and hotel rooms in the floors above. Images of typical commercial buildings are given in Figure 14.



Figure 14: Images of Hotels & Guest house

2.6. Construction practices in the country

Typical design and construction features of the existing building stock influence the thermal conditions of the building interior. Various factors impact the heat gain, cooling loads and overall energy consumption inside the buildings. These include the following:



Building Orientation, Layout and Form: The optimal solar heat gain & natural ventilation benefits can be achieved by ensuring proper orientation, layout & form of the buildings. After 2006 Tsunami, there has been a raise in 10 & 25 storey buildings in the region where earlier it was limited to 6 storey. However, the rapid urban sprawl in the region led to construction of buildings that are oriented in all directions with 2 sides enclosed with adjoining buildings. Various commercial buildings located near the sea are sea facing. The images of typical building orientation, layout & form in Figure 15 are depicted below:



Images showing closely spaced building structures



Images showing sea facing commercial buildings

Figure 15: Building forms & layouts in Male

Building Structure: Buildings are predominantly reinforced cement concrete structure. There are few steel structures and prefabricated construction practices carried out in Maldives. The cement blocks are used instead of clay bricks for construction of wall. Also, there are few multi storey complexes and hotels made up of prefabricated steel structure and glazing walls. The typical building structures are given in Figure 16



Figure 16: Images of the construction sites in Male

Building Envelope Materials

The building envelope refers to the exterior façade and it comprise of opaque components and fenestration **systems that protects the building's** interior and occupants from the weather conditions and shields them from other external factors e.g. noise, air pollution, etc. Opaque components include walls, roofs, slabs on grade (in touch with ground), basement walls, and opaque doors. Fenestration systems include windows, skylights, ventilators, and doors that are more than one-half glazed. Here are some of the building envelope materials used in the country.

- a) Walls: In all the building typologies, Masonry cement blocks are common wall materials with plaster & paint. RC walls are also in some cases with plasters & paint. Widespread availability of imported construction material has led to the adoption of cement blocks as the major material used in constructing walls.



Figure 17: Image showing Masonry blocks used in construction

- b) Fenestrations: In all the building typologies, windows & glazing are permitted only on the external faces on the roadside with Aluminum window with simple glass (6 to 10 mm) in single glazing. In Commercial & Government buildings, curtain wall glazing systems is used while in residential & hotels/resorts, tempered glass is used in shops & ground floor areas.



Figure 18: Image showing fenestration in building

- c) Roof: The most common roofing in all the building typologies is RC flat slab. Lysaght roofing sheets are used as well, either with timber forming or steel truss & rock wool insulation.

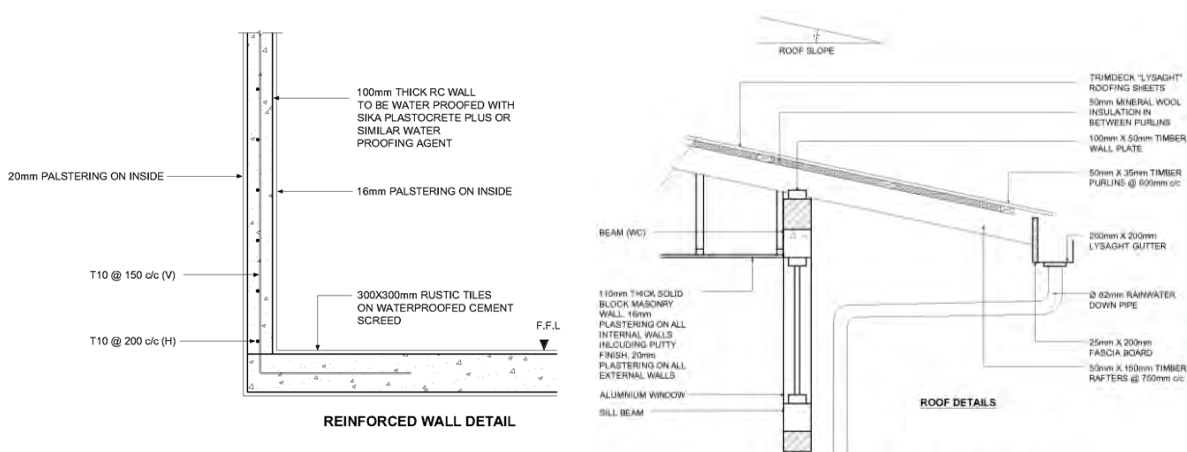


Figure 19: Typical wall & roof details

Thermal Resistance & Thermal Transmittance:

The building envelope is made of many layers of different materials. Every material exhibits different thermal properties. The resistance to heat flow across a material is its thermal resistance properties. As the building envelope is made of layers of different material it is necessary to determine the combined thermal resistance in order to determine the total thermal resistance offered by the wall. The reciprocal of this combined thermal resistance is thermal transmittance or U-value that measures the heat transfer across the walls & roof.

Wall Assembly

1. U- Value of the typical wall with RC Material

Thermal Resistance $R = \text{Thickness} / \text{thermal conductivity}$

Layers/Surface	Thickness (d) (m)	Conductivity (k) (W/m K)	Resistance ($r=d/k$) (m ² K/W)
RC Material	0.2	1.6	0.125

Inner Plaster	0.016	0.17	0.094
Outer Plaster	0.02	0.17	0.118
Total Resistance (R_T)			0.337

Total Thermal Resistance = Sum of the thermal resistance of each layer

$$R_T = R_{\text{reinforced concrete}} + R_{\text{inner plaster}} + R_{\text{outer plaster}}$$

$$U\text{-Value} = 1 / R_T$$

$$= 1 / 0.337$$

U-Value of wall with RC material = 2.97 W/m²K

2. U- Value of the typical wall with masonry block

Layers/Surface	Thickness (d) (m)	Conductivity (k) (W/m K)	Resistance (r=d/k) (m ² K/W)
Masonry block	0.2	0.8	0.25
Inner Plaster	0.016	0.17	0.094
Outer Plaster	0.02	0.17	0.118
Total Resistance (R_T)			0.462

Total Thermal Resistance = Sum of the thermal resistance of each layer

$$R_T = R_{\text{masonry block}} + R_{\text{inner plaster}} + R_{\text{outer plaster}}$$

$$U\text{-Value} = 1 / R_T$$

$$= 1 / 0.462$$

U-Value of wall with masonry block = 2.16 W/m²K

Roof Assembly

1. U- Value of the typical roof with RC slab

Thermal Resistance R = Thickness/ thermal conductivity

Layers/Surface	Thickness (d) (m)	Conductivity (k) (W/m K)	Resistance (r=d/k) (m ² K/W)
RC Material	0.15	1.6	0.093
Inner Plaster	0.016	0.17	0.094
Outer Plaster	0.02	0.17	0.118
Total Resistance (R_T)			0.305

Total Thermal Resistance = Sum of the thermal resistance of each layer

$$R_T = R_{\text{reinforced concrete slab}} + R_{\text{inner plaster}} + R_{\text{outer plaster}}$$

$$U\text{-Value} = 1 / R_T$$

$$= 1 / 0.305$$

U-Value of roof with RC slab= 3.27 W/m²K

2. U- Value of the typical roof assembly with timber forming & mineral wool insulation

Thermal Resistance R = Thickness/ thermal conductivity

Layers/Surface	Thickness (d) (m)	Conductivity (k) (W/m K)	Resistance (r=d/k) (m ² K/W)
Mineral Wool	0.05	0.035	1.428
Timber Purlins	0.035	0.15	0.233
Timber Rafters	0.15	0.15	1
Total Resistance (R_T)			4.758

Total Thermal Resistance = Sum of the thermal resistance of each layer

$$R_T = R_{\text{mineral wool}} + R_{\text{timber purlins}} + R_{\text{timber rafters}}$$

$$U\text{-Value} = 1/ R_T$$

$$= 1/ 4.758$$

U-Value of the roof assembly with timber forming & mineral wool insulation = 0.21 W/m²K

(Source: science-direct)

Summary	U-value (W/m ² K)
Wall with RC material	2.97
Wall with masonry block	2.16
Roof with RC slab	3.27
Roof with timber forming & mineral wool insulation	0.21

It is necessary to study the U-value of the building envelope as it impacts the energy performance index (annual energy consumed by the building per square meter of area) of the existing buildings. For instance, in cold climates, it is a general practice to use building materials with higher U-value so that heat from the sun during daytime can provide the required thermal comfort to reduce the load on the heating system.

Artificial Lighting

The type of lights used in different typologies varies. The most common type of artificial lights provided inside the building is LED & CFL. The residential building uses CFL however, they are moving towards LED. The commercial building uses fluorescent lamps. Although CFL is energy saving, LED will be better than CFL in the future.



LED



CFL

Figure 20: Artificial Lighting Systems

Air Conditioning Systems

Human comfort is an essential part of every building design. Thermal comfort being one of the major factors that affect the energy consumption rate, has an enormous impact on the interior comfort level. Also, when comparing the two different types of settings about the energy consumption of a country, it is said to be that cities tend to consume more electrical energy than that of rural areas. Since hot pavement and the high-rise concrete buildings re-radiate heat even after sun sets, the city air stays warm thus residential units consuming more energy to cool the interior increasing the electrical energy consumption for cooling.

Maldives being a tropical country among the tropics also being the city, one of the ways to reach thermal comfort is through air conditioning, which is very energy consuming. So, during the designing of a building if passive solar designs and bioclimatic architecture are taken into consideration, this can be greatly influenced thus reducing a large number of energy that the building consumes for heating and cooling.

The most common types of air conditioning system found in residential buildings are wall mounted split AC. However, newly constructed government & commercial buildings, ceiling mounted multi split VRV systems are used.

Older buildings still rely on single split wall units. Most of the residential buildings that are transformed to commercial buildings use the single split AC system as well. The large hotels use multi split wall or ceiling units while the smaller guest houses use single split AC system. Moreover, one of the Office building uses a chiller system. The Inverter ACs that are available in the market ranges from 9000 BTU to 24000 BTU. The common brands of AC systems are Daikin, LG, Blue Star, Hitachi, Panasonic. The Maldives Energy Authority is developing star labelling program for the AC systems.





Figure 21: Image showing outdoor units of split air conditioning systems

Plumbing

MWSC (Male' water and Sewerage Company) is the very first organization in the Maldives to institute a water production and wastewater management system. Although today this organization has become a multi-disciplinary engineering and manufacturing organization, this company has worked persistently to provide the populations with fresh water and manage wastewater sustainability. Currently they serve approximately more than 50% of the Maldivian Population.

Fresh water is supplied to all buildings and for each building an individual supply line is provided which then distributes water to respective areas through meters. The main purpose of these meters are for easy billing system. However, the meters help the occupants to identify and utilize their water in a maintainable manner.

Some residential buildings have ground wells which is utilized mainly for flushing since this helps to save the amount of freshwater usage. The per capita water consumption is 150 liters. 6 liters of water is used per flush.

The common products used in Maldives for sanitary wares are Grohe, Cotto and Khloer. Although Maldives receives high rainfall throughout the year, no rainwater harvesting systems are used in the buildings.

2.7. Typical building materials used in the construction sector

The construction sector of the Maldives is dependent on imports as almost all building materials such as cement and aggregates, base metals, wood, finishing materials and construction hardware is imported. This makes construction industry highly vulnerable to fluctuations in global commodity prices and changes in the exchange rate. Maldives has witnessed over 25% increase in the material import in 2018. According to Maldives Customs Services, 5 billion USD worth goods were imported in 2018 to Maldives. In 2018, the annual growth in construction sector related imports accelerated to 35%. The Figure 22 presents the import of construction related materials over the years.

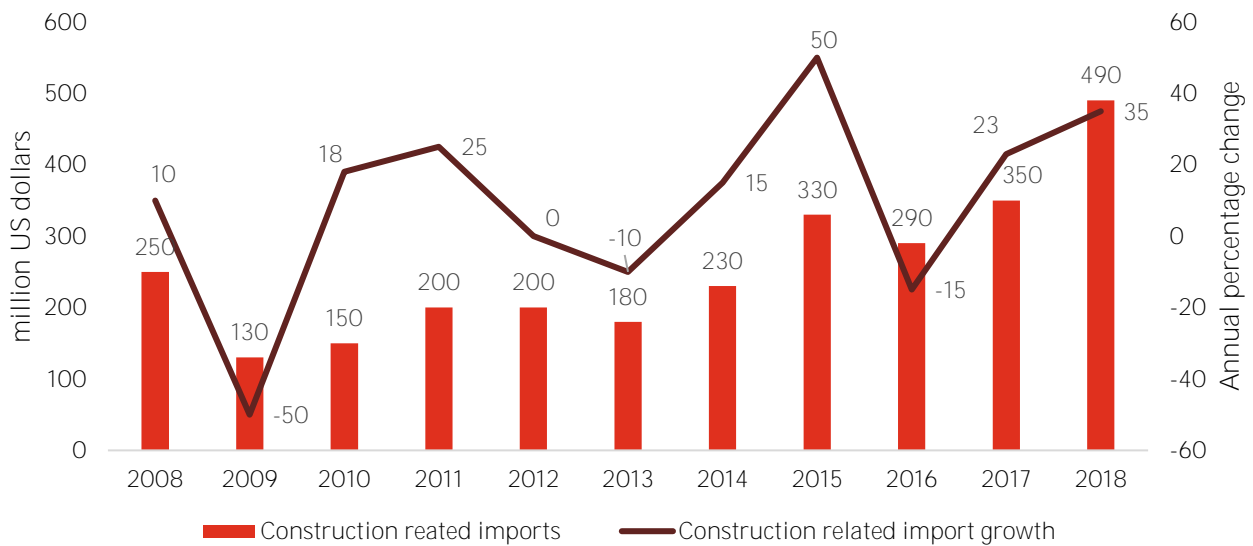


Figure 22: Yearly import cost in million US dollars

Major imports are from India, Malaysia, Singapore, China, Indonesia and UAE. About 41% of construction material is imported from India followed by UAE, Malaysia, Singapore, China & Indonesia. The Figure 23 represents the share of import of different construction materials and the countries from which they are imported. Most of the aggregate and sand is imported from India whereas steel is mostly imported from China and Maldives imports cement mostly from India, Singapore, Indonesia.

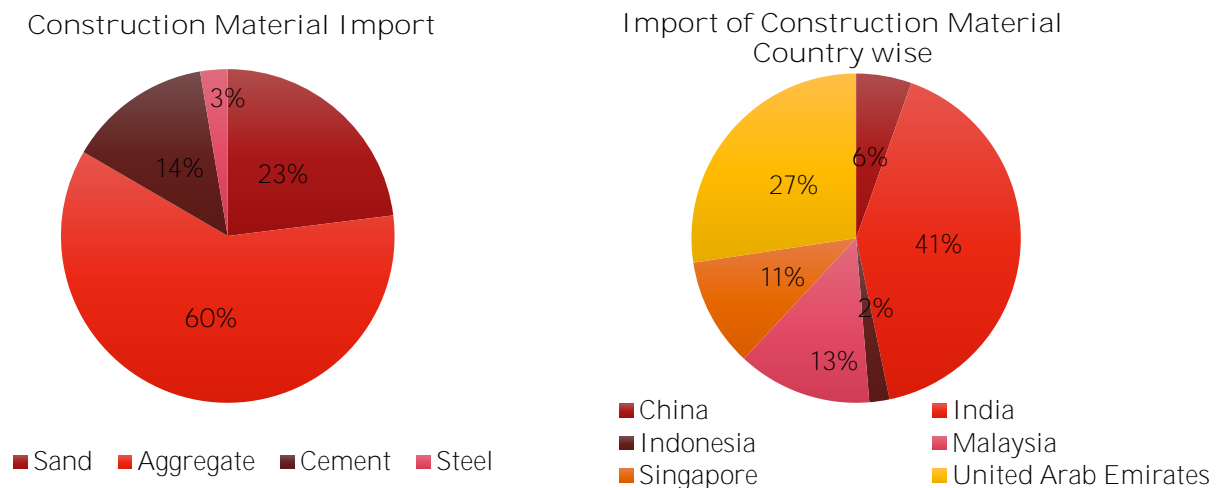
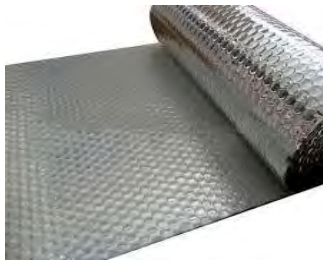
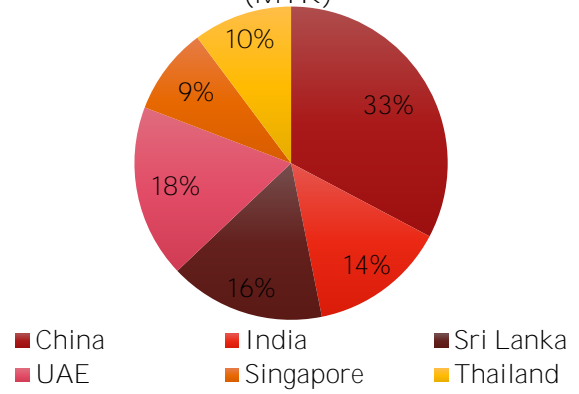


Figure 23: Construction Material wise import distribution & Country-wise imports of construction material

The materials such as heat insulating material, glass, cement blocks and stones that are mostly used in energy efficient green buildings for maintaining the energy balance in the building by making provisions like facades, sunshades are imported mostly from china. The figure below presents the share of finishing materials and the countries of import. Maximum import of Heat Insulating Material and Glass is from China – 33% and 28% respectively. Also, import from UAE and India is significant. Moreover, Maldives also imports the cement and stone blocks in significant amount. The import of almost 50% of cement and stone blocks are imported from China while 21% of cement blocks are imported from Singapore.



Import of Heat Insulating Material (MTK)



Import of Glass (MTK)

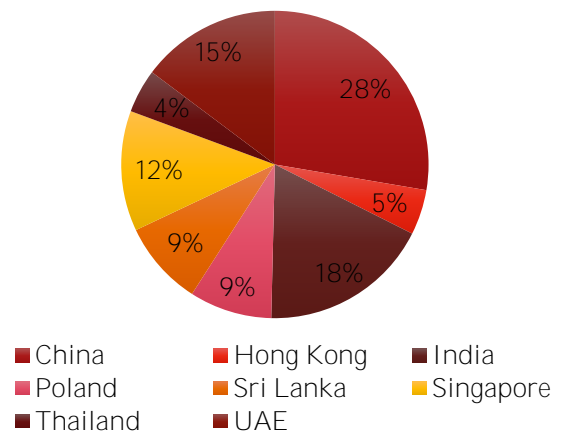


Figure 24: Pie Charts showing percentage imports of various building material by different countries

Marble



Granite



Ceramics



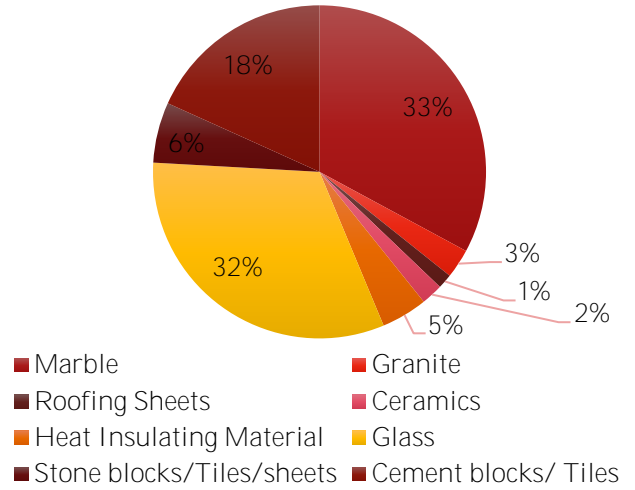
Stones



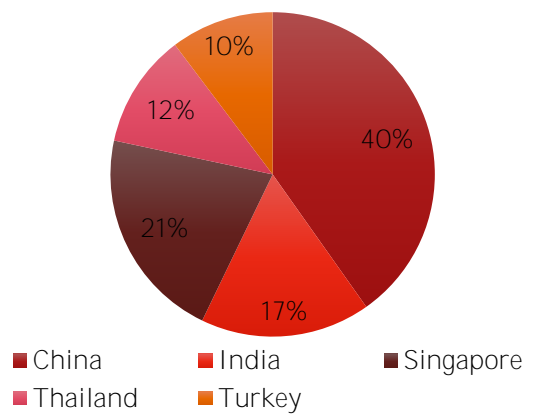
Roofing Sheets



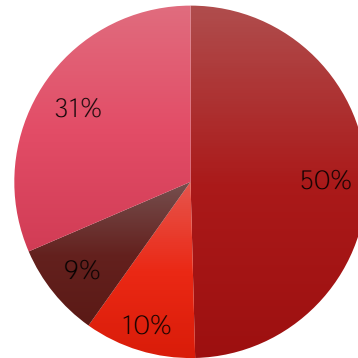
Import of Finishing Material (MTK)



Import of Cement Sheets (MTK)



Import of Stone blocks (MKT)



■ China ■ India ■ Indonesia ■ Turkey

Figure 25: Pie Charts showing percentage imports of various building material from different countries

Energy consumption from buildings can be significantly reduced by using building materials with lower embodied energy & thermal conductivity. Being an island country, most of the construction materials used in buildings are imported in Maldives. The existing import regulations sets standards for safety and quality of the materials being imported. There are no regulations for thermal performance of the materials being imported and used in the buildings. The energy efficiency guidelines can mandate the import of energy efficient building materials for future developments in addition to safety and quality standards.

3. Climate analysis of Maldives

3.1. Climate classification based on Köppen-Geiger system

The Köppen climate classification is one of the most widely used climate classification systems. This system, in general, recognizes five major climate types based on the annual and monthly averages of temperature and precipitation. The five climate groups, as shown in the above figure, are:

Group A: Tropical climates

Group B: Dry (arid and semiarid) climates

Group C: Temperate climates

Group D: Continental climates

Group E: Polar climates

These are the main group of the Köppen Geiger climate classification. The classification of the climate of any country, under Köppen-Geiger system is represented with the help of three letters. The second letter refers to the seasonal precipitation subgroup. The letter E stands for Polar climate zone and does not have a subgroup in terms of precipitation. The third and last letter of this type of climate classification method stands for rainfall and indicates the level of heat. This subgroup is not mentioned in case of tropical Climate which is denoted by the letter A.

Thus, the climate classifications are:

1. Af: Tropical Rainforest climate
2. Am: Tropical monsoon climate
3. Aw: Tropical Savanna climate
4. BWh: Hot desert climate
5. BWk: Cool desert climate
6. BSh: Hot Steppe climate
7. BSk: Cool steppe climate
8. Csa: Dry summer subtropical
9. Csb: Dry summer subtropical climate (cooler than Csa)
10. Cwa: Dry winter humid subtropical climate
11. Cwb: Dry winter maritime temperate climate
12. Cwc: Dry winter maritime temperate climate (cooler than Cwb)
13. Cfa: humid subtropical climate
14. Cfb: maritime temperate climate
15. Cfc: maritime subarctic climate
16. Dsa: Dry summer continental climate (with hot summer)
17. Dsb: Dry summer continental climate (with warm summer)
18. Dsc: Dry summer continental climate (with cool summer)
19. Dsd: Dry winter continental climate (with very cold winter)
20. Dwa: Dry winter continental climate (with hot summer)
21. Dwb: Dry winter continental climate (with warm summer)
22. Dwc: Dry winter continental climate (with cool summer)
23. Dwd: Humid continental climate (with very cold winter)
24. Dfa: Humid continental climate (with hot summer)
25. Dfb: Humid continental climate (with warm summer)
26. Dfc: Humid continental climate (with cool summer)
27. Dfd: Humid continental climate (with very cold winter)
28. ET: Tundra climate
29. EF: Ice cap climate
30. Cwc: Dry winter maritime temperate climate (cooler than Cwb)

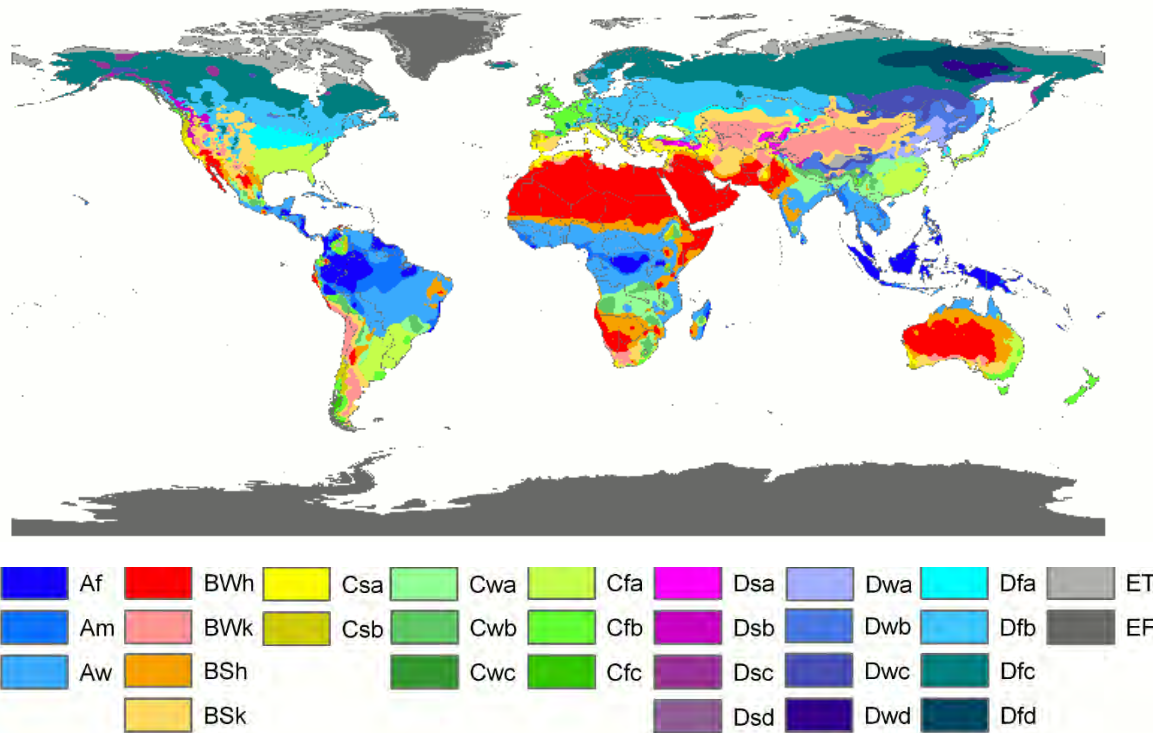


Figure 26: World Map of Climate classification based on Köppen-Geiger system

The Köppen Climate Classification for Male, Maldives is “Am” which indicates the climate as “**Tropical Monsoon Climate**”

Male consists of tropical monsoon climate, also known as a tropical wet climate or tropical monsoon and trade – wind seaside climate in climatic classification. In tropical monsoon climate monthly mean temperature generally remains above 18°C in entire year. Twelve months of the years are divided into dry and wet seasons. The dry season is of four months only (from January to April) and has minute influence on whole climate, and wet season goes from May to December. The average annual temperature at Male is 28.9 °C and average wind speed is 4.5 m/s.

The Köppen Climate Classification type for tropical wet climate is “Am” (Tropical Monsoon Climate). March and April are considered warm months with average temperature of 29.5 °C and December and January are the coldest months with average temperature of 28.3 °C. There are average 150-160 days of rainfall in Male, Maldives. The average maximum rainfall is received in the month of May i.e. 12.4 mm and average minimum rainfall is received in the month of March i.e. 4.4 mm.

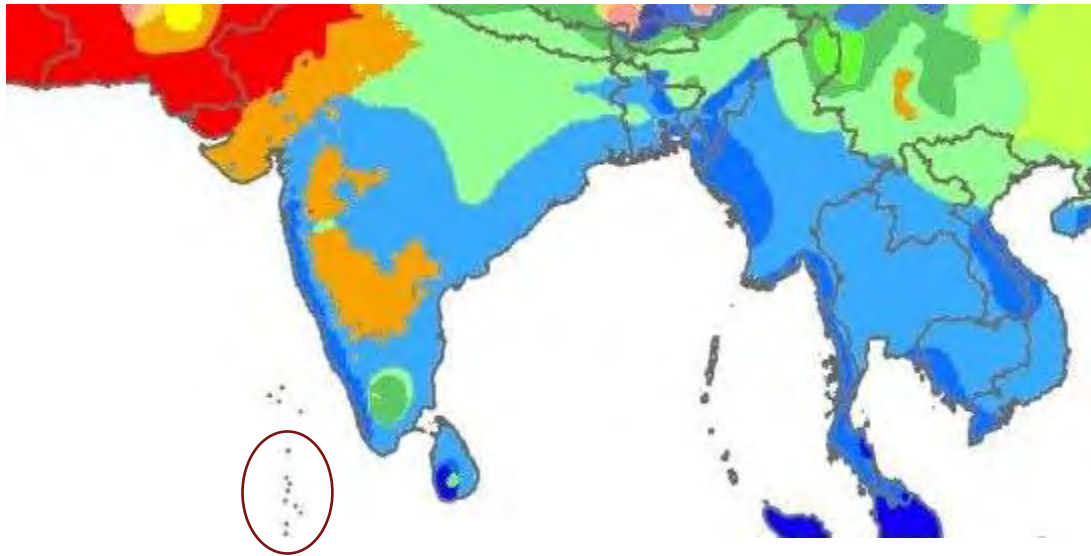


Figure 27: Climate classification of Male, Maldives based on Köppen-Geiger system

3.2. Climate analysis based on the information collected from Maldives Meteorological Service (MMS)

Maldives Meteorological Service (MMS) is the meteorological department of Maldives. This department provided the climate data comprising of Temperature (min. & max), Relative humidity, Wind speed and Rainfall for the period of last 10 years starting from 2008 -2018 for Male, Maldives. External climate components that affect the internal environmental are air temperature, relative humidity, rainfall, wind and solar radiations. The same have been analyzed in the subsequent sections.

3.2.1. Analysis of temperature data

The Figure 28 analyses the monthly average temperature along with the minimum and maximum temperatures recorded in Male.

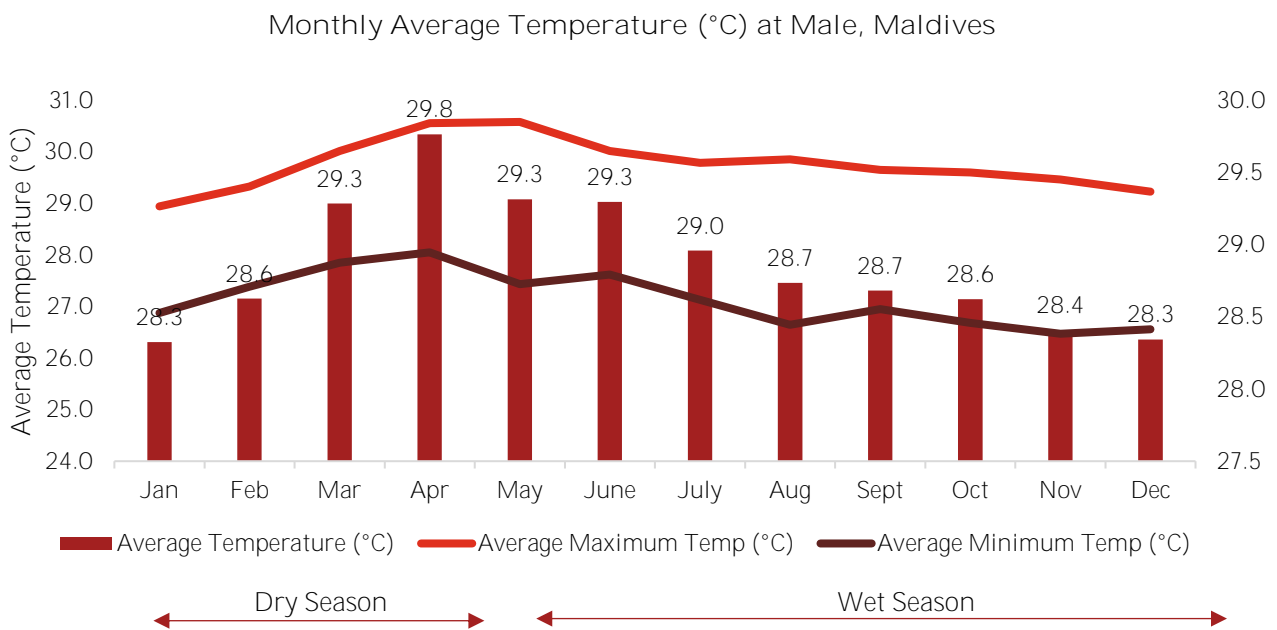


Figure 28: Monthly Average Temperature at Male, Maldives (°C)

The *Figure 28* shows the monthly average temperature range of Male, Maldives from 2008 – 2018. It is observed that the temperature is almost constant and above the comfortable range throughout the year. The monthly average temperature increases starting January, and peaks in April and then decreases by August and stays constant for the remaining months of the year. The average temperature for dry season is 29 °C with highest average temperature i.e. 29.8 °C in the month of April. The average temperature for wet season is 28.8 °C with and lowest i.e. 28.3 °C in the months of December. It is observed that the temperature above the comfortable range throughout the year requiring significant energy demand for space cooling.

In order to study the Climate Change scenario in Male, annual average temperature from 2008 to 2018 is presented in *Figure 29*

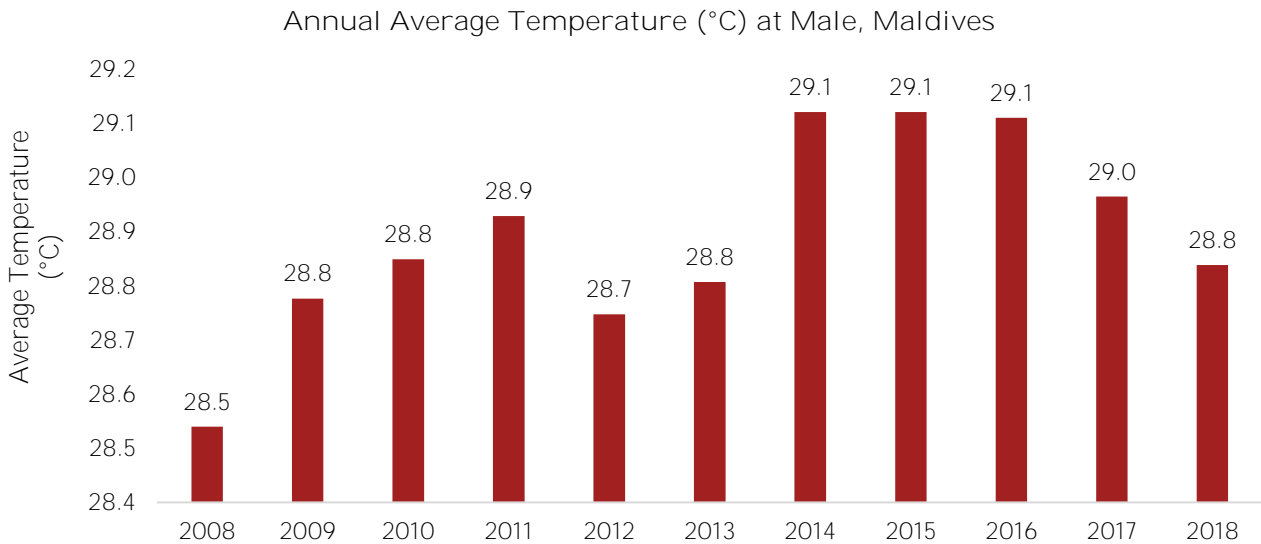


Figure 29: Annual Average Temperature at Male, Maldives (°C)

The *Figure 29* shows annual average temperature of Male from 2008 – 2018. It is observed that the lowest average temperature was recorded as 28.5 °C in 2008 and maximum temperatures were recorded as 29.1°C in 2014 to 2016. It is observed that average temperature rises in the last 10 years from 2008 to 2018 is around 0.5 °C to 0.6 °C.

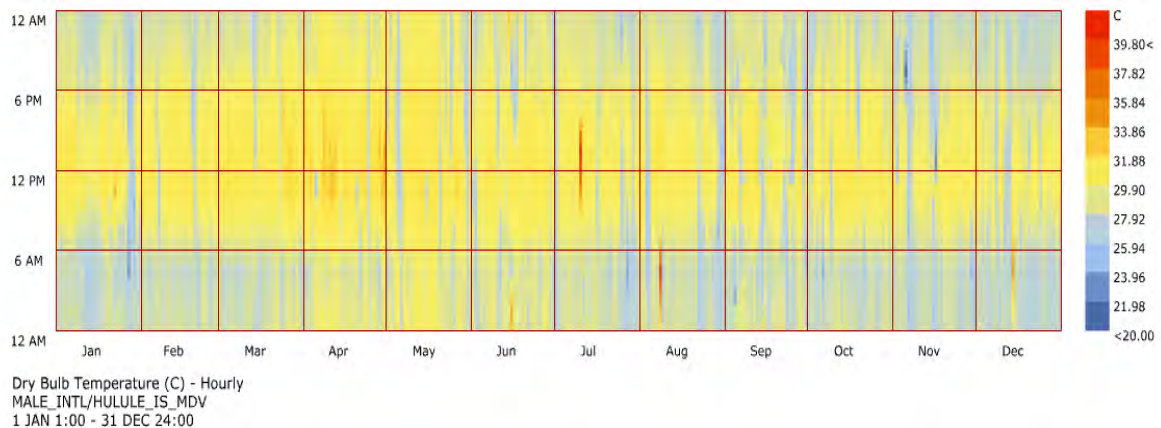


Figure 30: Daily Temperature in Male

The

Figure 30 shows Daily temperature range for Male. Temperature range is approximately between 29.9 °C and 31.8 °C during the day and between 21.9 °C and 23.9 °C at night. The average diurnal temperature difference was observed to around 8-10°C

3.2.2. Analysis of Relative Humidity Data

Relative humidity has substantial impact on thermal comfort level of building occupants along with the ambient air temperature.

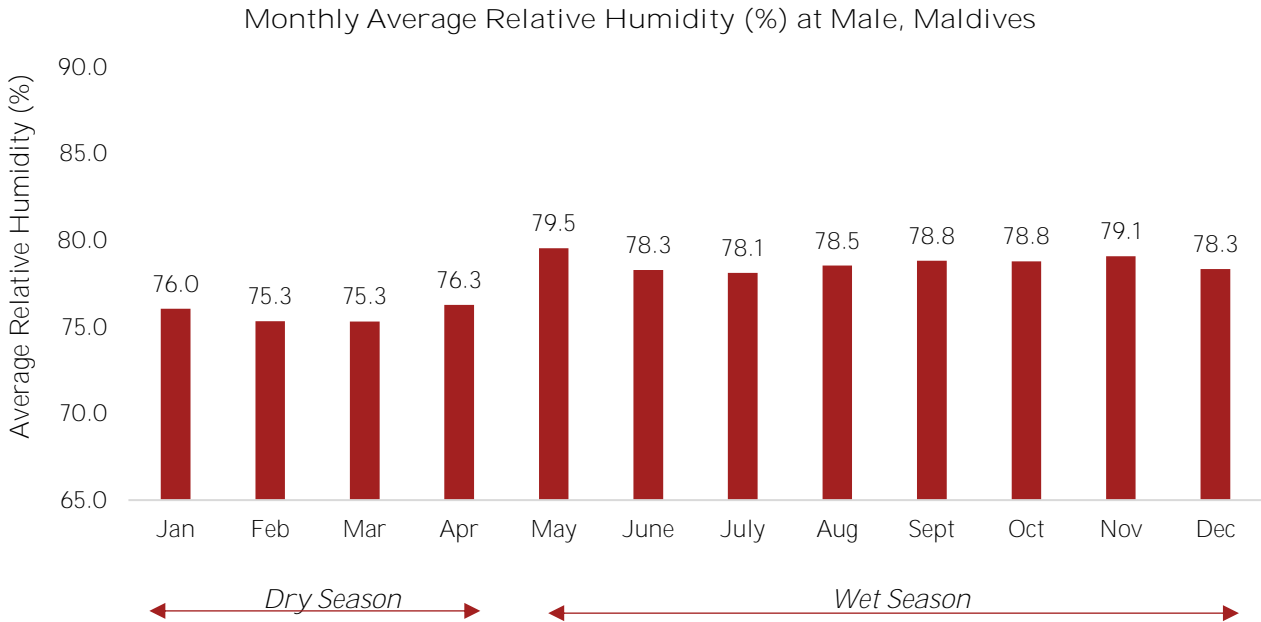


Figure 31: Monthly Average Relative Humidity at Male, Maldives (%)

The Figure 31 shows the monthly relative humidity (in %) of Male, Maldives from 2008 – 2018. It is observed that the average relative humidity ranges from 75% to 80% throughout the year. It can be concluded from the above graph that relative humidity is high, above 75% throughout the year.

3.2.3. Analysis of Rainfall Data

The annual average rainfall, maximum and minimum rainfall for different months from 2008 to 2018 is presented below.

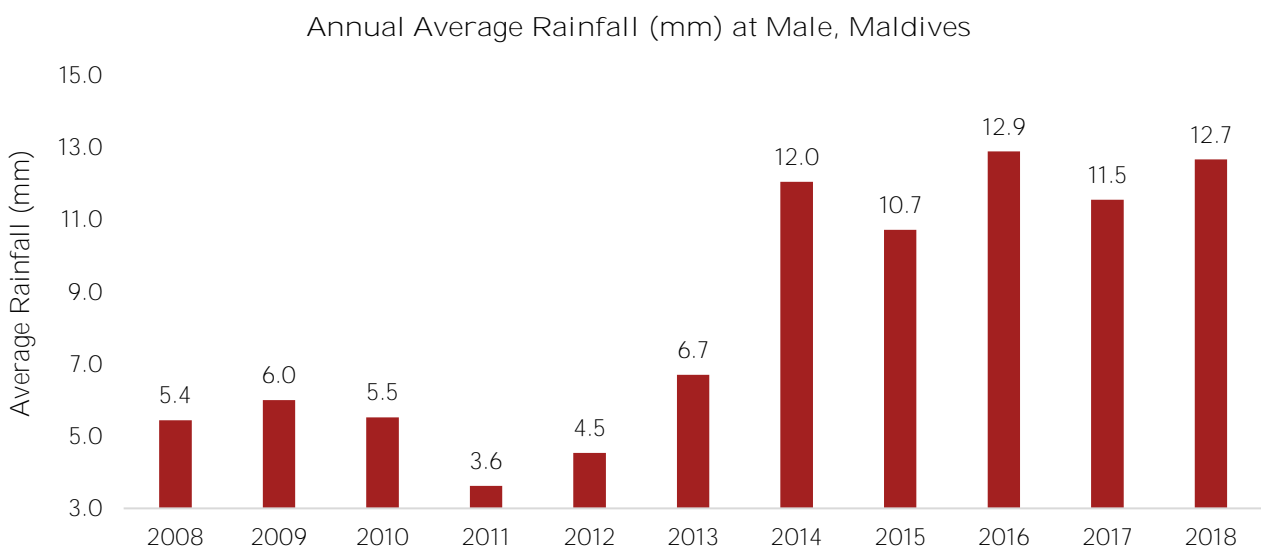


Figure 32: Annual Average Rainfall at Male, Maldives (mm)

The *Figure 32* shows the annual average rainfall (in mm) of Male, Maldives from 2008 – 2018. It can be observed from the above graph that rainfall is increasing from 2008 to 2010, then a sudden decrease in rainfall in 2011 and 2012. Highest rainfall has been found in 2016 and 2018. The analysis indicates that overall rainfall has increased from 2008 to 2018 by 57%. This results in high humidity levels in Male throughout the year requiring high usage of air conditioning throughout the year for thermal comfort.

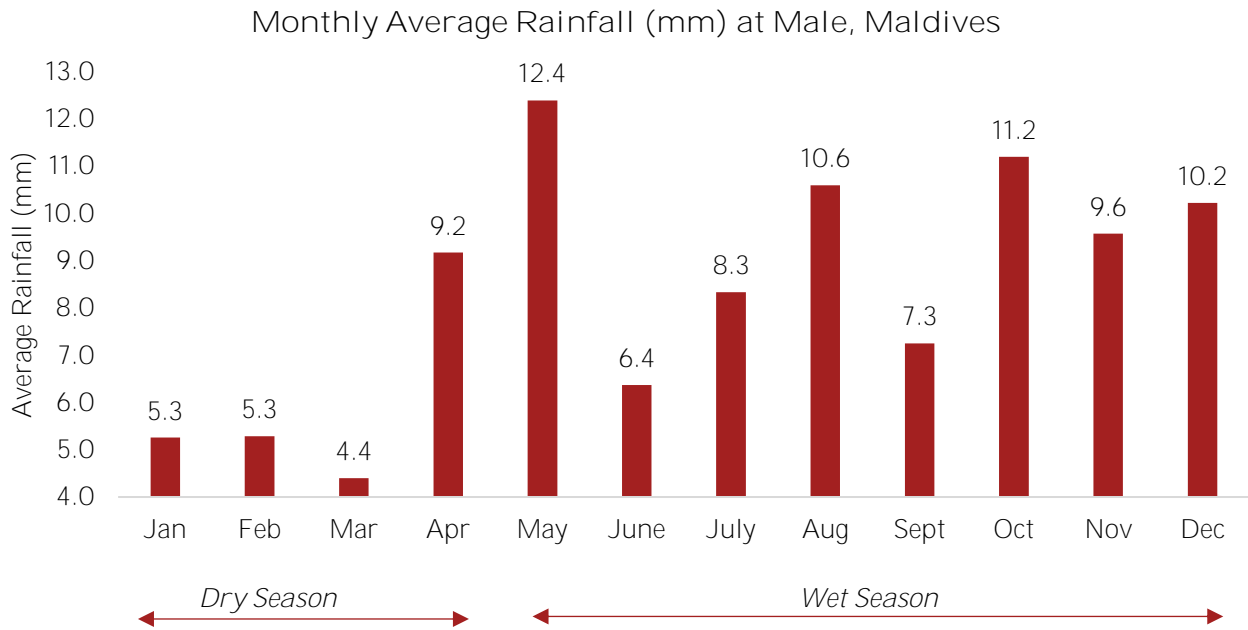


Figure 33: Monthly Average Rainfall at Male, Maldives (mm)

The *Figure 33* shows the monthly average rainfall (in mm) of Male, Maldives from 2008 – 2018. The average rainfall for dry season is 6.03 mm with lowest in the month of March 4.4 mm and the average rainfall for wet season is 9.5 mm with highest rainfall observed in the month of May 12.4 mm.

3.2.4. Analysis of Wind Speed

The wind speed in any region plays significant role in building design in order to design windows and its appropriate orientation to bring fresh air inside and to provide accurate ventilation for building occupants. The annual average wind speed, maximum and minimum wind speed for different months from 2008 to 2018 is presented below.

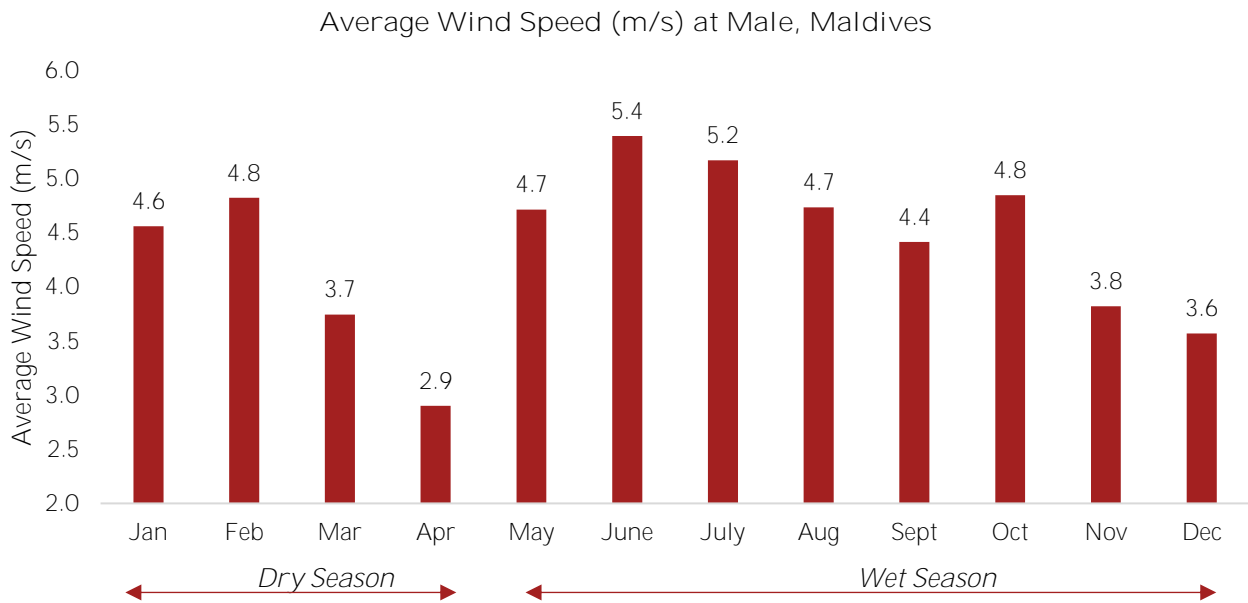
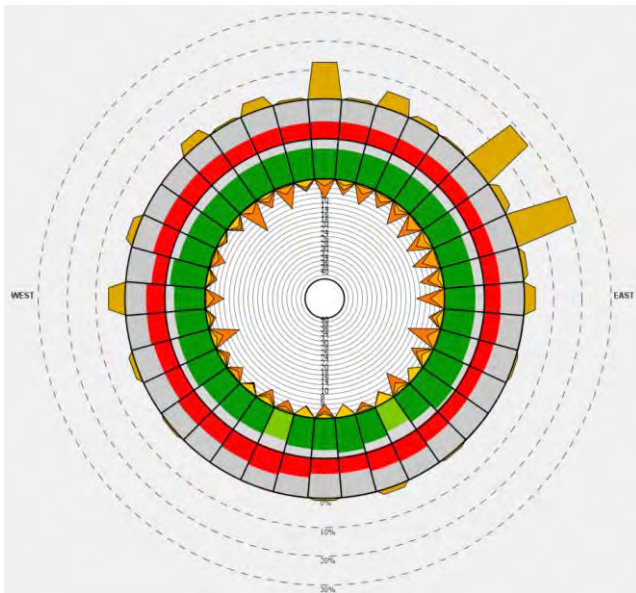
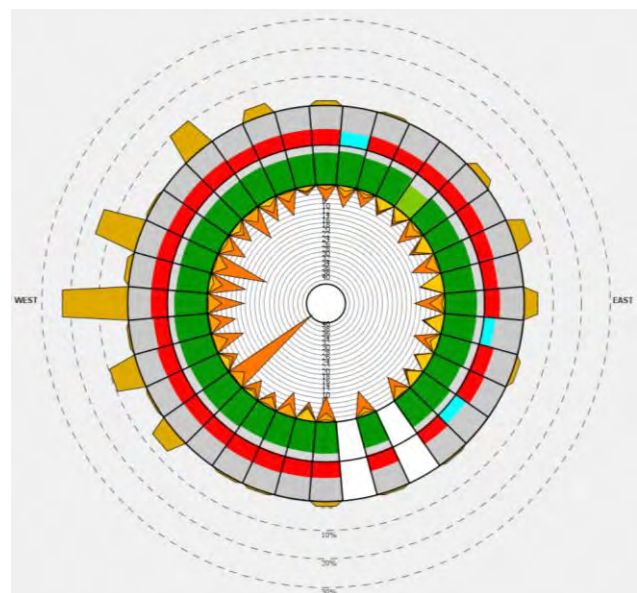


Figure 34: Monthly Average Wind Speed at Male, Maldives (m/s)

The *Figure 34* shows the monthly average wind speed (in m/s) of Male, Maldives from 2008-2018. It can be concluded from the above graph that wind speed is highest in the month of June and lowest in the month of April from 2008-2018. Average wind speed of dry and wet season is 4.0 m/s and 4.6 m/s respectively. Detailed analysis of Wind data from 2008-2018 indicates that in dry season predominant wind direction is North East (NE) and in wet season wind mainly flows in South West (SW) direction. Throughout the year wind predominantly flows from West direction.



Wind-Rose diagram showing wind direction (m/s) for Dry season (Jan- April) in Male, Maldives



Wind-Rose diagram showing wind direction (m/s) for Wet season (May Dec) in Male, Maldives

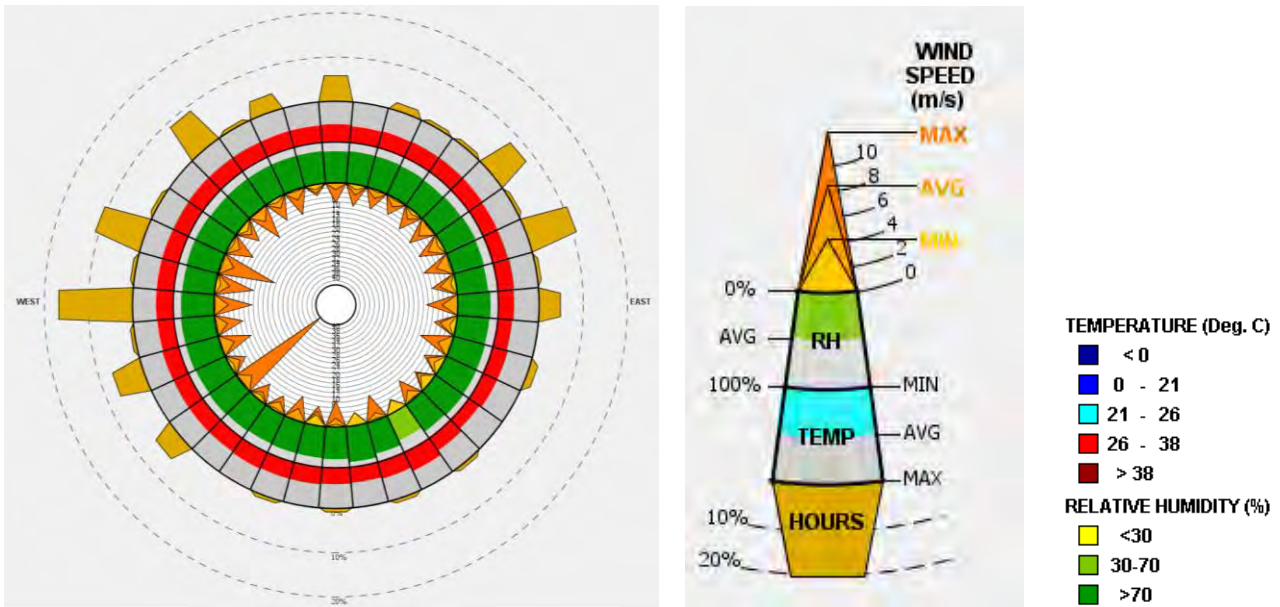


Figure 35: Wind-Rose diagram showing annual wind direction (m/s) for Male, Maldives

The Figure 35 show the annual wind direction (m/s) from January to December. It can be concluded that

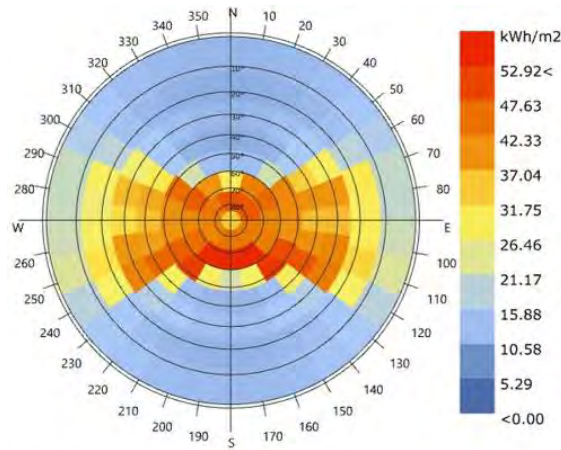
- Maximum wind flows in North East (ENE) direction in dry season
- Maximum wind flows from west direction in wet season
- Predominant wind direction is West for most part of the year

Maldives experiences high relative humidity throughout the year. During the wet period, the air is warm and humid. Therefore, for thermal comfort in outdoor areas, maximizing the wind on site can be an effective strategy. By having enhanced wind movement, body heat dissipation can be increased that would make space users feel comfortable. Therefore, effective natural ventilation by harnessing West winds for outdoor spaces and mechanical **ventilation for indoor spaces should be provided. Site's microclimate can also be improved through** vegetation, shaded walkways and seating areas etc.

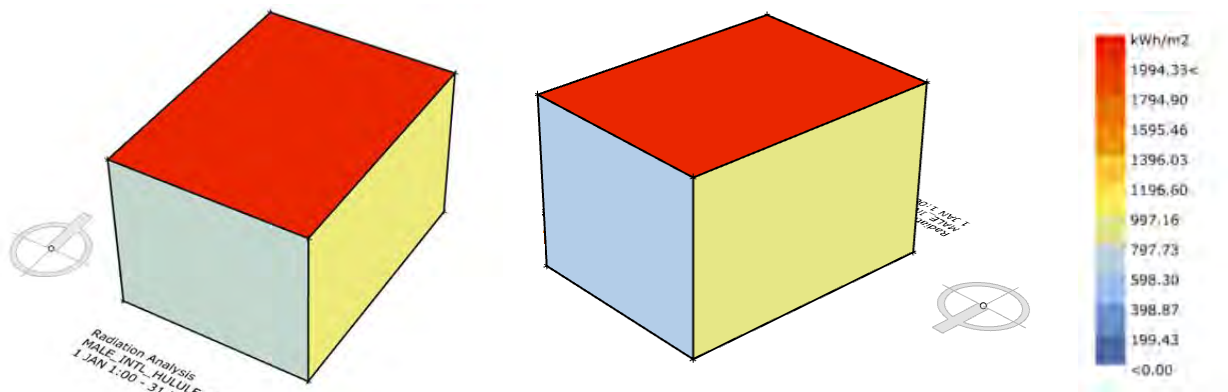
3.2.5. Analysis of Radiation

The direct solar radiation analysis studies the total amount of direct solar radiation energy falling over different surfaces (Example, building façade, roof etc.) in buildings. It is expressed in kWh/Sqm. The higher this number, higher would be the exposure intensity of that surface to direct solar radiation. High solar radiation would result in higher absorption of solar heat by the surface and subsequent increase in surface temperature. Through building facades, high solar radiation can result in high heat gains into the interiors. In summer this means increased air conditioning load and in winter it means lower heating load. The solar radiation analysis also helps in developing solar energy harness strategies for the project.

Figure 36 shows the solar radiation analysis for all critical orientations and roof of a building.



Total Radiation(kWh/m2)
MALE_INTL_HULULE_IS_MDV_1976
1 JAN 1:00 - 31 DEC 24:00



Solar Radiation received on East and South facades of a typical building

Solar Radiation received on North and West facades of a typical building

Figure 36: Analysis of Radiation for Male, Maldives

It is observed from the Figure 36 that North facades receive the least solar radiation (600 kWh/sqm). High solar radiations are observed on the East (1200 kWh/sqm) and West Façade (1200 kWh/sqm) and South facades (1000 kWh/sq.m). The roofs receive the highest solar radiation (2000 kWh/sqm).

3.2.6. Psychrometric Analysis and Passive Strategies Evaluation

A psychrometric chart is a graphical representation of the psychrometric processes of the air. Psychrometric processes include physical and thermodynamic properties such as dry bulb temperature, wet bulb temperature, humidity, enthalpy and air density.

It shows dry bulb temperature across the bottom and moisture content of the air up the side. The vertical scale is also called absolute humidity and can be shown as the humidity ratio in grams of water per kilogram of dry air, or as the vapor pressure. The curved line on the far left is the saturation line (100% Relative Humidity line) which represents the fact that at lower temperatures air can hold less moisture than at higher temperatures.

Each green dot on the chart represents the temperature and humidity of each of the 8760 hours in a year. Different design strategies are represented by specific zones on this chart. The percentage of hours that fall into each of the 16 different Design Strategy Zones gives a relative idea of the most effective passive cooling strategies.

The Figure 37 analyses the distribution of psychrometric data of Male in most effective design Strategy zone in order to create a unique list of design guidelines.

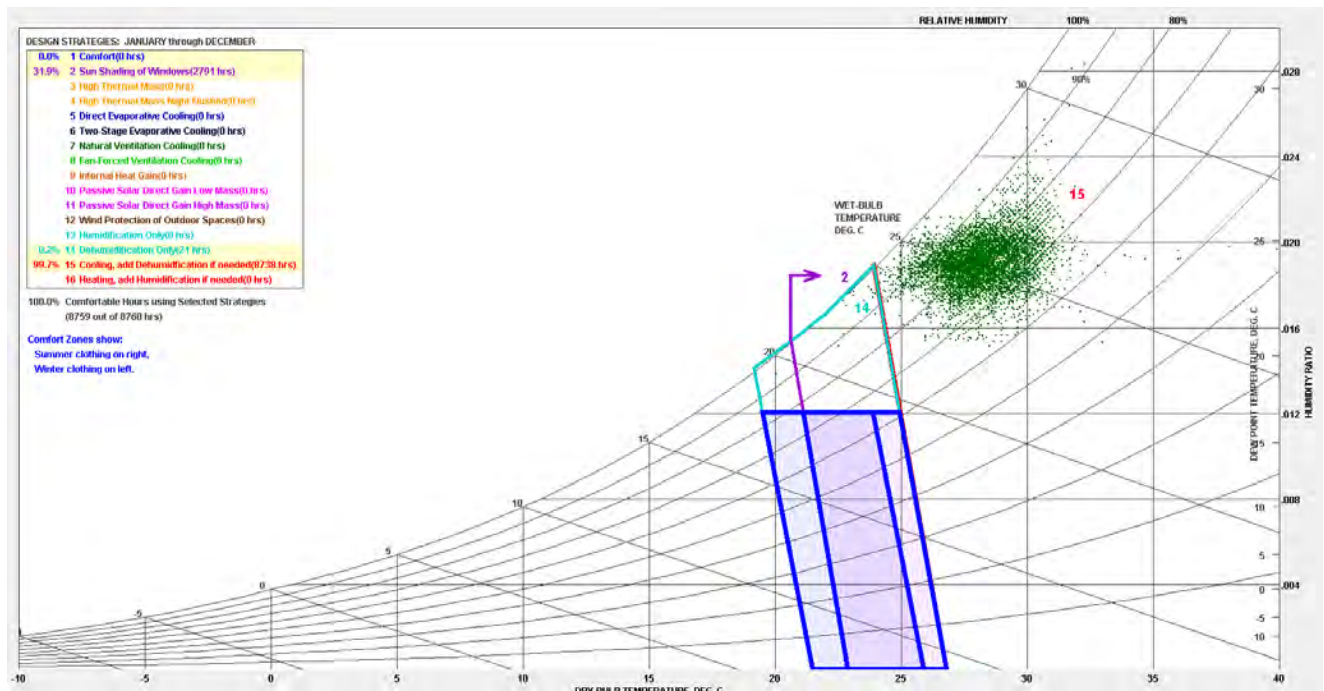


Figure 37: Psychrometric chart analysis for passive design strategies

Comfort criteria have been defined using ASHRAE Standard 55 -2004 Comfort model

It is analyzed through psychrometric chart that for the project site, due to high humidity throughout the year, thermal comfort cannot be achieved naturally. Various passive & low energy strategies shall be effective to achieve better thermal comfort reduce air conditioning load of the building.

1. Building Form and Orientation- Building architectural form and orientation in a hot humid climate can greatly affect the indoor climatic conditions, occupant comfort and energy consumption for air conditioning. The orientation of buildings needs to be designed in order to reduce the solar heat gains inside the building. The optimum shape for minimizing solar gains is achieved by elongating the north and south walls, creating a prominent east-west axis. Eastern and western exposures should be minimized, since they are difficult to shade and receive longer periods of direct radiation. Southern and northern exposures are easier to shade, especially with roof overhangs.
2. Solar shading is the single most effective strategy which will be effective for 32% of the total hours in a year. It will be effective to reduce overheating in summer , monsoon season. Solar shades are recommended in east, West and South facades of all buildings as shown in Figure 38.

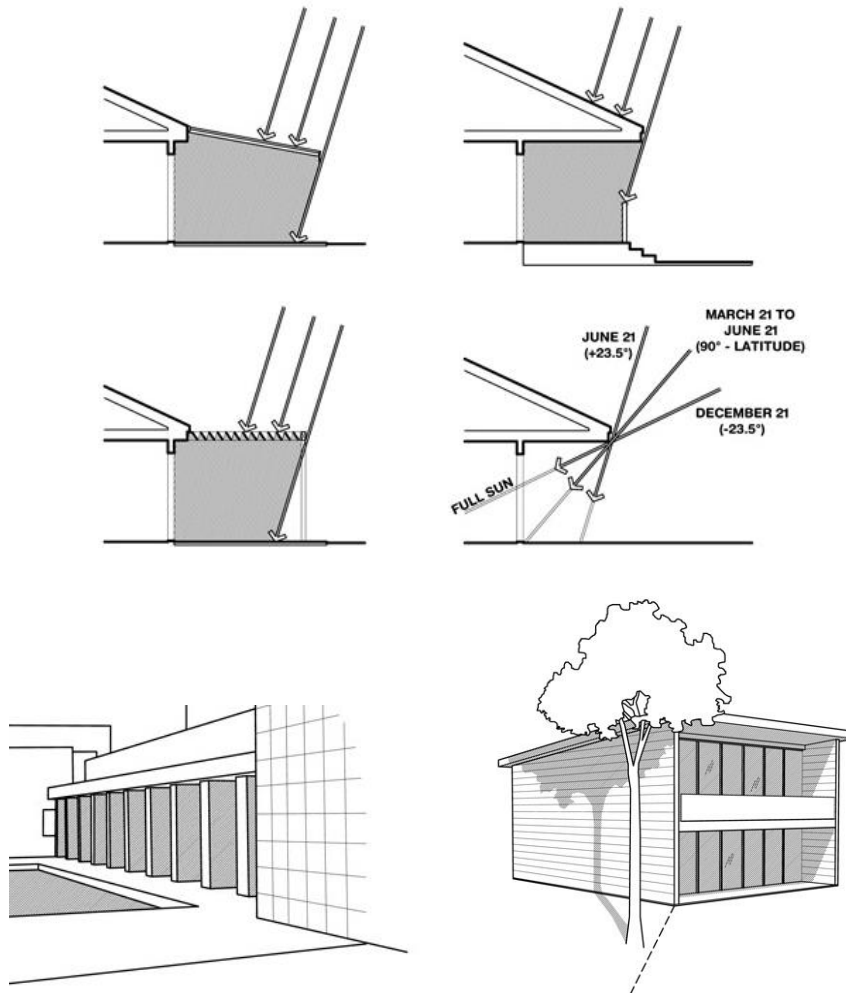


Figure 38: Solar shades are recommended in east, West and South facades of all buildings

Residential buildings should be provided with adequate openings in the external façade in order to facilitate for cross ventilation in the dwelling units.

3. Reduce internal heat gains will be effective during summer and monsoon season. The internal heat gains can be reduced by optimizing occupant density, indoor lighting power and equipment power of the building. Energy efficient LED and CFL light fixtures are recommended in the building to achieve optimized LPD (lighting power density) values for the buildings.
4. Increased Natural ventilation will help dissipate body heat more effectively during summer and monsoon period. Ventilation on building sites can be improved by raising building on stilts, orientation of building to enhance wind movement, providing cross or mechanical ventilation for indoor spaces.

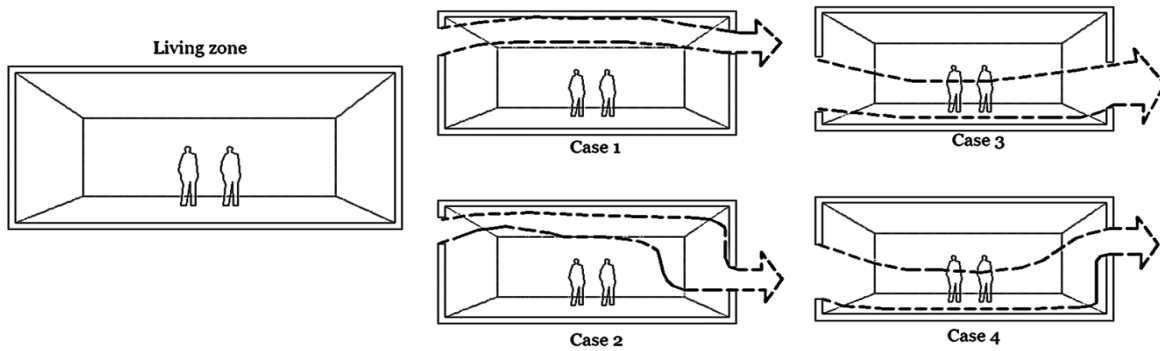


Figure 39: Natural ventilation examples

5. Window to wall glazing ratios: The unshaded glazed area should be minimized in south, east & west facades in order to reduce indoor air conditioning load of the building and thermal comfort around building perimeter. Higher glazing ratio can be provided in North East and North West facades.
6. Reduce heat island effect on roof: The analysis shows that roof shall receive high solar radiation. These solar radiations can be reflected by using light coloured finishes, high reflective finishes like white china mosaic tiles & high SRI paints. Terrace gardens can also be designed for accessible terraces to not only reduce heat island effect but also prevent glare discomfort to terrace users.



Cool Roof through white Coating



Cool Roof through China Mosaic



Cool Roof using Landscaping

Figure 40: Cool Roof Examples

7. Renewable energy harness It will be very efficient to install the solar PV panels & solar thermals over the roof to harness maximum solar energy followed by south and west facades.
8. Building Envelope
As observed from the analysis, the exterior walls in south and west direction and the roof receive high solar radiation leading to heat gain into the interiors. To prevent overheating of the building facades, reduce air conditioning load and improve thermal comfort, light coloured finishes on facades can be used. Further, insulation is also required to reduce the conductive heat gains inside the building.
9. Air conditioning is required to achieve thermal comfort for 93% occupied period in a year. But this can be reduced if building design minimizes overheating.

The proposed Energy Efficiency guidelines will be developed to incorporate the above passive and active design strategies for various typologies of new and existing buildings in Male and Hulhumale.

4. Energy Sector

4.1. Regulatory structure for energy sector in Male and Hulhumale

The Ministry of Environment is responsible for implementing government policies, regulations, programmes and projects related to the provision of clean water and appropriate sewerage services, provision of clean and affordable energy services, provision of clean and healthy environment free from pollution, protection of the islands from coastal erosion, advocate for the rights of small islands states in the fight against climate change, mobilize finance to adapt and mitigate the negative impacts of climate change, coordinating sustainable development goals within the government, and protection and preservation of natural environment. Below figures represents the departments that come under Ministry of Environment¹.

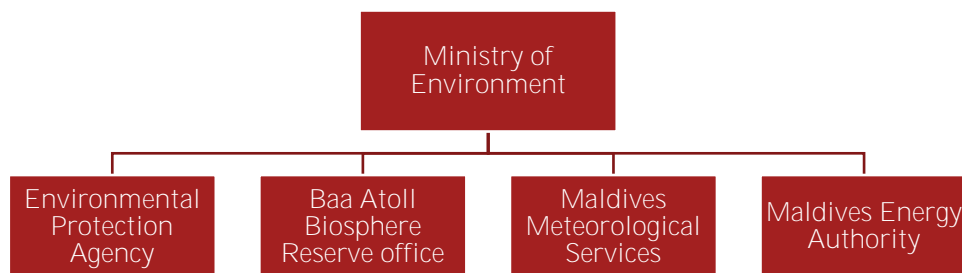


Figure 41: Energy & Environment Regulatory framework

- 1) Environmental Protection Agency: EPA is responsible for regulatory activities for protection, conservation and management of environment and biodiversity, as well as waste management and pollution prevention under the Environment Protection and Preservation Act (4/93). EPA also regulates Municipal Water Supply and Sewerage services under the Public Services Act (4/96).
- 2) Baa Atoll Biosphere Reserve office: Responsible to safeguard the bio-diversity of the region through Research & Development, conservation projects & creating awareness amongst the stakeholders.
- 3) Maldives Meteorological Services: Responsible for studying climatic conditions, weather forecast & issue warning against any climatic disaster such as earthquake & Tsunami
- 4) Maldives Energy Authority: MEA is the regulatory authority that develops policy, sets standards & regulations on production & use of energy & advice relevant government organization on energy. The regulator is mandated with establishing tariffs, issuing guidelines and regulations to ensure the reliability, security of the grids, and that the rights and obligations of consumers and service providers are safeguarded. State Trading Organization is the main importer and supplier of petroleum products.

Electricity and Water services are provided by 3 main state-owned utilities namely State Electric Company Limited, FENAKA Corporation Limited and Male' Water and Sewerage Company Private Limited.

¹ www.environment.gov.mv

4.2. Sources of energy in the country

Maldives has achieved universal access of electricity from 2008. Most of the energy needs of Maldives is met by imported fossil fuel. In 2017, 561,435 metric ton of fuel was imported. Out of this, 14,483 metric ton was cooking gas, 447,555 metric ton was diesel, 57,730 metric ton was petrol and 41,666 metric ton was aviation. The Figure 42 shows the import of fuel in Maldives over the years.

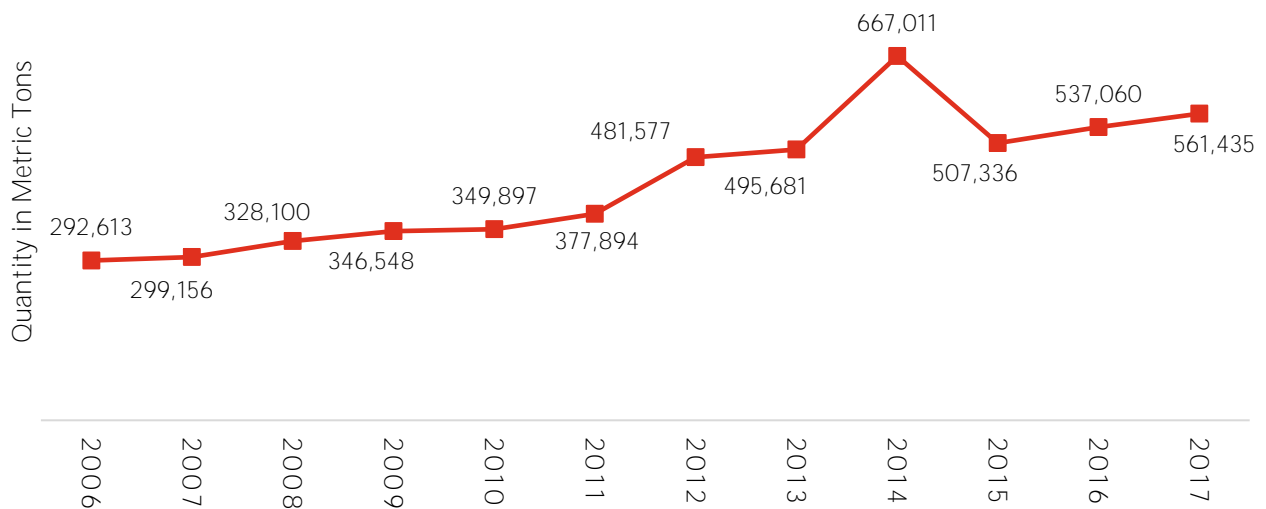


Figure 42: Yearly data of quantity of fuel imports in Maldives

Due to dispersed nature and small size of islands large storage of energy is not possible. The current storage capacity of country is only 28MT.

To cater the electricity demand about 240 MW, diesel generators are installed in the inhabited islands of Maldives. Electricity generation for the Greater Malé region accounts for 56.9% of the total electricity generation of all the inhabited islands. This is the region with the highest annual electricity consumption of about 400GWh, with an installed capacity of 101MW. In 2017, outer islands consumed 304GWh of electricity. The Figure 43 presents the consumption of electricity in Male and Hulhumale over the years.

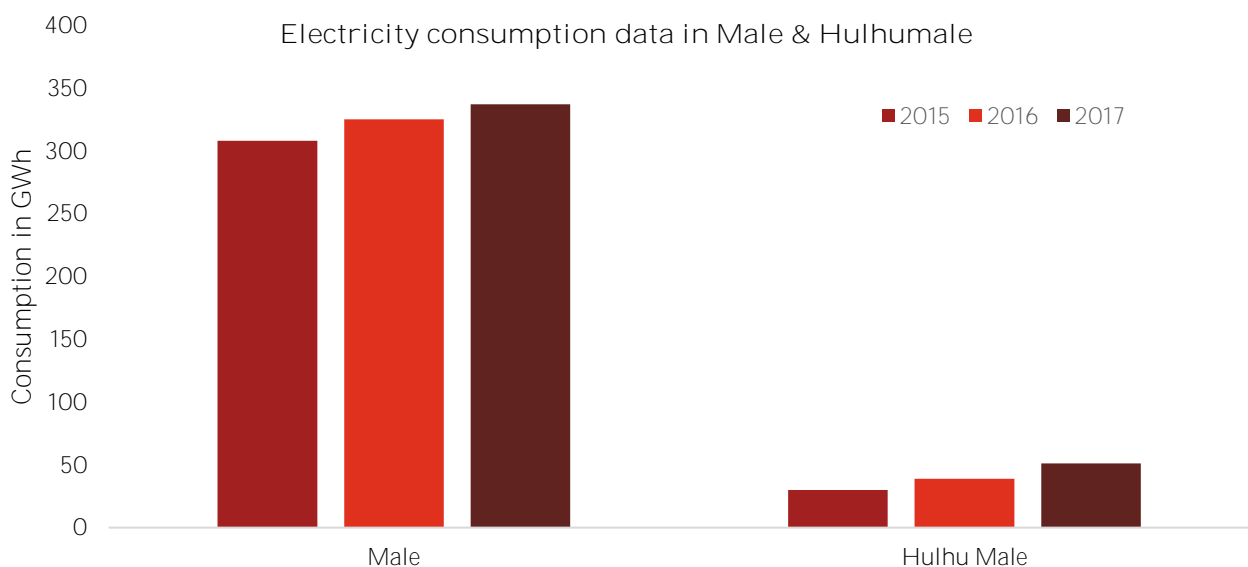


Figure 43: Electricity consumption data in Male & Hulhumale

To enhance the energy security of the country and reduce the carbon emission the government of Maldives in 2014 has initiated a program of diversifying the energy sector by adopting renewable energy. Through these programs, government has installed renewable system to reduce the peak daytime load by 30%. Solar PV- diesel-hybrid system is installed in some islands with feed-in tariff mechanism and net metering regulation in order to promote renewable energy at household levels. Government is investing \$ 55 million in renewable energy to meet the goal of adding 20MW of solar capacity by 2020 that will contribute to its target of 100% renewable generation by 2050. In 2018, the total installed capacity of Renewable Energy systems of the Maldives is 16MW. The Figure 44 shows the increase in the solar PV installations in Maldives over the years.

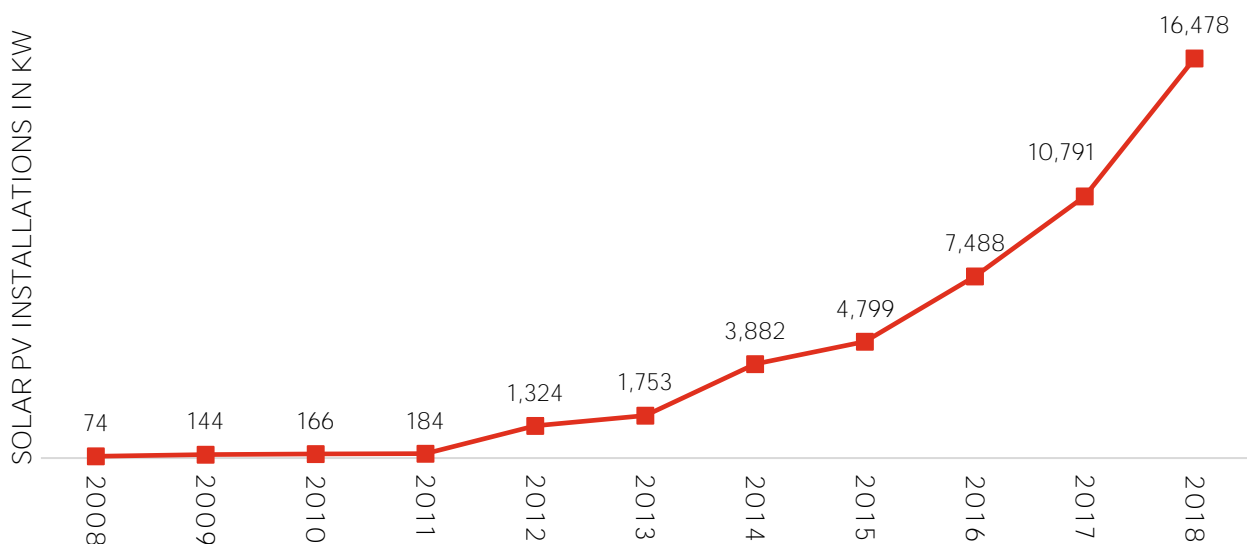


Figure 44: Installed capacity of solar PV over the years in Maldives

Government of Maldives is working on transforming the existing energy grids on the archipelago into a hybrid renewable energy system. The Preparing Outer Islands for Sustainable Energy Development Project is installing equipment for solar diesel hybrid grids on about 160 islands. To significantly reduce the need for diesel to generate electricity, it is installing energy management and control systems; energy storage; and improvements in distribution networks. The project will replace inefficient diesel-based power generation grids on the islands with hybrid systems of both renewable energy and diesel in order to reduce the cost of electricity and the emissions created, as well as lower the subsidy burden on the government budget. The project is targeted to complete by 2020.

4.3. Energy Policies

Energy Policy 2016

Maldives Energy Policy and Strategy 2016 consist of revised policies derived from Maldives Energy Policy and Strategy 2010. The document contains 5 key policy statements which are

- Strengthen institutional & regulatory framework of energy sector
- Promote energy conservation & efficiency
- Increase the share of renewable energy in the national mix
- Improve the reliability & sustainability of service & maintain universal access to the electricity
- Increase national energy security

Under Promotion of energy conservation and efficiency, the following objectives :

- a) Create an enabling environment for energy efficiency and energy conservation
- b) Increasing awareness on energy efficiency and energy conservation
- c) Adopt implementation of energy management practices
- d) Implementing energy labelling program for major energy consuming equipment and appliance in industrial and domestic sector
- e) Develop and publish Energy Efficiency Index.
- f) Develop a standard and monitoring plan for the quality of fossil fuel sold in the country
- g) Developing and enforcing standards for exhaust emissions for power plants, vehicles and vessels that use fossil fuel in order to improve air quality.

Energy efficient appliances:

The energy conservation is beneficial to Maldives as it reduces the energy imports that will contribute directly **into savings for country's foreign exchange as well as** reduce the dependence on imported fossil fuels. In order to consume low energy, Government of Maldives has launched '**Energy Efficiency Standards and Labelling**' programme that helps the customers to identify and use energy efficient appliances. Government initiated the National Energy Policy and Strategy in 2016, which encourage energy conservation. Home appliances such as refrigerators, automated washing machines and air conditioners would be labelled as a part of programme.

4.4. State Utilities Companies

Due the geographical conditions, Maldives have distributed electricity grid system. Also, the sea water is desalinated to supply fresh portable water to the region. Maldives have three main utilities companies STELCO, MWSC & FENAKA that supplies electricity & portable water in the region. Also, some of these utilities are involved in Sewer & waste management.

State Electricity Utility Companies (STELCO): It is a Government operated company established in 1949 with an installed capacity of 14kW to provide electricity to Male under different names such as Department of Electricity & Maldives Electricity Board. In 1997, STELCO was formed. As of 2017, it supplies electricity to 27080 customers in Male & 3655 customers in Hulhumale region².

Male Water & Sewerage Company (MWSC): It was established in 1995 to institute water production and wastewater management system in the male region. At present, it provides water and wastewater management to approximately more than 50% of the Maldivian population. The company has become multi-disciplinary engineering & manufacturing organization providing engineering solutions for integrated utilities and manufactures PE & PVC pipes. It is providing innovative utility solution for water, wastewater and power for resorts, government & contract clients³.

FENAKA Corporation Limited is a state-owned utility company that was established by in 2002 by merging six different utilities companies. It has a mandate to provide island communities with electricity, sewerage & waste management services. It provides services to 16 atolls, a total of 152 islands.

Source: www.fenaka.com.mv

Description	Hulhumale	Male
Electricity provider	STELCO	STELCO
Maximum Peak Load(kW)	-	56,048
Peak load time	21:00	15:00

² www.stelco.com.mv

³ www.mwsc.com.mv

Installed capacity (kW)	17,400	80,320
Installed generation sets	800x1, 1000x7, 1200x1, 1600x6	1000x6, 1600x9, 2000x2, 2160x3, 4320, 5760, 6500x2, 8730x2, 8900
Monthly average usage (kWh)	4,272,559.5	28,080,134.33
Yearly electricity production (kWh)	51,270,714	336,961,612

4.5. Electricity tariffs in the country

The energy sector of Maldives has determined electricity tariff based on average tariff, divided by number of customers in three categories residential, business and governmental. Maldives Energy Authority (MEA) has approved new electricity tariffs to provide electricity to domestic customers which include two tariff structures – **one for Greater Male’ Region (Male’, Hulhumale’, Vilimale’)** and **one for all the rest of the inhabited islands**. There are total of 186 powerhouses in inhabited islands. FENAKA Corporation Ltd. (FENAKA) operates 148 powerhouses while State Electric Company Ltd. (STELCO) operates 35 powerhouses and Male’ Water and Sewerage Company Pvt. Ltd. (MWSC) operates 1 powerhouse at V.Rakeedhoo. The following table represents the domestic electricity tariff in Greater Male region for different building typologies are shown below:

Table 3 Tariff rates in MVR for Residential buildings

Units (Band 30 days)	Tariff Rates in MVR
Units 0-100	1.5
Units 101-200	1.7
Units 201-300	2.15
Units 301-400	2.5
Units 401-500	2.95
Units 501-600	3.55
Units 601>	4.25

Table 4 Tariff rates in MVR for Business (Commercial) buildings

Units (Band 30 days)	Tariff Rates in MVR
Units 0-100	3.30
Units 101-200	3.35
Units 201-300	3.65
Units 301-400	4.0
Units 401-500	4.35
Units 501-600	5.75
Units 601>	6.65

Table 5 Tariff rates in MVR for Government & Institutes buildings

Units (Band 30 days)	Tariff Rates in MVR
Units 0-100	3.30
Units 101-300	3.35
Units 301-500	3.65
Units 501-600	4.0
Units >600	4.35

In addition to this, surplus base charges are added that depends on the fuel prices.

4.6. Analysis of Building Electricity Consumption

Major energy consumption in building is in the form of electricity which is used by various building assets such as lighting system, ACs etc. The electricity analysis is a method to assess the way how the consumers use electricity. It helps to understand the electricity consumption pattern of the buildings as per building typology, operational schedule etc. It has been found that electricity consumption varies for different types of buildings. Intent of electricity consumption analysis of the buildings is to develop the energy efficiency guidelines for Male and Hulhumale. It will play significant role for engineers and architects to design, construct and operate the buildings with energy savings potential.

To perform the analysis, electricity consumption data of all the buildings was obtained from the state electric company (STELCO) which provides electricity to Maldives. All buildings in Male and Hulhumale have been categorized into four different categories. These four categories are Residential, Commercial, Government and Hotels & Guest houses, and are shown in Figure 45 below.

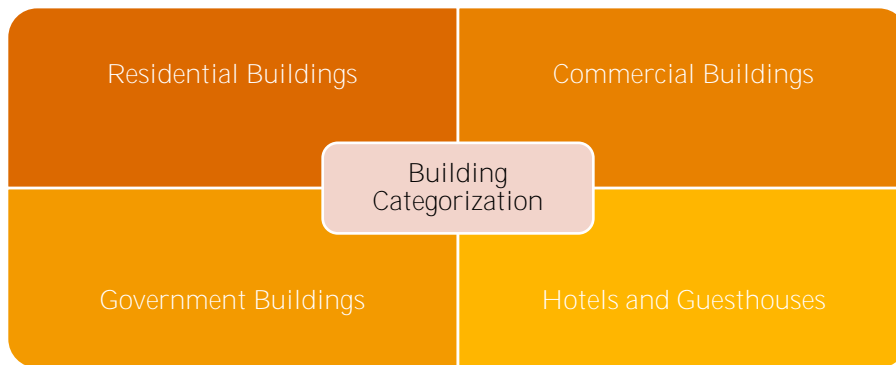


Figure 45: Building typologies in Male and Hulhumale, Maldives

4.6.1. Analysis of Electricity Connection

The total number of electricity connections in Male and Hulhumale in year 2016 and 2017 is shown below in Figure 46.

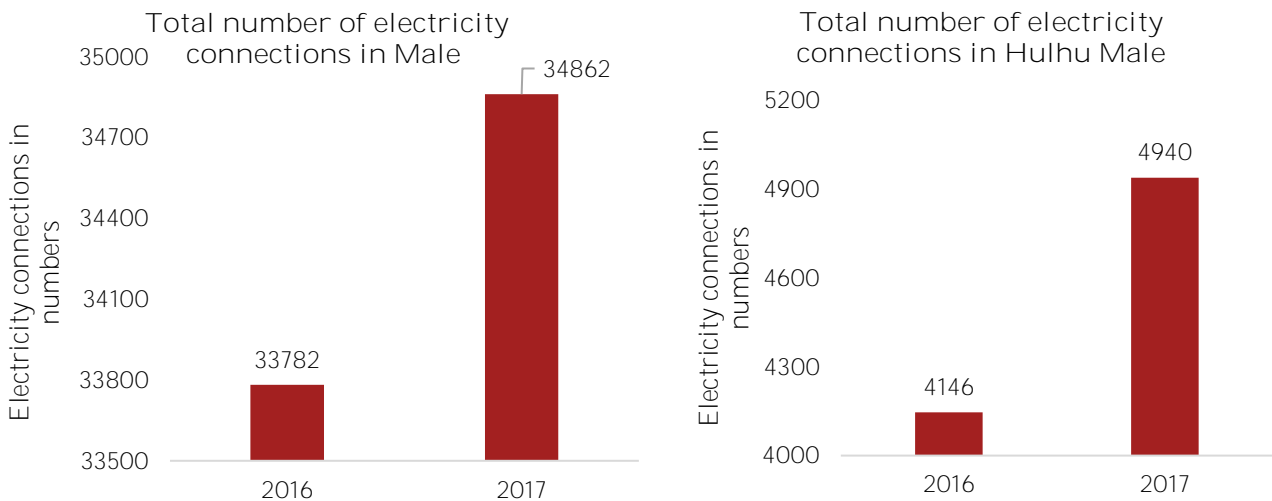


Figure 46: Total number of electricity connections in 2016 and 2017, Male and Hulhumale

The Figure 46 shows the total number of electricity connections in Male and Hulhumale for the years 2016 and 2017. Electricity connections in Male are more than Hulhumale. However, a 19% increase in the number of electricity connections is observed in Hulhumale from 2016 to 2017, whereas in Male, which is about 4% from 2016 to 2017. This indicates a rapid growth of development in Hulhumale.

Electricity consumption varies for different building typologies as per their operational schedules, e.g. office buildings are operational mainly for the daytime, and residential buildings are operational for 24 hours of the day, so it is required to consider the number of electric connections separately for all the building typologies. It was observed that out of the total connections, 77% connections belong to residential sector and 23% belong to non-residential sector.

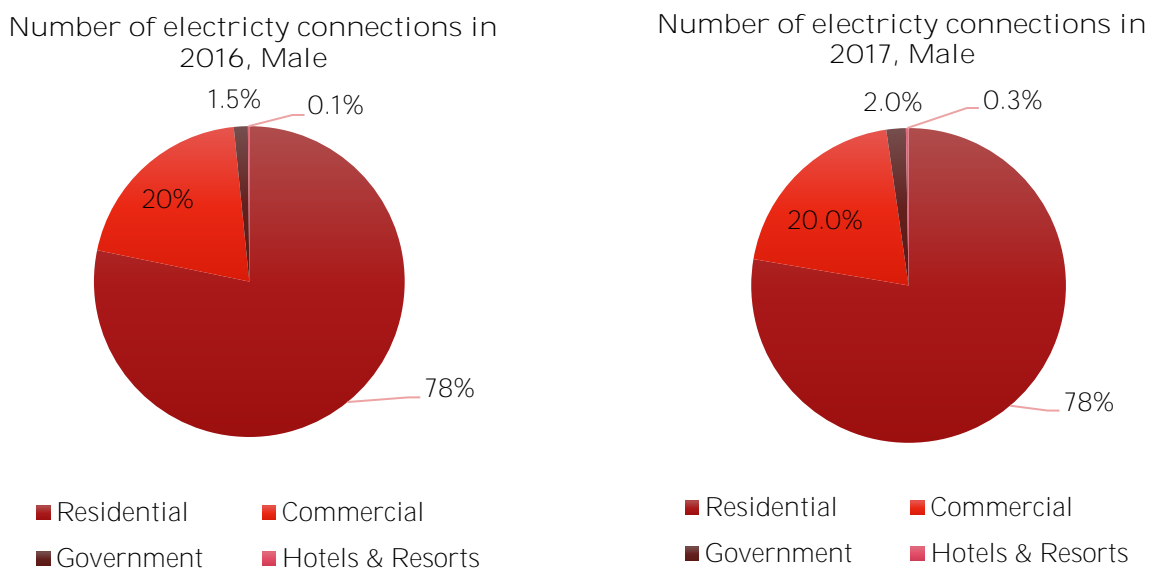
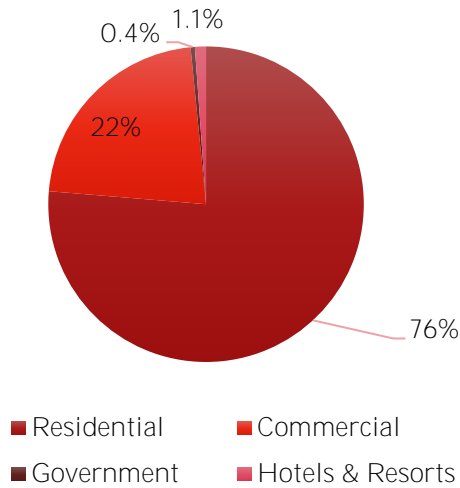


Figure 47: Total number of electricity connections in 2016 and 2017, Male

Number of electricity connections in 2016, Hulhu Male



Number of electricity connections in 2017, Hulhu Male

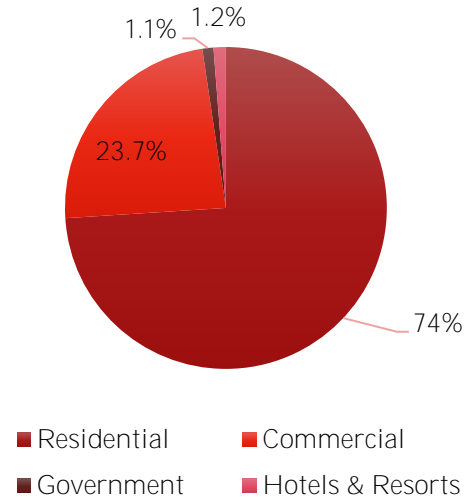


Figure 48: Total number of electricity connections in 2016 and 2017, Hulhumale

The above Figure 47 & Figure 48 shows the number of electricity connections (in percentage) building type wise for Male and Hulhumale respectively. It can be concluded from above figures that nearly 78% connections belong to Residential buildings followed by Commercial, Government and Hotels and guesthouse buildings respectively in years 2016 and 2017 for Male. Similarly, nearly 76% connections belong to Residential buildings in 2016, and 74% in 2017, followed by Commercial buildings., Government and Hotels & guesthouse buildings consists of 1.1 % and 1.2 % of total electric connections respectively in Hulhumale.

Number of electricity connections have been analyzed individually for all 4 building typologies in the years 2016 and 2017 for Male and Hulhumale, which is presented below.

Number of electricity connections in 2016 and 2017, Male

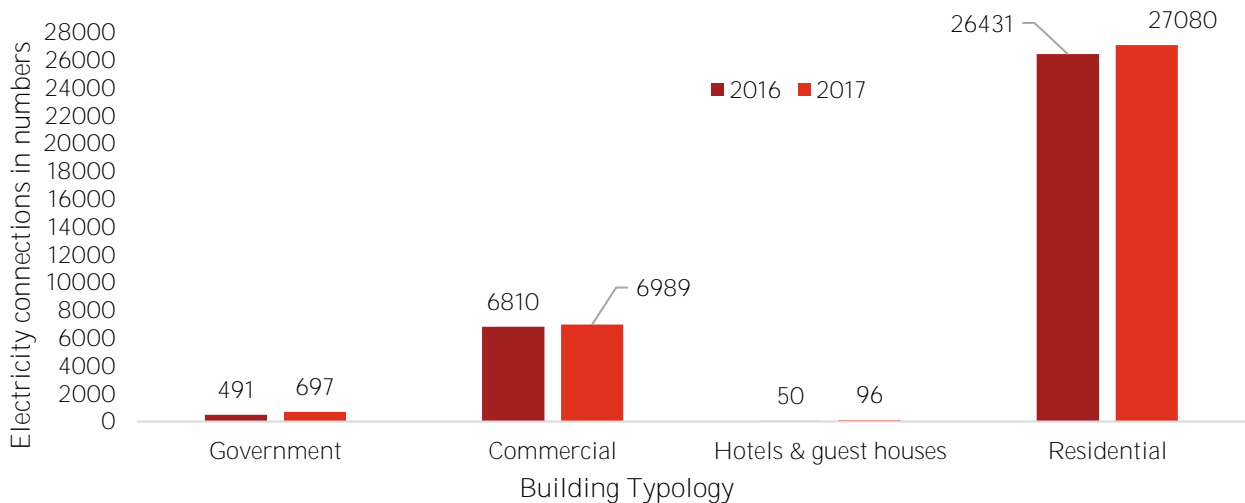


Figure 49: Total number of electricity connections for all building typologies in Male

The Figure 49 shows the total number of electricity connections for Government, Commercial, Hotel & guesthouses and Residential buildings in Male for the Years 2016 and 2017. In 2016, number of connections for Residential, Hotels & guesthouses, Commercial and Government buildings are 26431, 50, 6810 and 491

respectively. Similarly, in 2017, number of connections for Residential, Hotels & guesthouses, Commercial and Government buildings are 3655, 61, 1169 and 55 respectively. It can be concluded that maximum number of electricity connections are for Residential buildings followed by Commercial buildings, Government buildings and Hotels & guesthouses. Residential and commercial buildings connections have increased by 2.5%, Government buildings connections increased by 42%, and Hotels & guesthouses connections have increase by 92% from 2016 to 2017.

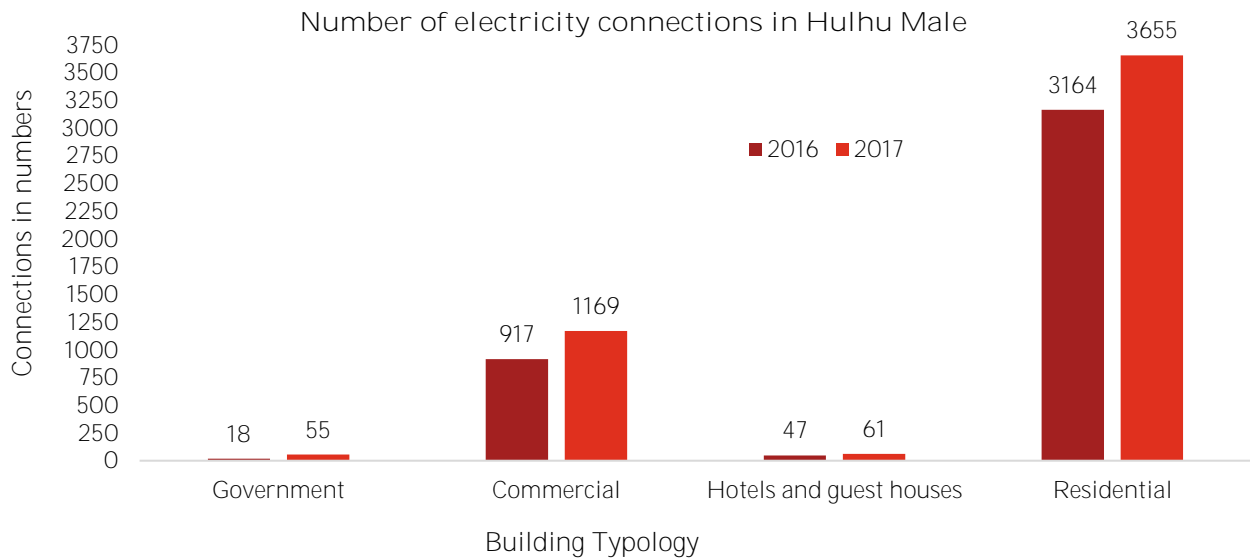


Figure 50: Total number of electricity connections for all building typologies in Hulhumale

The Figure 50 shows the total number of electricity connections for Government, Commercial, Hotel & guesthouses and Residential buildings in Hulhumale for the Years 2016 and 2017. In 2016, number of connections for Residential, Hotels & guesthouses, Commercial and Government buildings are 3164, 47, 917 and 18 respectively. Similarly, in 2017, number of connections for Residential, Hotels & guesthouses, Commercial and Government buildings are 3655, 61, 1169 and 55 respectively. It can be concluded that Residential buildings has maximum number of connections, followed by Commercial buildings, Hotels & guesthouses and Government buildings. Residential buildings connections have increased by 16%, Commercial buildings connections have increased by 27%, Hotels & guesthouses connections have increased by 30% and a rapid growth of nearly 206% has been noticed in Government buildings connections from 2016 to 2017.

4.6.2. Analysis of Electricity Consumption

After analyzing the number of connections for all 4 typologies in Male, and Hulhumale, analysis of electricity consumption pattern for all 4 typologies have been conducted. Detailed analysis of electricity consumption has been done and presented in *Figure 51*.

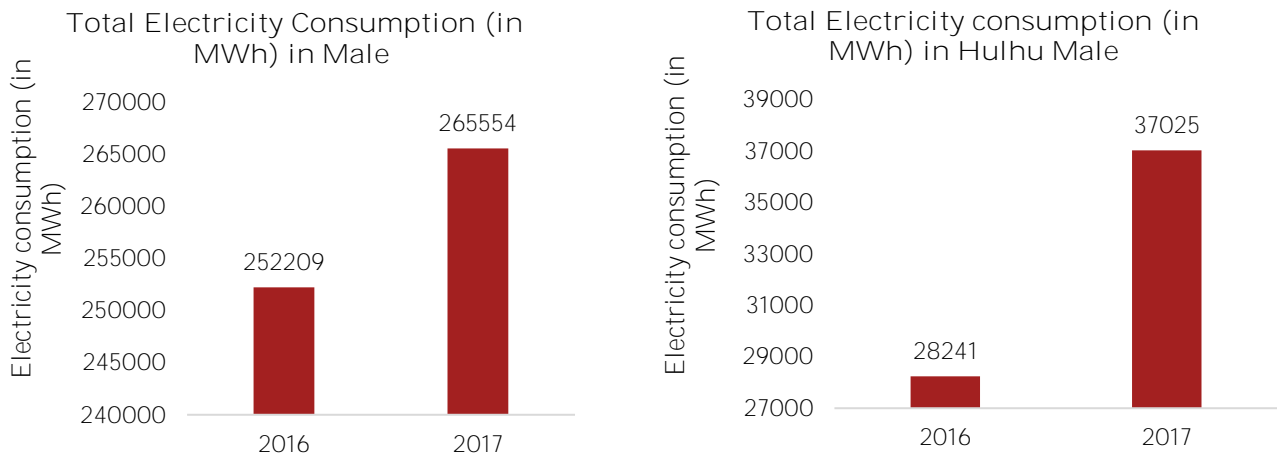


Figure 51: Total Electricity consumption (in MWh) in 2016 and 2017, Male

The total electricity consumption in Male is 252,209 MWh in 2016 and 265,554 MWh in 2017. It is observed that total electricity consumption has increased by nearly 5% from 2016 to 2017. Similarly, the total electricity consumption in Hulhumale is 28,241 MWh in 2016 and 37,025 MWh in 2017. It is observed that total electricity consumption has increased by nearly 31% from 2016 to 2017.

Electricity consumption has been analyzed distinctly for all 4 building typologies in the years 2016 and 2017 for Male and Hulhumale, which is presented in *Figure 52*.

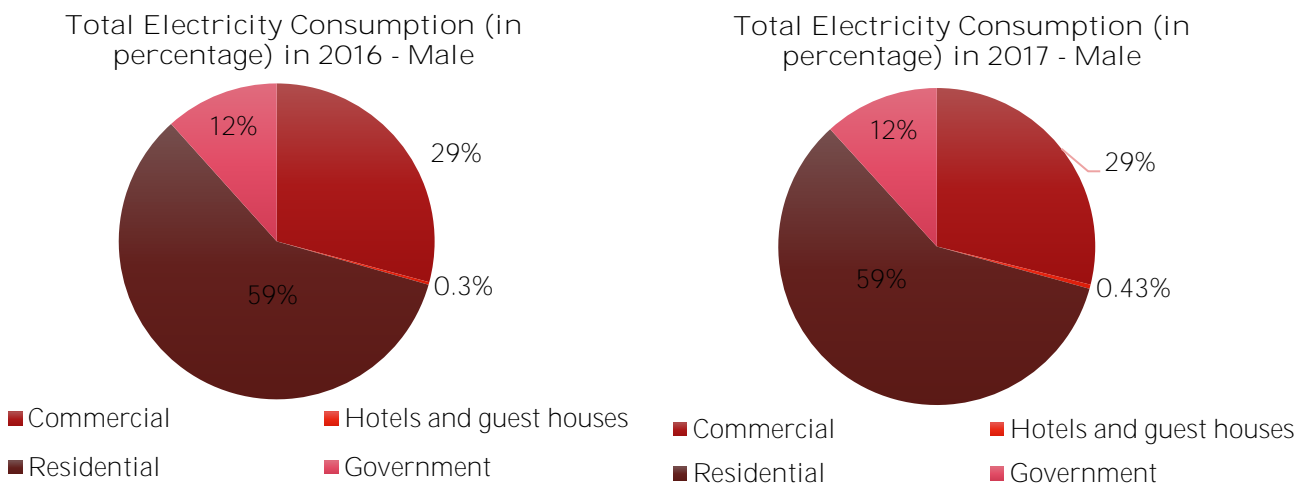
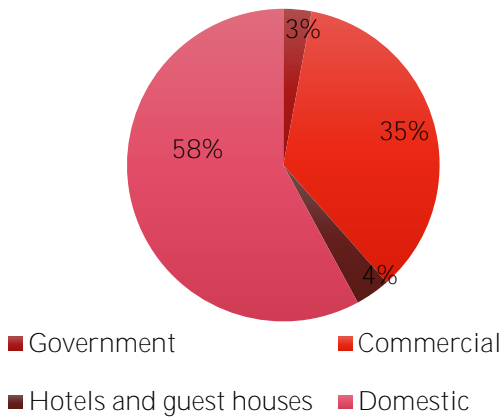


Figure 52: Total electricity consumption (in percentage) for different typologies in 2016 and 2017, Male

It can be concluded from the *Figure 52* that maximum 59% of the electricity is consumed in Residential buildings followed by 29% in Commercial buildings, 12% in Government buildings, and nearly 0.3% to 0.43% in Hotels and guesthouses in the years 2016 and 2017.

Total Electricity Consumption (in percentage) in 2016, Hulhu Male



Total Electricity Consumption (in percentage) in 2017, Hulhu Male

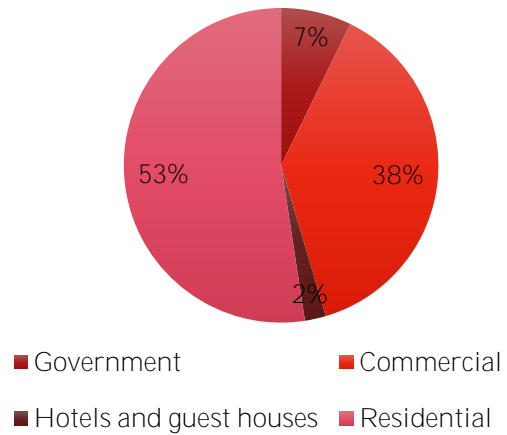


Figure 53: Total electricity consumption (in percentage) for different typologies in 2016 and 2017, Hulhumale

It can be concluded from the Figure 53 that maximum 58% of the electricity is consumed in Residential buildings followed by 35% in Commercial buildings, 4% in Hotels and guest houses and 3% in Government buildings in the year 2016. Similarly, It can be concluded from the Figure 53 that maximum 53% of the electricity is consumed in Residential buildings followed by 38% in Commercial buildings, 7% in Government buildings, and 2% in Hotels and guest houses.

After analyzing the electricity consumption pattern annually, it is important to analyze the monthly electricity consumption for all building typologies in the years 2016 and 2017 for Male and Hulhumale, which has been analyzed individually, and is presented below

4.6.3. Monthly Electricity Consumption pattern for Male in 2016 and 2017

In order to perform the detailed electricity consumption analysis, monthly energy consumption pattern for Male has been analyzed in years 2016 and 2017 for all 4 types of building typologies.

Monthly electricity consumption of Government buildings in Male

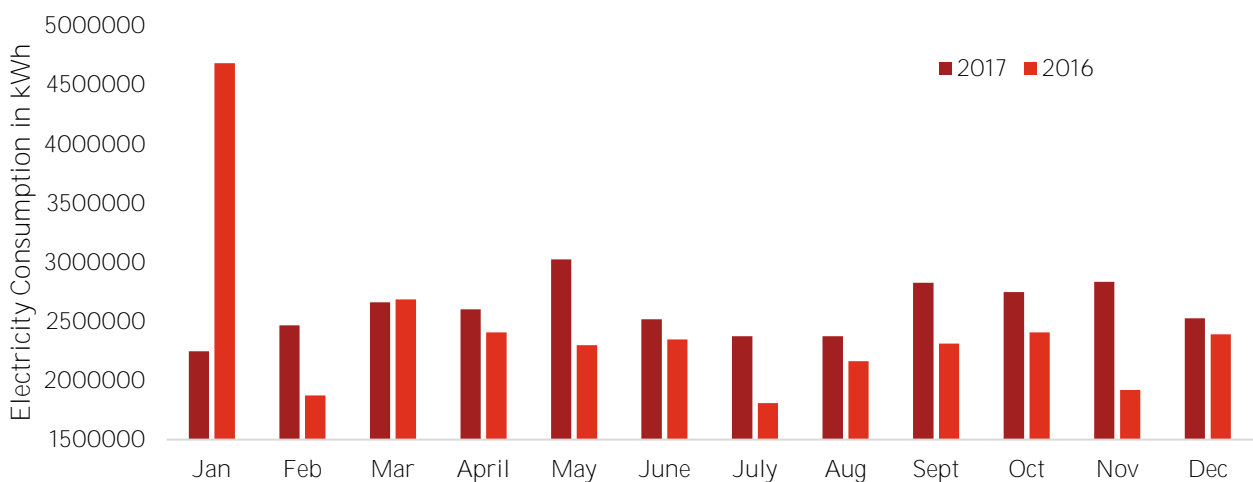


Figure 54: Monthly electricity consumption (kWh) of Government buildings in 2016 and 2017 – Male

From Figure 54, it can be concluded that Government buildings in Male have maximum electricity consumption in January and has lowest electricity consumption in July in 2016. However, in 2017 maximum electricity

consumed by Government buildings in the month of May and minimum electricity is consumed in the month of January. The average increase in electricity consumption of the Government buildings from 2016 to 2017 is approximately 6.5% due to increase in number of connections by nearly 42%.

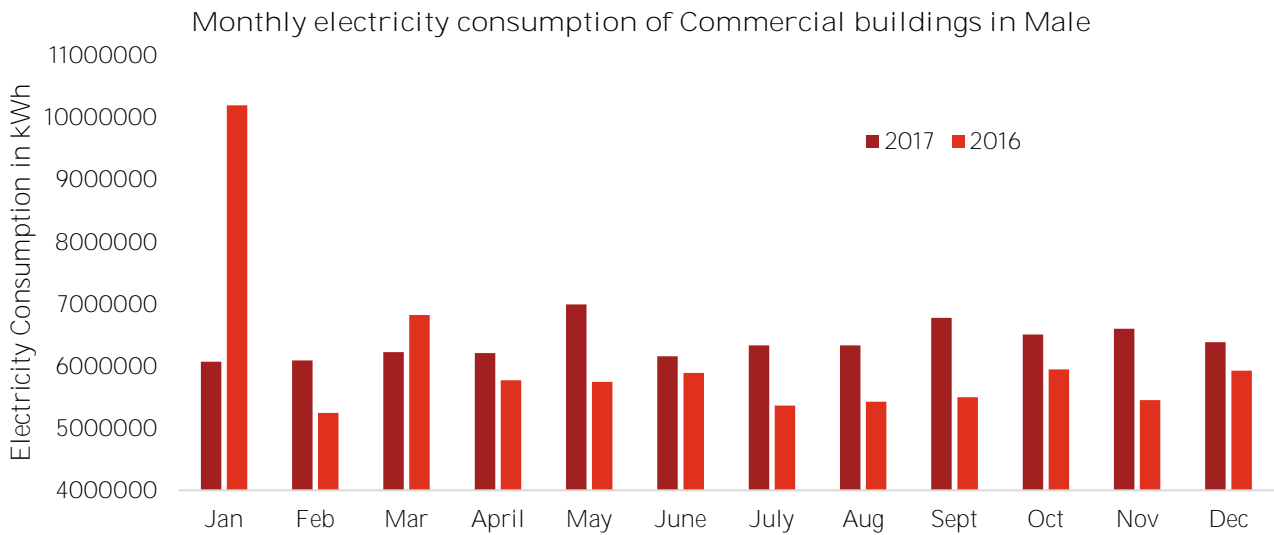


Figure 55: Monthly electricity consumption (kWh) of Commercial buildings in 2016 and 2017 – Male

From Figure 55, it can be concluded that Commercial buildings in Male have maximum electricity consumption in January and has lowest electricity consumption in February in 2016. However, in 2017 maximum electricity consumed by Commercial buildings in the month of May and minimum electricity is consumed in the month of January. The average increase in electricity consumption of the Commercial buildings from 2016 to 2017 is approximately 4.6% due to increase in number of connections by nearly 2.6%.

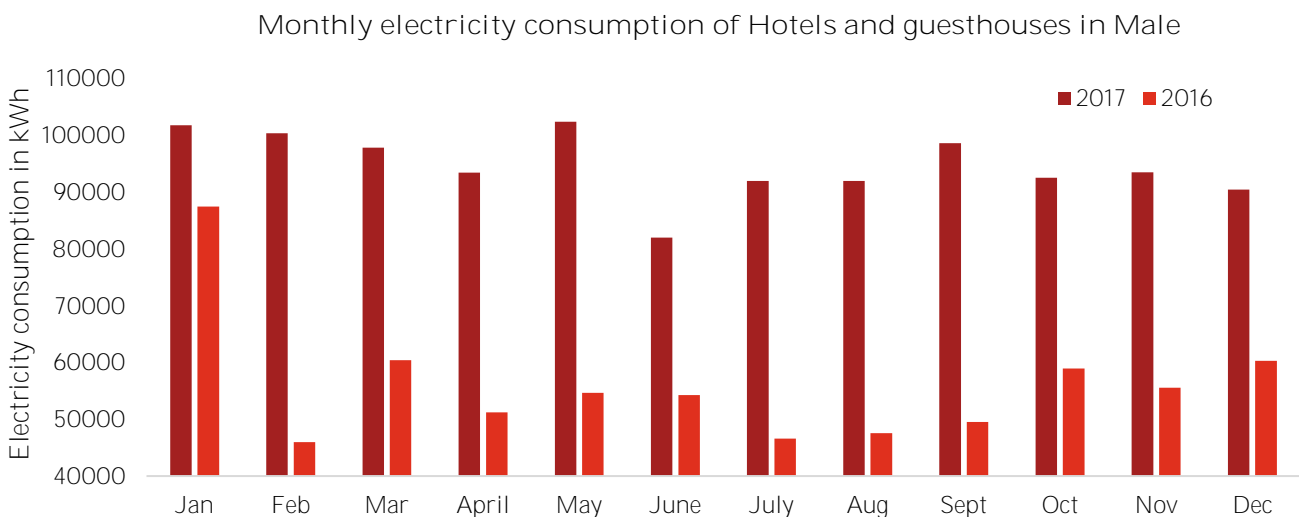


Figure 56: Monthly electricity consumption (kWh) of Hotels and guesthouses buildings in 2016 and 2017 – Male

From Figure 56, it can be concluded that Hotels and guesthouses buildings in Male have maximum electricity consumption in January and has lowest electricity consumption in February in 2016. However, in 2017, maximum electricity consumed by Hotels and guesthouses buildings in the month of May and minimum electricity is consumed in the month of June. The average increase in electricity consumption of the Hotels and

guest houses buildings from 2016 to 2017 is approximately 69.1% due to increase in number of connections by nearly 92%.

Monthly electricity consumption of Residential buildings in Male

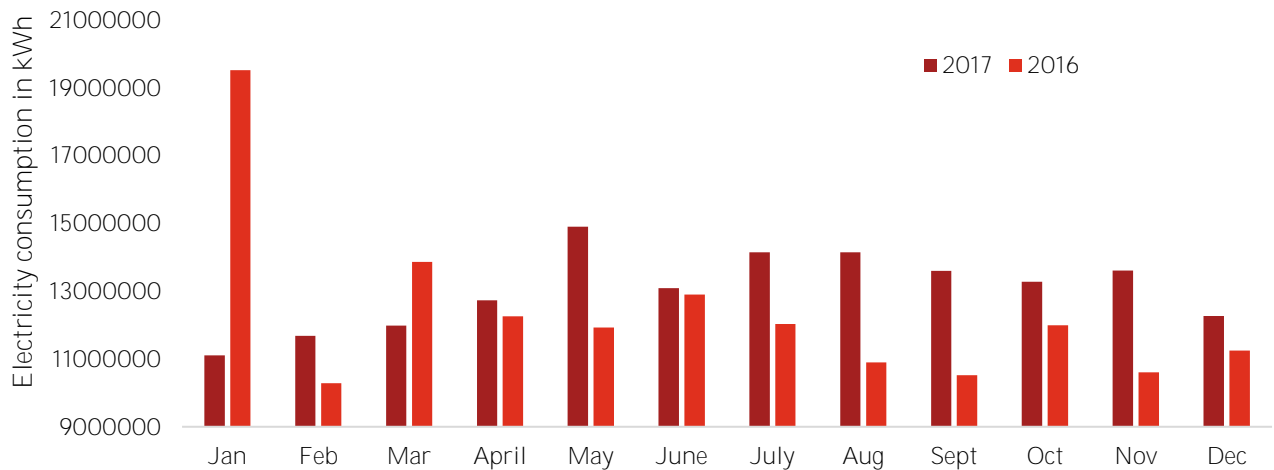


Figure 57: Monthly electricity consumption (kWh) of Residential buildings in 2016 and 2017 – Male

From Figure 57, it can be concluded that Residential buildings in Male have maximum electricity consumption in January and has lowest electricity consumption in February in 2016. However, in 2017, maximum electricity consumed by Residential buildings in the month of May and minimum electricity is consumed in the month of January. The average increase in electricity consumption of Residential buildings from 2016 to 2017 is approximately 5.7% due to increase in number of connections by nearly 2.5%.

4.6.4. Monthly Electricity Consumption pattern for Hulhumale in 2016 and 2017

In order to perform the detailed electricity consumption analysis, monthly electricity consumption pattern for Hulhumale has been analyzed in years 2016 and 2017 for all 4 types of building typologies.

Monthly electricity consumption of Government buildings in Hulhu Male

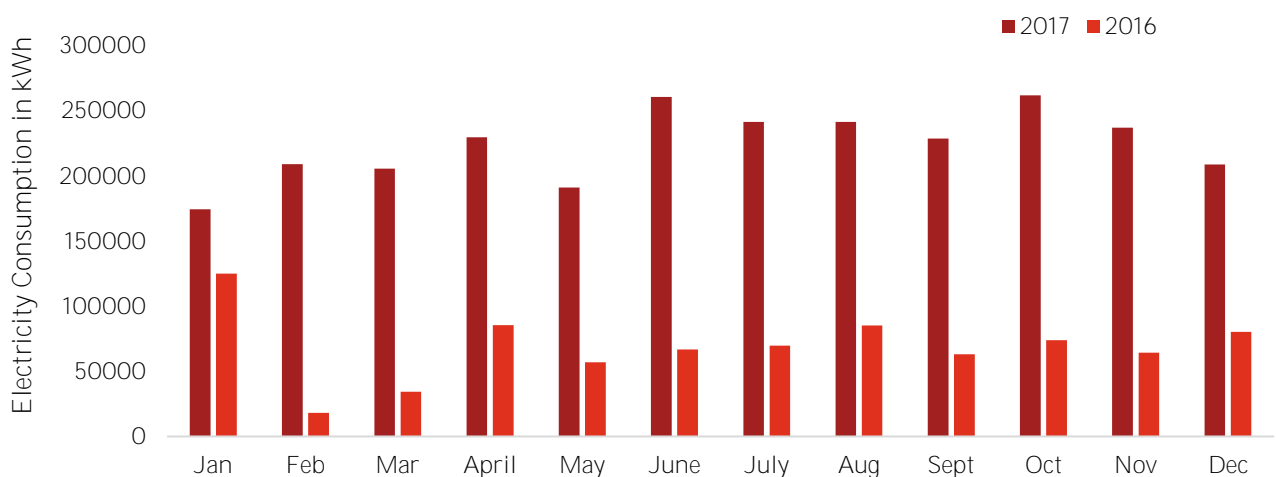


Figure 58: Monthly electricity consumption (kWh) of Government buildings in 2016 and 2017 – Hulhumale

From Figure 58, it can be concluded that Government buildings in Hulhumale have maximum electricity consumption in January and has lowest electricity consumption in February in 2016. However, in 2017,

maximum electricity consumed by Government buildings in the month of October and minimum electricity is consumed in the month of January. The average increase in electricity consumption of Government buildings from 2016 to 2017 is approximately 227% due to increase in number of connections by nearly 206%.

Monthly electricity consumption in Commercial buildings in Hulhu Male

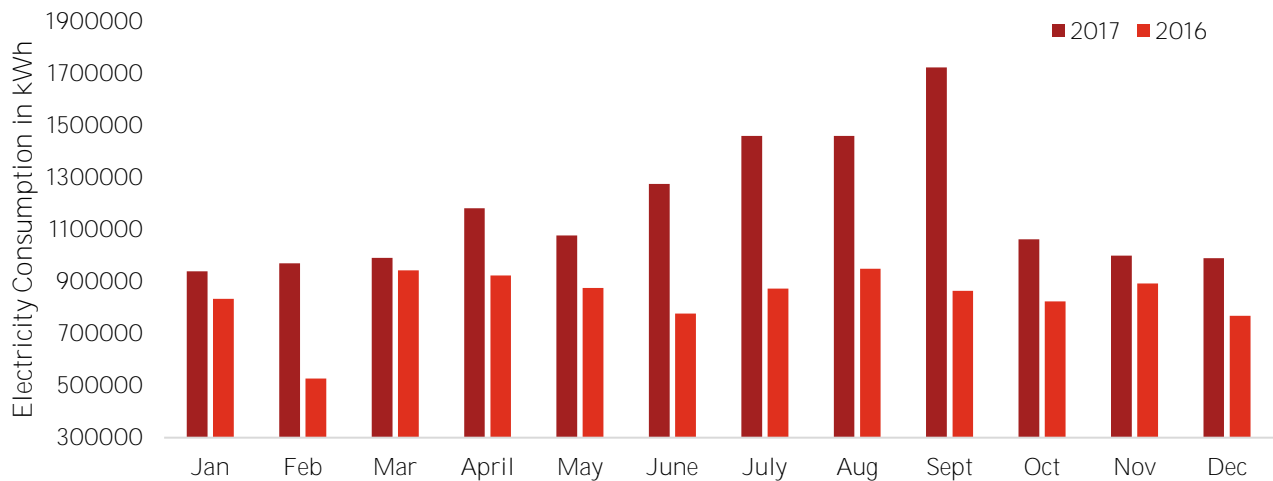


Figure 59: Monthly electricity consumption (kWh) of Commercial buildings in 2016 and 2017 – Hulhumale

From *Figure 59*, it can be concluded that Commercial buildings in Hulhumale have maximum electricity consumption in August and has lowest energy consumption in February in 2016. However, in 2017, maximum electricity consumed by Commercial buildings in the month of September and minimum electricity is consumed in the month of January. The average increase in electricity consumption of Commercial buildings from 2016 to 2017 is approximately 41% due to increase in number of connections by nearly 27%.

Monthly electricity consumption in hotel buildings-Hulhu Male

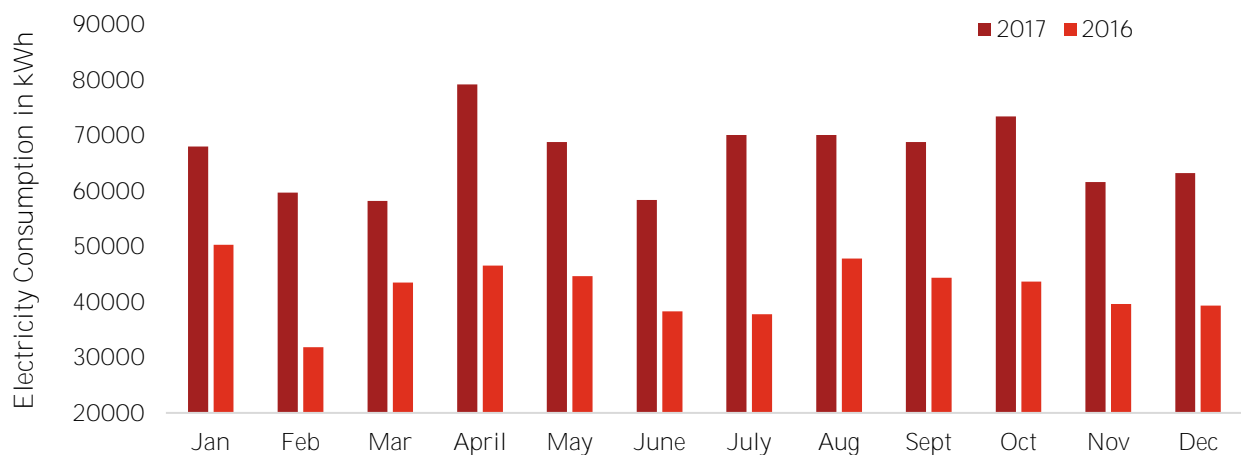


Figure 60: Monthly electricity consumption (kWh) of Hotel and guesthouse buildings in 2016 and 2017 – Hulhumale

From *Figure 60*, it can be concluded that Hotels and guesthouses buildings in Hulhumale have maximum electricity consumption in January and has lowest electricity consumption in February in 2016. However, in 2017, maximum electricity consumed by Hotels and guesthouses buildings in the month of April and minimum electricity is consumed in the month of March. The average increase in electricity consumption of Hotel and

guesthouse buildings from 2016 to 2017 is approximately 57% due to increase in number of connections by nearly 30%.

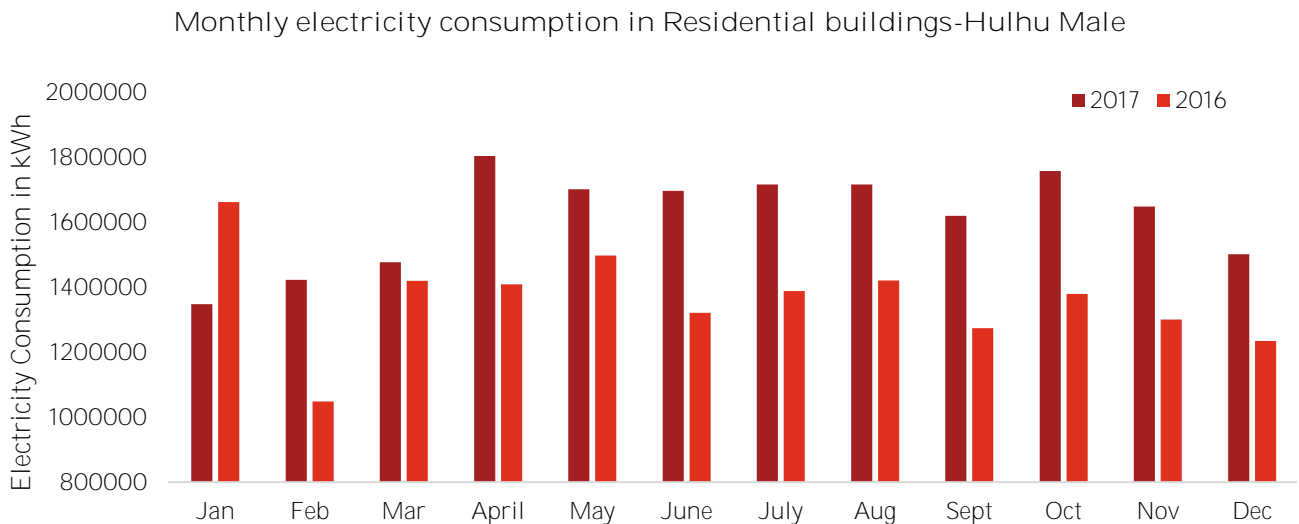


Figure 61: Monthly electricity consumption (kWh) of Residential buildings in 2016 and 2017 – Hulhumale

From *Figure 61*, it can be concluded that Residential buildings in Hulhumale have maximum electricity consumption in January and has lowest electricity consumption in February in 2016. However, in 2017, maximum electricity consumed by Residential buildings in the month of April and minimum electricity is consumed in the month of January. The average increase in electricity consumption of Residential buildings from 2016 to 2017 is approximately 19% due to increase in number of connections by nearly 16%.

4.6.5. Summary

4.6.5.1. Average Annual Electricity Consumption per connection for Male

Annual electricity consumption per connection has been analyzed for all types of building typologies in 2016 and 2017 in Male and is shown in below tables.

Table 6: Average Annual Electricity Consumption per connection in 2016 and 2017, Male

Total Average Annual Electricity Consumption of Male in 2016 and 2017				
Parameters	Residential	Commercial	Government	Hotels and Guest Houses
Total Electricity Consumption in 2016 and 2017 (MWh)	305480	150151	62132	1553
Total number of connections	53511	13799	1188	146
Average Electricity Consumption per connection in 2016 and 2017 (MWh)	5.7	10.9	53.7	11.7
Average Electricity Consumption per connection in 2016 and 2017 (kWh)	5708	10880	53680	11716

It is concluded from Table 6 that average annual energy consumption per connection in years 2016 and 2017 for Residential, Commercial, Government, and Hotels and Guesthouses is 5708 kWh, 10880 kWh, 53680 kWh, and

11716 kWh respectively at Male. Government buildings has highest average energy consumption per connection followed by Hotels & Guesthouses, Commercial and Residential buildings.

4.6.5.2. Energy Performance Index for buildings in Male

The Energy performance index for the various building typology in Male is given below.

Commercial Buildings

Table 7: EPI for Commercial Buildings, Male

Energy Performance Index (kWh/m ² /year)			
Building Name	Electricity Consumption (kWh/year)	Area (m ²)	EPI (kWh/m ² /year)
MA FREE PARK GR FLOOR (ICE CONTAINER) BODUFULHAH GOALHI	120720	298	405
M PALM SPRING 2VANA BAI KABAAISAA RANI HIGUN	74575	216	345
G GOOD LIFE GR FLOOR FIHAARA LONUZIYAARAIY MAGU	66861	204	328
M ILEX JAVAHIRU MAGU	45507	143	318
G NILEENA GR AND 1ST FLOOR FIHAARA SABDHERIYAA MAGU	40539	166	244
MA TOMATOA GROUND FLOOR JAMAALUDHDEEN HIGUN	11082	46	240
MA ORCHARD NO.4 GROUND FLOOR FIHAARA CHAMPAA MAGU	10488	107	98
MA DHONVELI/RIYALICE MAL.PTL AMEENEE MAGU	10216	134	76
M VICTORY HOUSE NO.2 GROUND FLOOR (FIHAARA) ASAREE GOALHI	11495	153	75
H WHITE CEDAR GR FLOOR HITHIGAS MAGU	11101	177	63

It was observed that energy performance index for commercial buildings in Male ranges between 63 to 405 kWh/m²/year.

Hotels & Guest Houses

Table 8: EPI for Hotels & Guest Houses, Male

Energy Performance Index (kWh/m ² /year)			
Building Name	Electricity Consumption (kWh/year)	Area (m ²)	EPI (kWh/m ² /year)
M AAZAMAAN VILLA GROUND FLOOR KULHIDHOSHU MAGU	31847	96	331
M NASEEMEEGE 1ST FLOOR (GUEST HOUSE) CHAMPA MAGU	17905	54	331
H NISREEN VILLA GROUND FLOOR KALHU HURAA MAGU	14288	115	125
G FAMAAS VILLA GRFLOOR LILY MAGU	26452	227	116
H VEYMUI VILLA VAIJEHEY MAGU	16006	228	70
H KASMEERU GARDEN HOTEL JANAVAREE HIGUN	16073	426	38

It was observed that energy performance index for hotel & guest houses in Male ranges between 38 to 331 kWh/m²/year.

Governmental Buildings

Table 9: EPI for Government Buildings, Male

Energy Performance Index (kWh/m ² /year)			
Building Name	Electricity Consumption (kWh/year)	Area (m ²)	EPI (kWh/m ² /year)
H PROSECUTOR GENERAL OFFICE (3RD FLOOR) MAJEEDHEE MAGU	52344	97	540
FACULTY OF HOSPITALITY AND TOURISM STUDIES - NEW BUILDING RAHDHEBAI HINGUN	996920	8060	124
H VELAANAAGE 1ST FLOOR (BLOCK - A) AMEER AHMED MAGU	120418	1188	101
M DHAARUL EEMAAN 1ST FLOOR MAJEEDHEE MAGU	10550	135	78
M RED LEAF GROUND FLOOR FIHAARA IRAMAA MAGU	12779	189	67
H VELAANAAGE 9TH FLOOR (BLOCK - B) AMEER AHMED MAGU	53069	1188	45
H VELAANAAGE GR. FLOOR AMEER AHMED MAGU	52020	1188	44
H ATHIREEGE AAGE NO:2 AMEERU AHMED MAGU	52671	1554	34

It was observed that energy performance index for Government Buildings in Male ranges between 67 to 540 kWh/m²/year.

Residential Buildings

Table 10: EPI for Residential Buildings, Male

Energy Performance Index (kWh/m ² /year)			
Building Name	Electricity Consumption (kWh/year)	Area (m ²)	EPI (kWh/m ² /year)
M SILVER CLOUD HAVEEREE HIGUN	500852	1327	378
H HAALHALAMAAGE GROUND FLOOR FIHAARA LONUZIYARAI MAGU	86535	297	291
M BEAUTEEN HOUSE NO.5 GROUND FLOOR CARNATION MAGU	5343	37	144
H SHABA SHINE 5TH FLOOR LONUZIYAARAIY MAGU	7863	65	121
M LAIRA GR FLOOR SHAHEEHDU ALI HINGUN	5341	60	89
G ANZAANEEGE AAGE 1ST FLOOR BODURASGEFAANU MAGU	2536	33	76
M ZAMZAMEEGE (1ST FLOOR) YAAGOOOTH GOALHI	1951	26	74
M GNAMGNAMGE 5TH FLOOR CARNATION MAGU	8780	123	71
H OXFORD 5TH FLOOR KIBIGAS MAGU	2566	48	53

M AIR DAWN NO.2 BURUZU MAGU	46233	985	47
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It was observed that energy performance index for Residential buildings in Male ranges between 47 to 378 kWh/m²/year.

4.6.5.3. Average Annual Electricity Consumption per connection for Hulhumale

Annual electricity consumption per connection has been analyzed for all types of building typologies in 2016 and 2017 in Hulhumale, is shown in below tables.

Table 11: Average Annual Energy Consumption per connection in 2016 and 2017, Hulhumale

Total Average Annual Electricity Consumption of Hulhumale in 2016 and 2017				
Parameters	Residential	Commercial	Government	Hotels and Guest Houses
Total Electricity Consumption in 2016 and 2017 (MWh)	38507	18927	7832	281
Total number of connections	6819	2086	73	108
Average Electricity Consumption in 2016 and 2017 (MWh)	5.6	9.1	134.5	2.6
Average Electricity Consumption in 2016 and 2017 (kWh)	5621	9058	134528	2597

It is concluded from the above table that average annual electricity consumption per connection in years 2016 and 2017 for Residential, Commercial, Government, and Hotels and Guesthouses is 5621 kWh, 9058 kWh, 134528 kWh, and 2597 kWh respectively at Hulhumale. Government buildings has highest average electricity consumption per connection followed by Commercial, Residential, and Hotels & Guesthouses buildings.

4.6.5.4. Energy Performance Index for buildings in Hulhumale

The Energy performance index for the various building typology in Hulhumale is given below.

Commercial Buildings

Table 12: EPI for Commercial Buildings, Hulhumale

Energy Performance Index (kWh/m ² /year)			
Building Name	Electricity Consumption (kWh/year)	Area (m ²)	EPI (kWh/m ² /year)
HULHUMALE' GOATHI (11040) B-325 GROUND FLOOR - RESTAURANT NIROLHU MAGU 18 NO.GOALHI	65942	154	428
HULHUMALE' GOATHI (10404) A-90 -	72670	183	397
HULHUMALE' GOATHI (10086) B-47 GROUND FLOOR FIHAARA -	59925	153	392
HULHUMALE' N3 COMMERCIAL UNIT (11132) GROUND FLOOR - FIHAARA CHANBEYLEE MAGU	207071	568	365

HULHUMALE' GOATHI (10554) C-122 GROUND FLOOR - FIHAARA HAN'DHUVAREE HINGUN 02 NO.GOALHI	27140	86	316
GOATHI 10513 C-88 GR.FLOOR FIHAARA -	25848	87	297
HULHUMALE' GOATHI (10430) B-192 GROUND FLOOR - FIHAARA NIROLHU MAGU	28086	104	270
HULHUMALE' INDUSTRIAL AREA (10275) M2-07 MIDHILI MAGU	269250	1000	269
HULHUMALE' GOATHI (10838) B-272 GROUND FLOOR - FIHAARA NIROLHU MAGU	26337	119	221
HULHUMALE' GOATHI (11019) B-311 -	26934	134	201
HULHUMALE' GOATHI (10074) B-34 GROUND FLOOR FIHAARA -	28477	145	196
HULHUMALE' GOATHI (10367) A-70 GROUND FLOOR - RESTAURENT HIRUNDHU MAGU	26452	152	174
HULHUMALE' GOATHI (10402) A-88 FIRST FLOOR HIRUDHU MAGU	28692	191	150
HULHUMALE' GOATHI (10712) A-100 GROUND FLOOR - A -	26631	184	145
HULHUMALE' INDUSTRIAL AREA (10300) M3-15 GROUND FLOOR - WORKSHOP -	63482	500	127
HULHUMALE' INDUSTRIAL AREA (10696) M3-53 WORKSHOP -	66179	563	118
HULHUMALE' INDUSTRIAL AREA M3-11 (10296) -	51895	500	104
HULHUMALE' GOATHI (10197) C-25 FIRST FLOOR -	5091	84	61
HULHUMALE' GOATHI (10516) C-85 FIRST FLOOR KAANEYSHION MAGU	4919	84	59
HULHUMALE' INDUSTRIAL AREA (10690) M3-65 GROUND FLOOR - C - -	27886	514	54
HULHUMALE' INDUSTRIAL AREA (10288) M3-03 -	52028	1000	52

It was observed that energy performance index for Commercial buildings in Hulhumale ranges between 52 to 428 kWh/m²/year.

Hotels & Guest Houses

Table 13: EPI for Hotels & Guest Houses Buildings, Hulhumale

Energy Performance Index (kWh/m ² /year)			
Building Name	Electricity Consumption (kWh/year)	Area (m ²)	EPI (kWh/m ² /year)
HULHUMALE' GOATHI (10467) B-174 -	54256.68	77	705
HULHUMALE' GOATHI (11118) B-377 SECOND FLOOR NIROLHU MAGU	58935	99	595

HULHUMALE' GOATHI (11049) A-129 GROUND FLOOR - A KAANI MAGU	60898	146	417
HULHUMALE' GOATHI (10467) B-174 -	41694	104	401
HULHUMALE' GOATHI (10488) B-214 GROUND FLOOR - RECEPTION NIROLHU MAGU	34697	105	330
HULHUMALE' GOATHI (11118) B-377 FIRST FLOOR NIROLHU MAGU	39626	134	296
HULHUMALE' GOATHI (11010) B-302 GROUND FLOOR LANSIMOO MAGU	36279.88	136	267
- HULHUMALE' GOATHI (11070) A-136 GROUND FLOOR KAANI MAGU	27260	141	193
- HULHUMALE' GOATHI (11049) A-129 FIRST FLOOR NIROLHU MAGU 19 NO.GOALHI	22889	146	157
- HULHUMALE' GOATHI (10349) A-62 THIRD FLOOR HIRUDHU MAGU	19390	128	151
- HULHUMALE' GOATHI (11054) B-337 SECOND FLOOR NIROLHU MAGU 07 NO.GOALHI	23251	154	151
- HULHUMALE' GOATHI (10366) A-69 FIRST FLOOR HIRUDHU MAGU	13791	108	128
- HULHUMALE' GOATHI (10787) B-221 THIRD FLOOR -	14449	121	119
- HULHUMALE' GOATHI (10092) B-41 SECOND FLOOR NIROLHU MAGU	16958	151	112
- HULHUMALE' GOATHI (10585) C-153 -	7363	73	101
- HULHUMALE' GOATHI (10026) B-11 FIRST FLOOR NIROLHU MAGU	8803	122	72
- HULHUMALE' GOATHI (10349) A-62 FIRST FLOOR HIRUDHU MAGU	8964	128	70
- HULHUMALE' GOATHI (11103) B-374 FIRST FLOOR KELAA MAGU	8470	134	63
- HULHUMALE' GOATHI (10075) B-33 THIRD FLOOR NIROLHU MAGU 06 NO.GOALHI	9075	149	61

It was observed that energy performance index for hotel & guest houses in Hulhumale ranges between 61 to 705 kWh/m²/year.

Government Buildings

Table 14: EPI for Government Buildings, Hulhumale

Energy Performance Index (kWh/m ² /year)			
Building Name	Electricity Consumption (kWh/year)	Area (m ²)	EPI (kWh/m ² /year)
- HULHUMALE' GOATHI (10203) C-31 GROUND FLOOR FIHAARA -	9197	84	109
- HULHUMALE' GOATHI (10203) C-31 GROUND FLOOR FIHAARA -	9197	84	109
- HULHUMALE' GOATHI (10194) C-22 GROUND, FIRST FLOOR -	2971	84	35
- GOATHI - 10192 C-20 -	2581	84	31

- HULHUMALE' GOATHI (11030) B-312 NIROLHU MAGU	3496	134	26
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It was observed that energy performance index for Government buildings in Hulhumale ranges between 26 to 109 kWh/m²/year.

Residential Buildings

Table 15: EPI for Residential Buildings, Hulhumale

Energy Performance Index (kWh/m ² /year)			
Building Name	Electricity Consumption (kWh/year)	Area (m ²)	EPI (kWh/m ² /year)
- HULHUMALE' GOATHI (10541) C-107 -	22118	86	257
- HULHUMALE' GOATHI (10216) C-44 FIRST FLOOR - B HITHIGAS MAGU 04 NO.GOALHI	16025	84	191
- HULHUMALE' GOATHI (10187) C-15 GROUND -	15374	84	183
- HULHUMALE' GOATHI (10389) A-81 -	33498	193	174
- HULHUMALE' GOATHI (10541) C-107 -	14895	86	173
- HULHUMALE' GOATHI 10200 C-28 FIRST FLOOR -	14199	84	169
- HULHUMALE' GOATHI (10122) B-60 GROUND FLOOR HALAVELI MAGU	17267	109	158
- HULHUMALE' GOATHI (10151) B-96 SECOND FLOOR -	14608	97	151
- HULHUMALE' GOATHI (10442) B-198 SECOND FLOOR NIROLHU MAGU	13352	104	128
- HULHUMALE' GOATHI (10358) A-66 GROUND FLOOR HIRUNDHU MAGU	18497	150	123
- HULHUMALE' GOATHI (10396) B-133 -	17253	142	122
- HULHUMALE' GOATHI (10396) B-133 -	16938	142	119
- HULHUMALE' GOATHI (11184) SECOND FLOOR NIROLHU MAGU	13371	123	109
- HULHUMALE' GOATHI (10712) A-100 GROUND FLOOR - A -	20090	184	109
- HULHUMALE' GOATHI (10374) B-120 -	13396	124	108
- HULHUMALE GOATHI (10214) C-42 GROUND FLOOR - A -	5687	84	68
- HULHUMALE' GOATHI (10558) C-126 SECOND FLOOR -	5669	86	66
- HULHUMALE' GOATHI (10360) B-119 GROUND FLOOR -	6001	96	63
- HULHUMALE' GOATHI (10180) C-08 GROUND FLOOR -	5180	84	62
- HULHUMALE' GOATHI (10576) C-144 FIRST FLOOR -	5248	86	61
- HULHUMALE' GOATHI (10537) C-111 -	5198	86	60
- HULHUMALE' GOATHI (10539) C-109 GROUND FLOOR -	5176	86	60

It was observed that energy performance index for Government buildings in Hulhumale ranges between 60 to 257 kWh/m²/year.

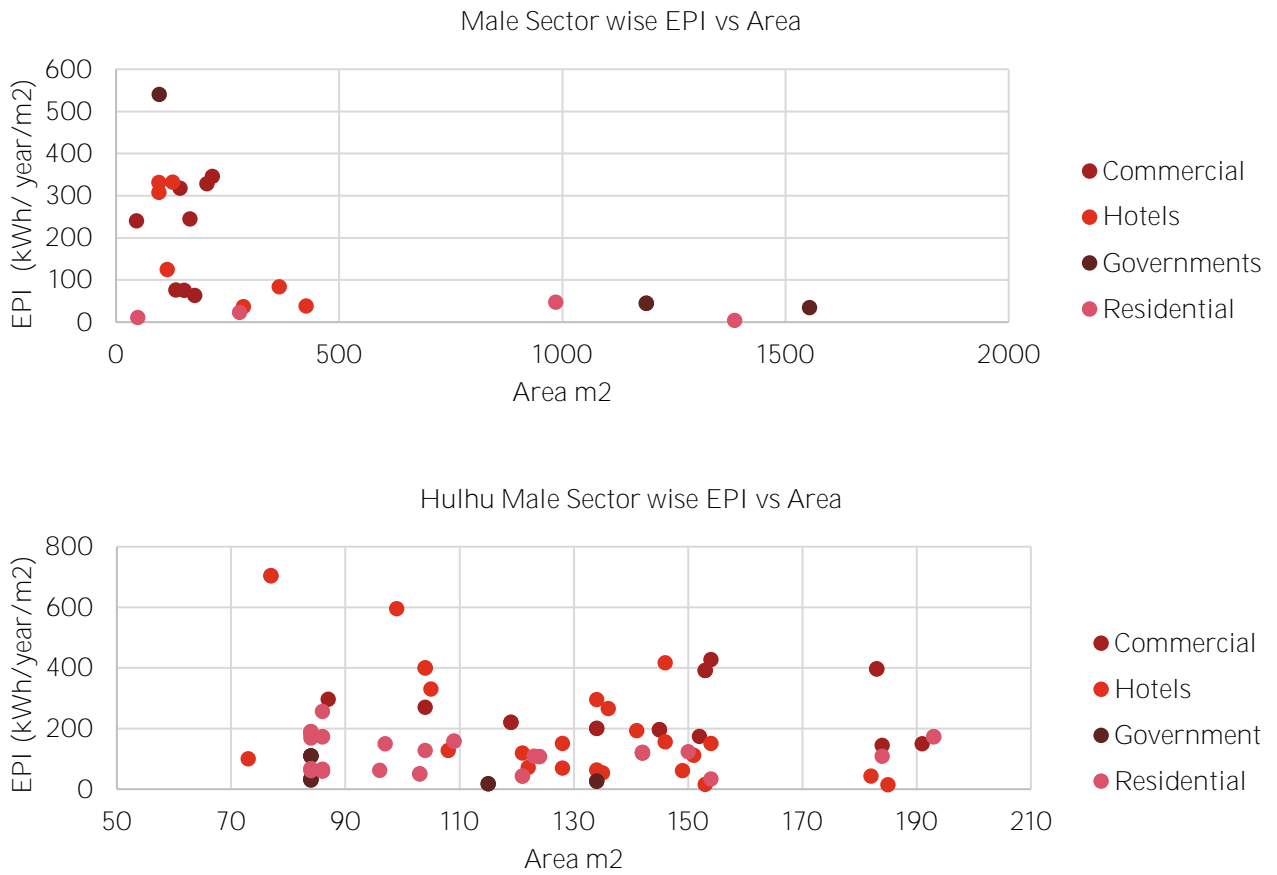


Figure 62: Scatter graph showing EPI of buildings in Male and Hulhumale

4.6.6. Key findings of Electricity Consumption Analysis

After performing the detailed analysis, concluded key points are summarized below:

Rapid increase in the number of electricity connections in Hulhumale by about 19% than in Male which is about 4% from 2016 to 2017 as Hulhumale is emerging with new developments

77% of electricity connections are in Residential buildings followed by Commercial buildings 20%, government buildings 2% and hotels and guest houses 1%.

Electricity consumption of Hulhumale has increased by 31% from 2016 to 2017 whereas the increase in Male is by 5%

The average electricity consumption per connection is highest in case of Government buildings in both Male and Hulhu Male and lowest in case of Residential buildings in Male and Hotels and guest houses in Hulhumale

In Male and Hulhumale, electricity consumption has similar variation pattern in terms of various building typologies.

In 2016, electricity consumption of January month is extremely high in Male as compared to rest of the year.

In 2017, electricity consumption in hotel and guest houses has almost doubled in both Male and Hulhumale

5. Water Sector

5.1. Regulatory structure for water consumption in Male and Hulhumale

The Water and Sanitation Department of Ministry of Environment of Maldives develops policies and regulations, facilitates and coordinates the mobilization and use of resources for water and sewage systems. It functions to provide safe water and sustainable, affordable and environmentally-friendly sewerage systems in the Maldives. The department provides advice to both the government and the private sector in the planning and implementation of water and sanitation programmes and in the provision and usage of such services.

The department consists of the following two sections and four units:

- (1) Planning and development section: This section comprises of – (a) The policy and planning unit, and (b) The project development unit.
- (2) The project management section is divided into (a) Project coordination, implementation and monitoring, and (b) The project design and supervision.

5.2. Sources of Water in the country

From the year 1950 onwards, it has been noticed that the sea level has been rising by 0.03-0.06 inches every year in Maldives, and is **expected to rise 1.5 feet by 2100, losing 77 percent of the country's land area, leading to a significant impact on water quality in the Maldives.** Moreover, higher level of evaporation is noticed owing to warmer temperatures. This reduces the amount of rainwater left to infiltrate through the ground into the aquifers. These ground water aquifers are the main source of freshwater available in Maldives and occur in the porous coral of sands and rainfall. There are no rivers or streams in any of the islands of Maldives. The freshwater source in Maldives is scarce, and this water scarcity is temporal and spatial. The ground water is available at the depth of 1-1.5m below the ground surface. Nowadays, this ground water has been depleted because of salt-water intrusion due to over extraction of ground water.

During water shortage, the desalinated water is the main source of water that is supplied to the people. The demand for desalinated water is very high during dry season from January to April. Desalinated water is transported on ships to the islands. However, this process is challenging as increasing number of islands are facing the water storage. To overcome this issue, government has developed water supply schemes to increase the public rainwater harvesting capacity to the targeted islands. Under such schemes, reverse osmosis treatment plants with storage tanks are installed in the targeted islands. By the end of 2016, 41% of the population had access to safe water supply. At present, 21 islands have piped water supply systems with household connections. The *Figure 63* shows the water distribution in Greater Male over years.

Water distribution in Male and Hulhumale

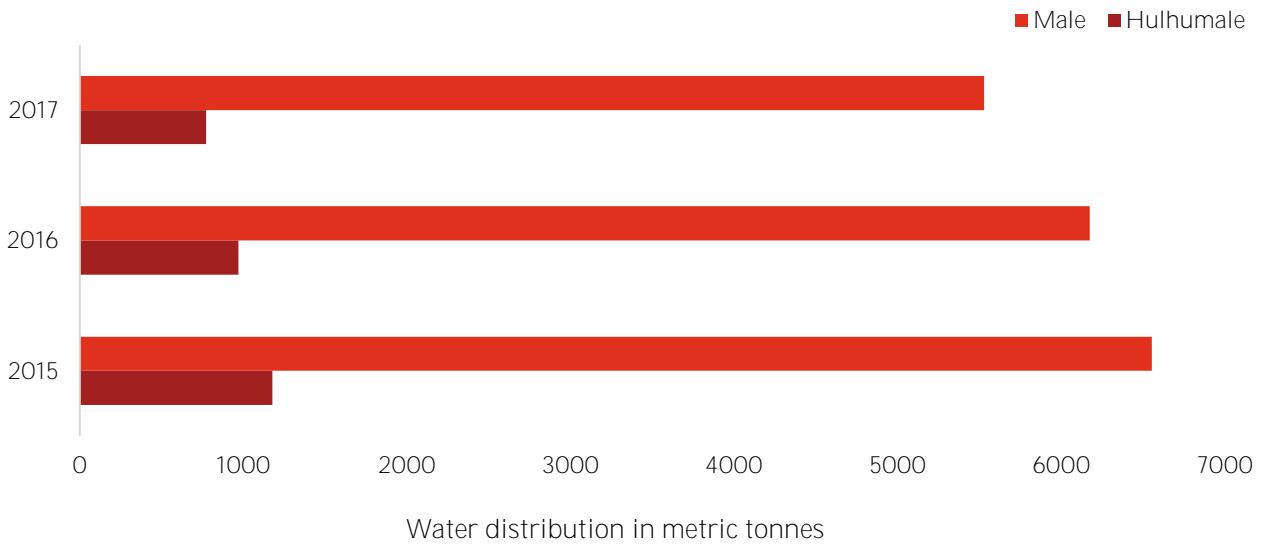


Figure 63: Water distribution in Greater Male

The detailed analysis of the water scenario in Male and Hulhumale is presented in the following section.

5.4 Water tariffs in the country

The tariff is divided into two components:

- (a) Fixed charges
- (b) Variable charges

The fixed charges part of the tariff for all types of meters is 30 MVR, whether it is a domestic, commercial or institutional type of connection, whereas the variable part of tariff depends on the building typology and also varies with consumption of water.

		Variable charges (in MVR**/m ³)	Fixed charges (in MVR/m ³)
Domestic	0-100 lpd*	22	30
	101-500 lpd	70	
	501 and above	95	
Institutional		75.95	30
Commercial		101.26	30

*lpd refers to Liters per day

**MVR is Maldivian Rufiyaa

5.3. Analysis of Building Water Consumption

Water analysis is a method to assess the way how the consumers use water. It helps to understand the water consumption pattern of the buildings as per building typology, operational schedule etc. It has been found that water consumption varies for different types of buildings. Intent of water consumption analysis of the buildings for understanding the real estate growth in Male and Hulhumale.

5.3.1. Analysis of Water Connection

The total number of water connections in Male and Hulhumale in year 2016 and 2017 is shown below in Figure 64.

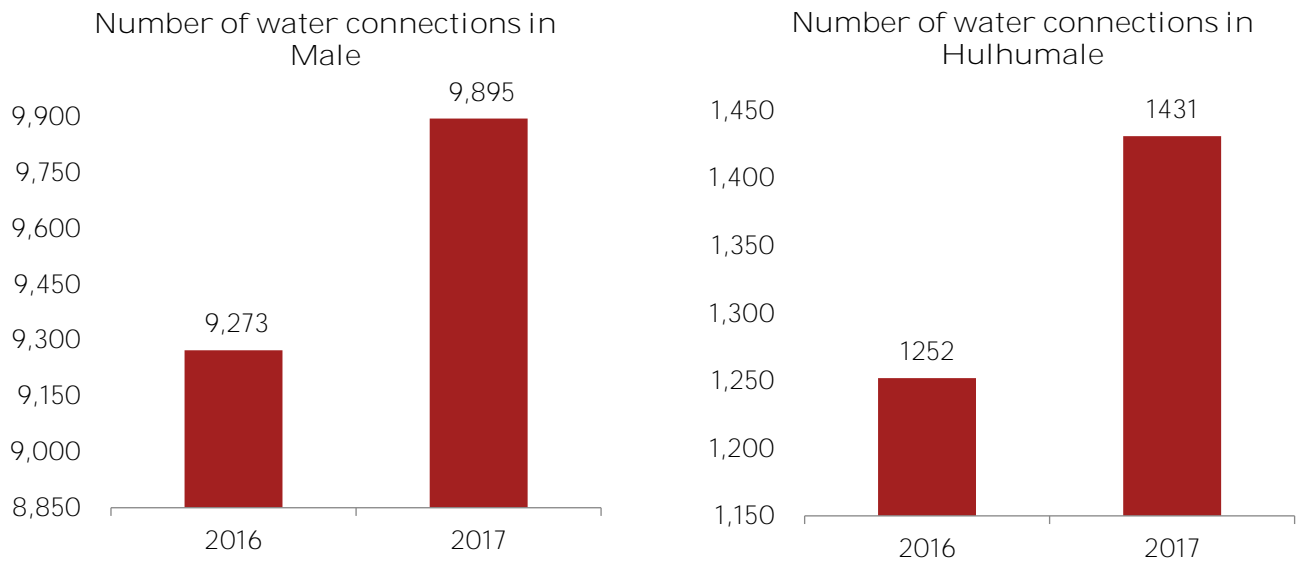
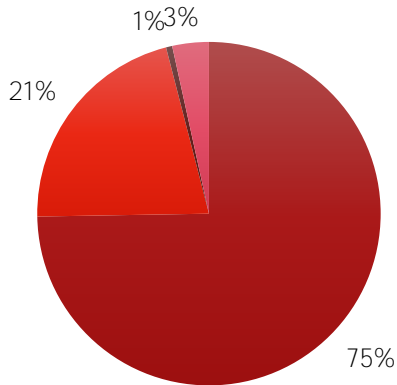


Figure 64: Total number of water connections in 2016 and 2017 for Male and Hulhumale

The Figure 64 shows the total number of water connections in Male and Hulhumale for the years 2016 and 2017. In 2016, Male had 9273 connections whereas Hulhumale had 1252 water connections. The number of connections for Male and Hulhumale for 2017 are 9895 and 1431 respectively. Water connections in Male is more than Hulhumale. However, a 14.2% increase in the number of water connections is observed in Hulhumale from 2016 to 2017, whereas in Male, which is about 6.7% from 2016 to 2017. This indicates a rapid growth of development in Hulhumale.

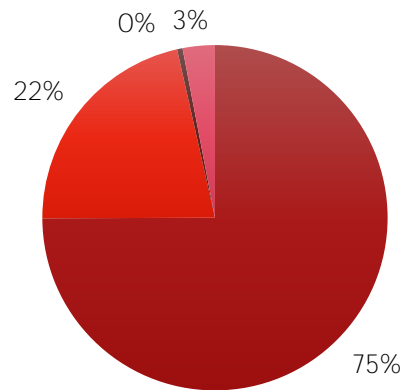
Water consumption varies for different building typologies as per their operational schedules, e.g. office buildings and commercial buildings are operational mainly for the daytime, whereas hotels and guesthouses, and residential buildings are operational for 24 hours of the day, so it is required to consider the number of connections separately for all the building typologies. It was observed that out of the total connections, 75% connections belong to residential sector and the rest belong to non-residential sector.

Breakup of water connections (percentage) in 2016 Male



■ Residential ■ Commercial
■ Hotels and Guesthouses ■ Government

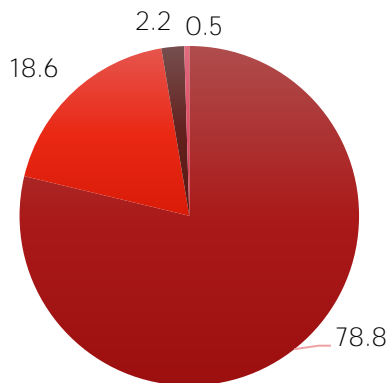
Breakup of water connections (percentage) in 2017 Male



■ Residential ■ Commercial
■ Hotels and Guesthouses ■ Government

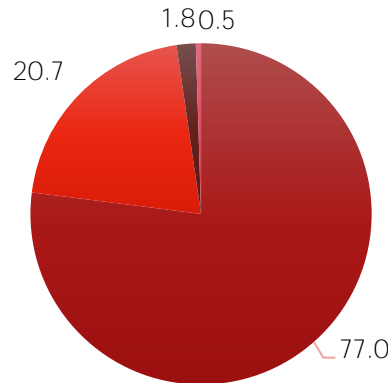
Figure 65: Breakup of water connections in various building typologies in 2016 and 2017, Male

Number of water connections (percentage) in 2016 in Hulhumale



■ Residential ■ Commercial
■ Hotels and Guesthouses ■ Government

Number of water connections (percentage) in 2017 in Hulhumale



■ Residential ■ Commercial
■ Hotels and Guesthouses ■ Government

Figure 66: Total number of water connections in 2016 and 2017 in Hulhumale

Above figure shows the number of water connections (in percentage) in various building typologies for Male and Hulhumale. It can be concluded from Figure 66 that nearly 78% connections belong to Residential buildings followed by Commercial buildings, Hotels & guesthouse, and Government buildings respectively in years 2016 and 2017 for Male. Similarly, Figure 66 shows that nearly 77% connections belong to Residential buildings, followed by Commercial buildings, Hotels & guesthouse, and Government buildings consisting of 20.7%, 1.8% and 0.5% of total water connections respectively in Hulhumale.

Number of water connections have been analyzed individually for all 4 building typologies in the years 2016 and 2017 for Male and Hulhumale, which is presented below.

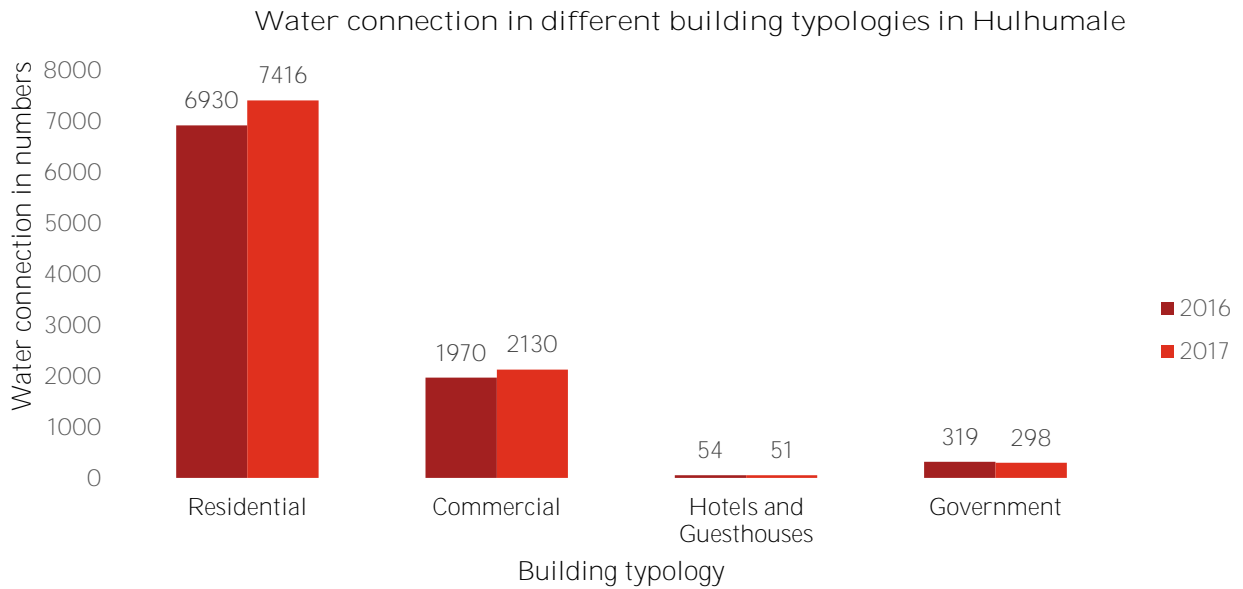


Figure 67: Total number of water connections for all building typologies in Male

Figure 67 shows the total number of water connections for Residential, Commercial, Hotel & guesthouses and Government buildings in Male for the years 2016 and 2017. In 2016, number of connections for Residential, Commercial, Hotels & guesthouses, Government buildings are 6930, 1970, 54 and 319 respectively. Similarly, in 2017, number of connections for Residential, commercial, Hotels & guesthouses and Government buildings are 7416, 2130, 51 and 298 respectively. It can be concluded that maximum number of water connections are for Residential buildings followed by Commercial buildings, Government buildings and then Hotels & guesthouses. Residential and commercial buildings connections have increased by 7% and 8.1% respectively, Government buildings connections decreased by 6.5%, and Hotels & guesthouses connections have decreased by 5.5% from 2016 to 2017.

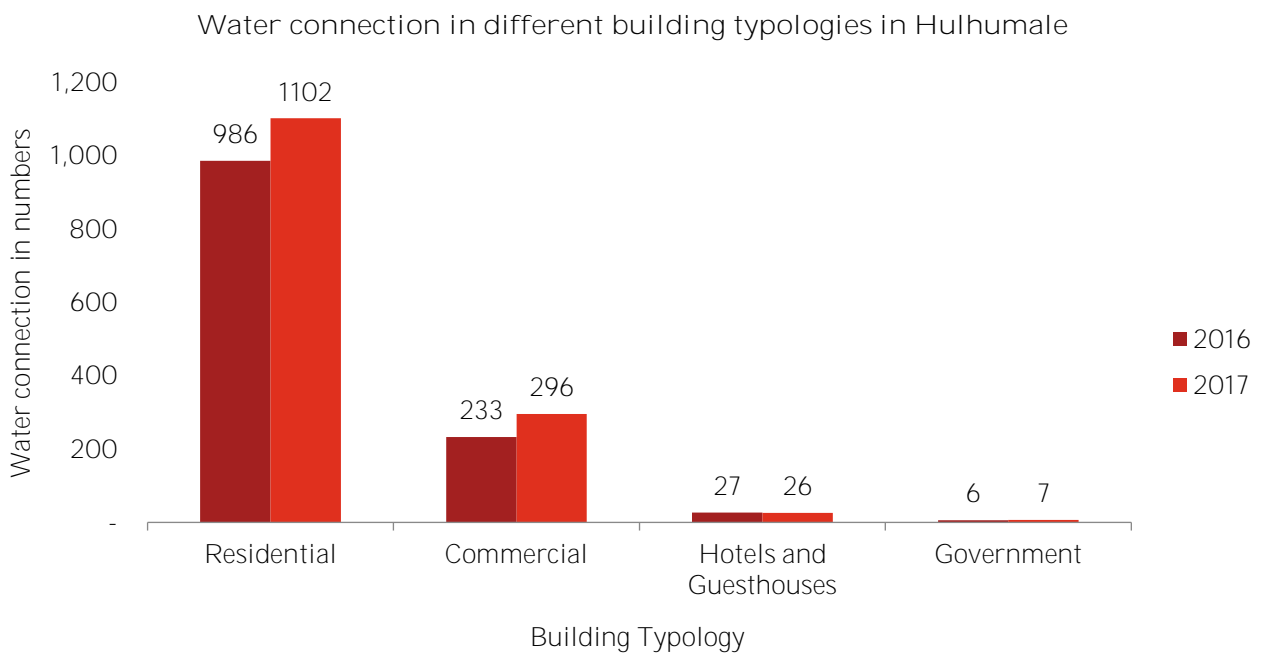


Figure 68: Total number of water connections for all building typologies in Hulhumale

Figure 68 shows the total number of water connections for Residential, Commercial, Hotel & guesthouses and Government buildings in Hulhumale for the Years 2016 and 2017. In 2016, number of connections for Residential, Commercial, Hotels & guesthouses and Government buildings are 986, 233, 27 and 6 respectively. Similarly, in 2017, number of connections for Residential, Hotels & guesthouses, Commercial and Government buildings are 1102, 26, 296 and 7 respectively. It can be concluded that Residential buildings has maximum number of connections, followed by Commercial buildings, Hotels & guesthouses and lastly Government buildings. Residential buildings connections have increased by 11.7%, Commercial buildings connections have increased by 27%. Number of water connections in residential and commercial buildings have increased drastically in Hulhumale.

5.3.2. Analysis of Water Consumption

After analyzing the number of connections for all 4 typologies in Male and Hulhumale, analysis of water consumption pattern has been conducted. Detailed analysis of water consumption has been done and presented below in Figure 69.

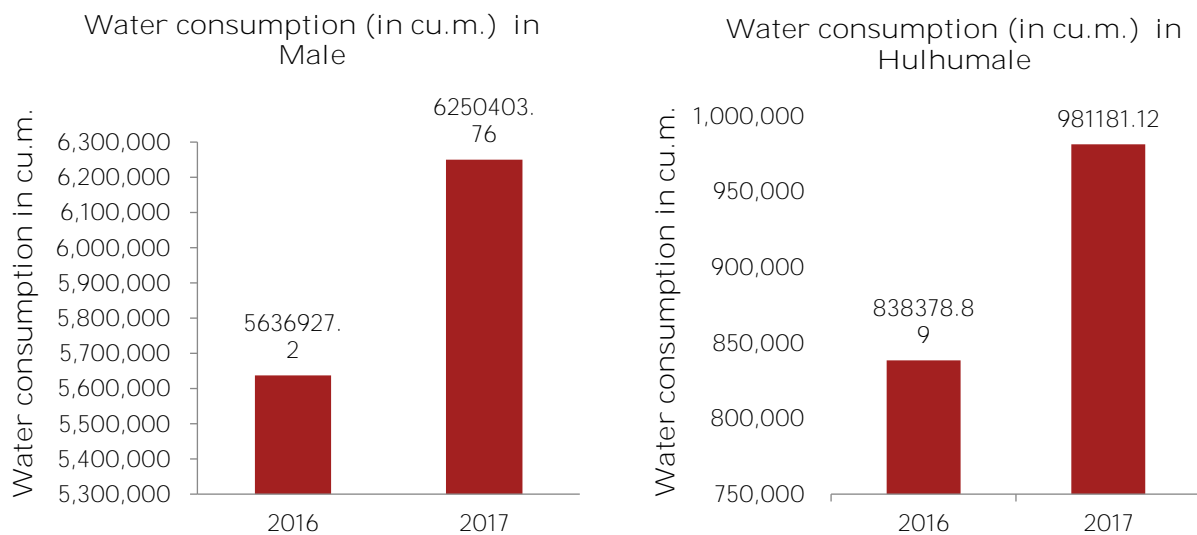
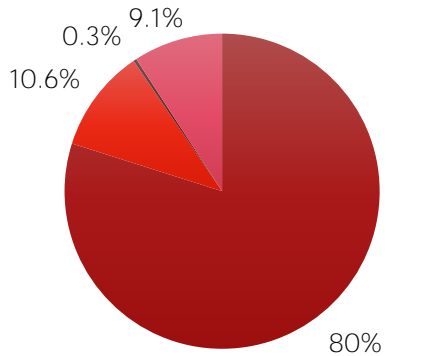


Figure 69: Total water consumption in 2016 and 2017 in Male and Hulhumale

The total water consumption in Male is 5,636,927 m³ in 2016 and 6,250,404 m³ in 2017. It is observed that total water consumption has increased by nearly 10.8% from 2016 to 2017. Similarly, the total water consumption in Hulhumale is 838,378 m³ in 2016 and 981,181 m³ in 2017. It is noticed in above graph that total water consumption has increased by nearly 17% from 2016 to 2017.

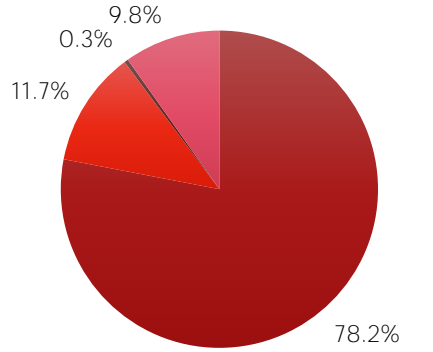
Water consumption has been analyzed distinctly for all 4 building typologies in the years 2016 and 2017 for Male and Hulhumale, which is presented below in Figure 70 & Figure 71 respectively.

Breakup of water consumption in 2016 - Male



■ Residential ■ Commercial
■ Hotels and guest houses ■ Government

Breakup of water consumption in 2017 - Male

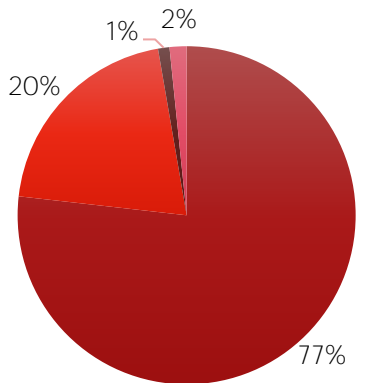


■ Residential ■ Commercial
■ Hotels and guest houses ■ Government

Figure 70: Breakup of water consumption (in percentage) for different typologies in 2016 and 2017, Male

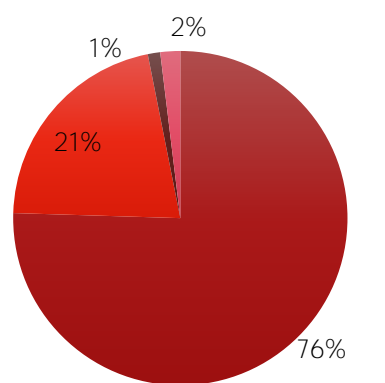
For the year 2016, in Male, the residential water consumption is about 80% followed by commercial sector which consumes about 10.6%. The water consumption of government buildings is about 9.1% whereas hotels and guesthouses consume approximately about 0.3% of water. For the year 2017, the residential water consumption decreased to 78.2%. Commercial sector consumes about 11.7%. The water consumption of government buildings is about 9.8% whereas hotels and guesthouses consume approximately about 0.3% of water.

Breakup of water consumption in 2016 - Hulhumale



■ Residential ■ Commercial
■ Hotels and Guesthouses ■ Government

Breakup of water consumption in 2017 - Hulhumale



■ Residential ■ Commercial
■ Hotels and Guesthouses ■ Government

Figure 71: Breakup of water consumption (in percentage) for different typologies in 2016 and 2017, Hulhumale

In 2016, Hulhumale's residential water consumption is maximum which is on average about 77% followed by 20% of water consumption by commercial buildings. The government sector consumes about 2% whereas hotels and guest houses consume 1% of total water. Similar pattern was observed in 2017.

After analyzing the water consumption pattern annually, it is important to analyze the monthly water consumption for all building typologies in the years 2016 and 2017 for Male and Hulhumale, which has been analyzed individually, and is presented below.

5.3.3. Monthly Water Consumption pattern for Male in 2016 and 2017

In order to perform the detailed water consumption analysis, monthly water consumption pattern for Male has been analyzed in years 2016 and 2017 for all 4 typologies of buildings.

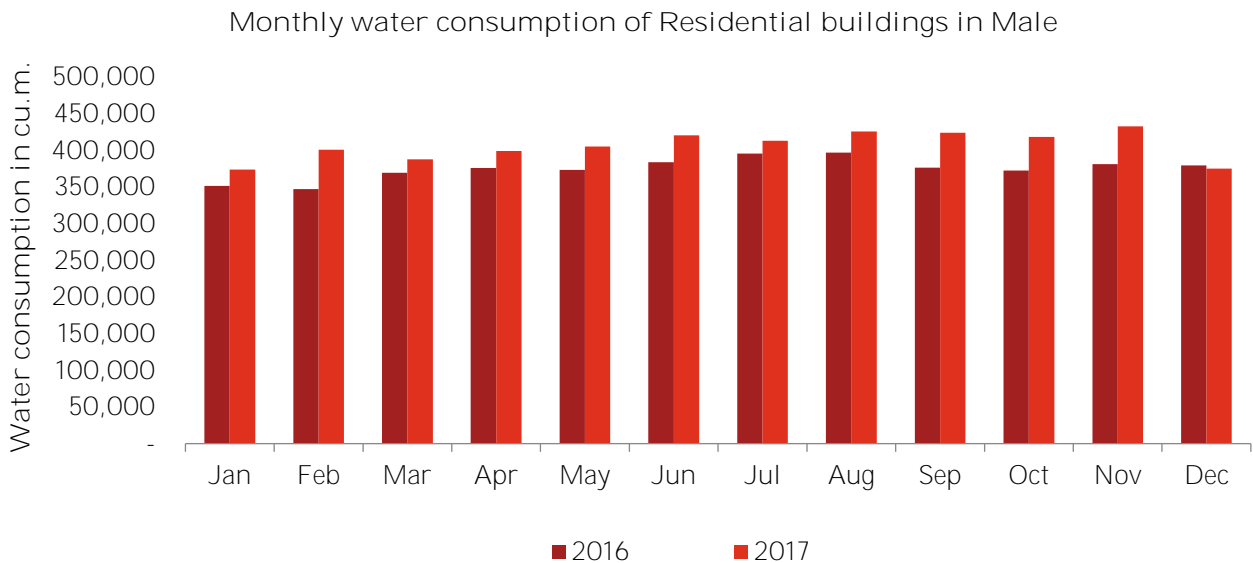


Figure 72: Monthly water consumption of Residential buildings in 2016 and 2017 – Male

From *Figure 72*, it can be concluded that Residential buildings in Male have maximum water consumption in July and August and has lowest water consumption in February in 2016. However, in 2017, maximum water consumed by Residential buildings in the month of November and minimum water is consumed in the month of December. It can be concluded that water consumption is constant almost throughout the year, varying between 350,000 m³ to 380,000 m³.

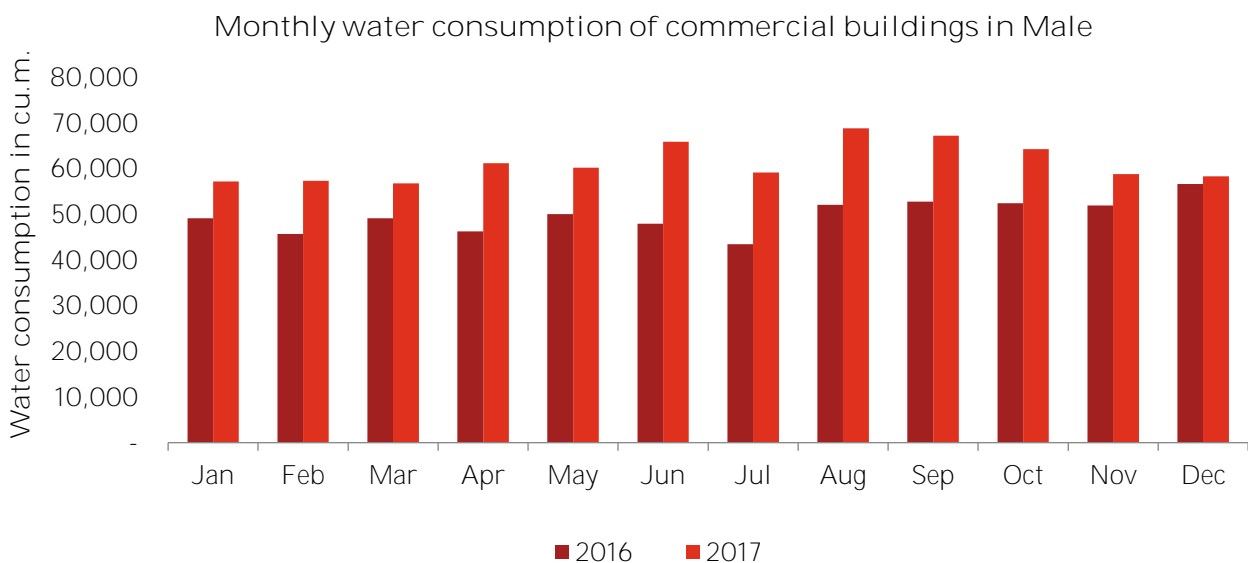


Figure 73: Monthly water consumption of Commercial buildings in 2016 and 2017 – Male

From *Figure 73*, it is observed that Commercial buildings in Male have maximum water consumption in December and has lowest water consumption in July in 2016. However, in 2017 maximum water consumed by Commercial buildings in the month of August and minimum water is consumed in the month of March. The average increase in water consumption of the Commercial buildings from 2016 to 2017 is approximately 23.03% due to increase in number of connections by nearly 8.1%.

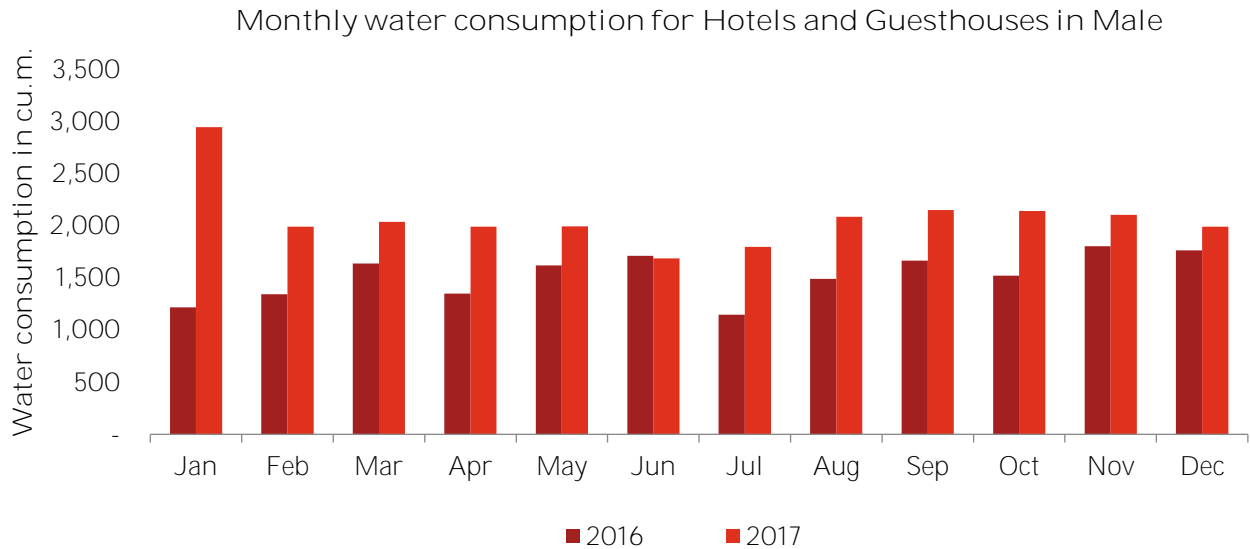


Figure 74: Monthly water consumption of Hotels and guesthouses buildings in 2016 and 2017 – Male

From *Figure 74*, it can be concluded that Hotels and guesthouses buildings in Male have maximum water consumption in November and has lowest water consumption in July in 2016. However, in 2017, maximum water consumed by Hotels and guesthouses buildings in the month of January and minimum water is consumed in the month of June. Although the number of connections decreased by 5.5%, the average consumption increased by 36.3%.

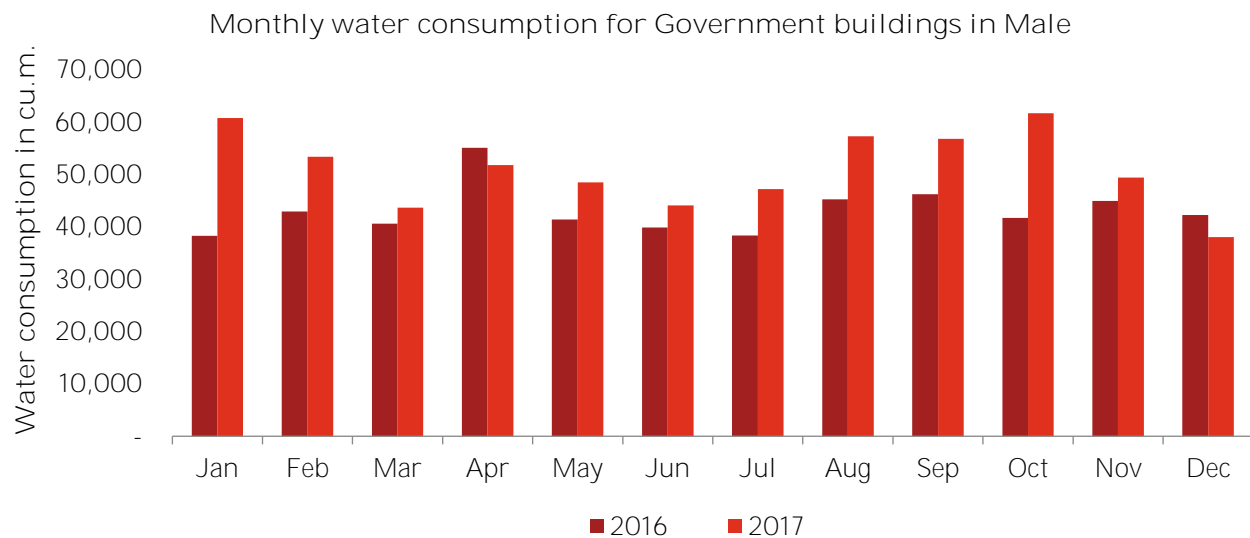


Figure 75: Monthly water consumption of Government buildings in 2016 and 2017 – Male

From *Figure 75*, it can be concluded that Government buildings in Male have maximum water consumption in April and has lowest water consumption in July in 2016. However, in 2017 maximum water consumed by

Government buildings in the month of October and minimum water is consumed in the month of December. A decrease in the number of water connections by 6.5% from 2016 to 2017 can be noticed, however the average consumption has increased by 18.5%.

5.3.4. Monthly Water Consumption pattern for Hulhumale in 2016 and 2017

In order to perform the detailed water consumption analysis, monthly water consumption pattern for Hulhumale has been analyzed in years 2016 and 2017 for all 4 types of building typologies.

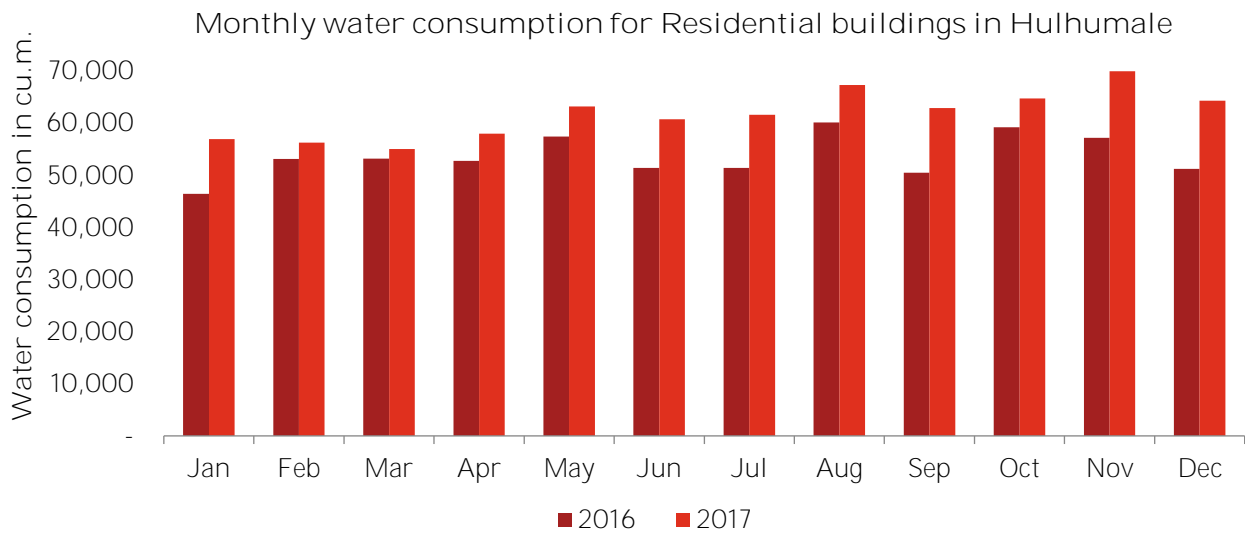


Figure 76: Monthly water consumption of Residential buildings in 2016 and 2017 – Hulhumale

From Figure 76, it can be concluded that Residential buildings in Hulhumale have maximum water consumption in August and has lowest water consumption in January in 2016. However, in 2017, maximum water consumed by Residential buildings in the month of November and minimum water is consumed in the month of March. It is observed that the average increase in water consumption of Residential buildings from 2016 to 2017 is approximately 15.03% due to increase in number of connections by nearly 10.5%.

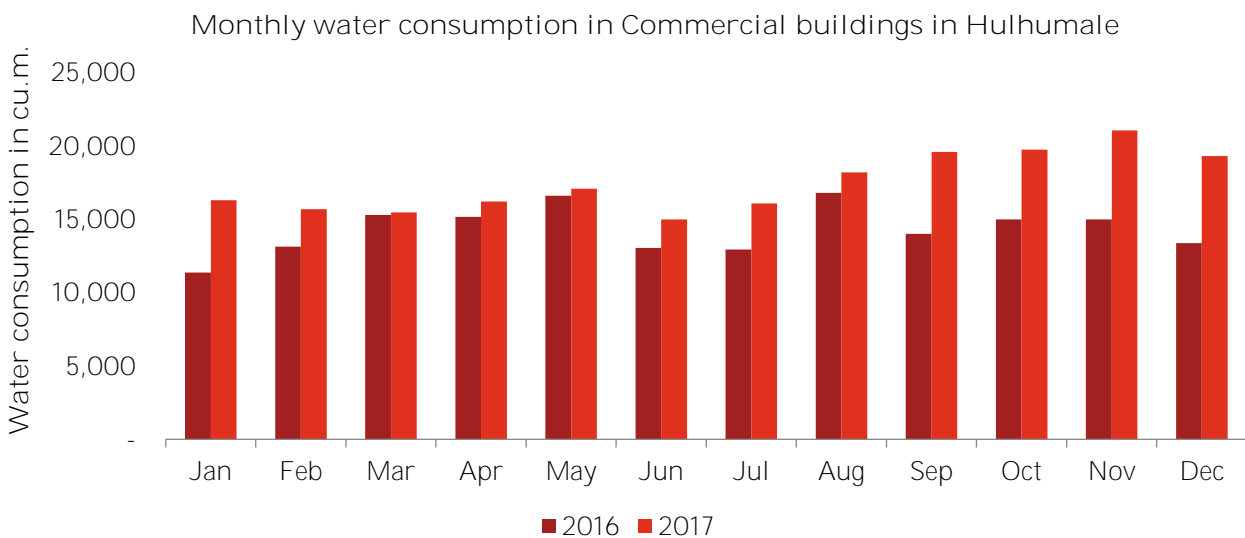


Figure 77: Monthly water consumption of Commercial buildings in 2016 and 2017 – Hulhumale

It is observed in Figure 77 that in 2017 water consumption on an average is about 17,488 m³ except from month of June to November, where it has raised from 15,008 m³ to 21,070 m³ with highest in month of November. However, in 2017, maximum water consumed by Commercial buildings in the month of November and minimum water is consumed in the month of June.

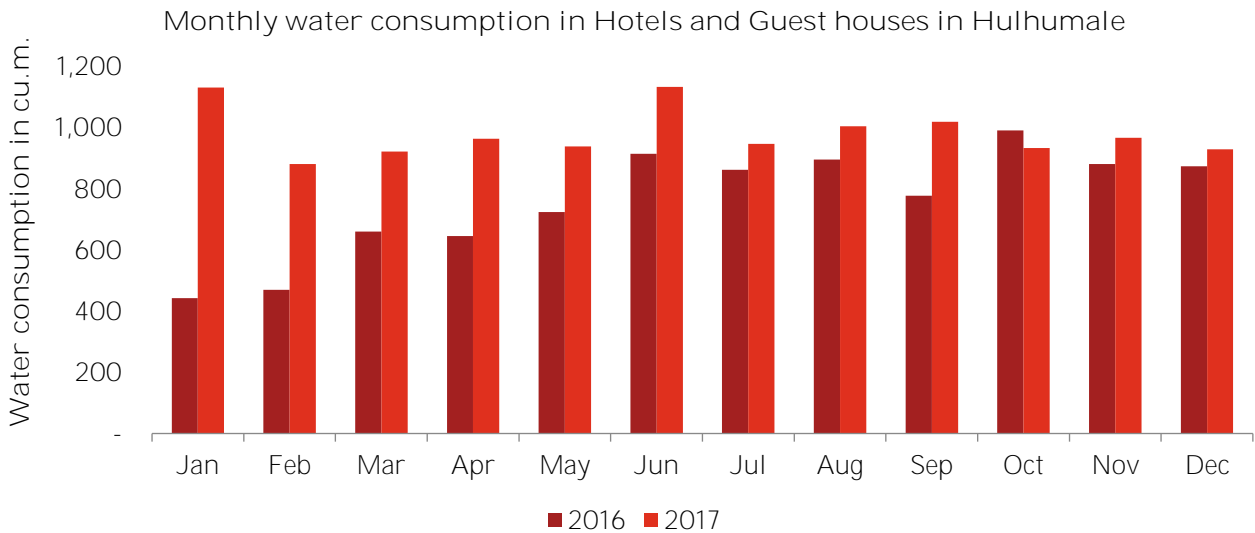


Figure 78: Monthly water consumption of Hotel and guesthouse buildings in 2016 and 2017 – Hulhumale

From Figure 78, it can be concluded that Hotels and guesthouses buildings in Hulhumale have maximum water consumption in October and has lowest water consumption in January in 2016. There is a drastic increase in the water consumption from 2016 to 2017.

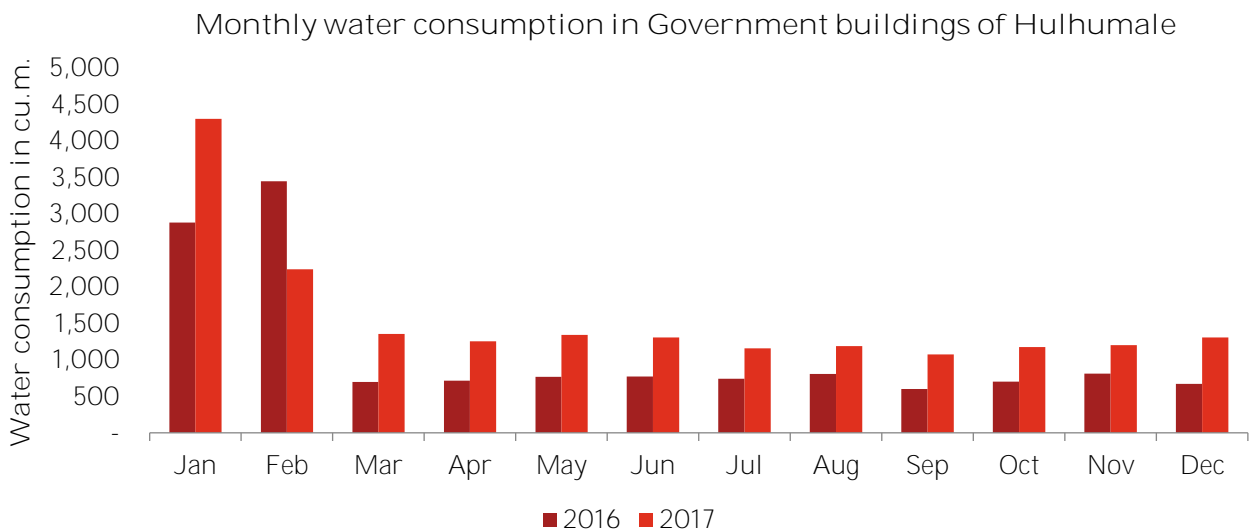


Figure 79: Monthly water consumption of Government buildings in 2016 and 2017 – Hulhumale

From Figure 79, it can be observed that there is a sudden increase in water consumption in the months of January and February for 2016 and 2017. The Government buildings in Hulhumale have maximum water consumption in February and has lowest water consumption in September in 2016. However, in 2017, maximum water consumed by Government buildings in the month of January and minimum water is consumed in the month of

September. The average increase in water consumption of Government buildings from 2016 to 2017 is approximately 38.9% due to increase in number of connections by nearly 16.6%.

5.3.5. Summary

5.3.5.1. Average Annual Water Consumption per connection for Male

Annual water consumption per connection has been analyzed for all types of building typologies in 2016 and 2017 in Male is shown in Table 16.

Table 16: Average Annual Water Consumption per connection in 2016 and 2017, Male

Total Average Annual Water Consumption of Male in 2016 and 2017				
	Residential	Commercial	Hotels and Guest Houses	Government
Total Water Consumption in 2016 and 2017 (cu. mt.)	1308	649	827	3676
Total number of connections	14346	4100	105	617
Average Water Consumption per connection in 2016 and 2017 (cu. m.)	654	325	413	1838

It is concluded from the Table 16 that average annual water consumption per connection in years 2016 and 2017 for Residential, Commercial, Hotels and Guesthouses, and Government buildings is 654 m³, 325 m³, 413 m³ and 1838 m³ respectively at Male. Government buildings has highest average water consumption per connection followed by Residential, Hotels & Guesthouses, and Commercial buildings. Reason for the same will be further investigated through detailed study and analysis.

5.3.5.2. Average Annual Water Consumption per connection for Hulhumale

Annual water consumption per connection has been analyzed for all types of building typologies in 2016 and 2017 in Hulhumale, is shown in Table 17.

Table 17: Average Annual Water Consumption per connection in 2016 and 2017, Hulhumale

Total Average Annual Water Consumption of Hulhumale in 2016 and 2017				
	Residential	Commercial	Hotels and Guest Houses	Government
Total Water Consumption in 2016 and 2017 (cu.m.)	1384428	381689	20934	32506
Total number of connections	2088	529	53	13
Average Water Consumption per connection in 2016 and 2017 (cu.m.)	663	723	396	2484

It is concluded from the Table 17 that average annual water consumption per connection in years 2016 and 2017 for Residential, Commercial, Hotels and Guesthouses, and Government buildings is 663 m³, 723 m³, 396 m³, and

2484 m³ respectively at Hulhumale. Government buildings has highest average water consumption per connection followed by Commercial, Residential, and Hotels & Guesthouses.

5.3.6. Key findings of Water Consumption Analysis

After performing the detailed analysis, concluded key points are summarized below:

Hulhumale is emerging with new developments. Hence, a rapid increase of about 14.2% in the number of water connections in Hulhumale can be witnessed whereas water connections in Male increases by 6.7% from 2016 to 2017.

75% of water connections are in Residential buildings followed by Commercial buildings 22%, government buildings 3% and hotels and guest houses 0.3%.

The average water consumption per connection is highest in case of Government buildings in both Male and Hulhumale and lowest in case of Commercial buildings in Male and Hotels and guest houses in Hulhumale

In Male and Hulhumale, water consumption has similar variation pattern in terms of various building typologies.

In 2017, water consumption of August month is extremely high in Male as compared to rest of the year.

6. Key Findings

The assessment of the local conditions and building systems gave good insights on all aspects of building design and construction sector such as the local climatic conditions, the existing construction practices, the energy & water consumption pattern in the region, building regulatory structure and approval system. Following are the key findings from the analysis:

- Maldives has seen a rapid growth in the real estate sector owing to growth in local population & increase in tourist influx over the last few years. Male region is densely populated therefore, all the new developments are being planned and constructed in Hulhumale. The government is providing incentives to the local people to move to Hulhumale by building infrastructure in the region.
- Hulhumale is being developed in 2 phases. Phase I development involved construction of sports complex, school, malls, hospitals & community center & the Phase II of the development involves construction of housing complex with 7000 units, water parks, business parks, ports & tourism islands in Hulhumale city, referred as Youth city, is ongoing. Housing Development Corporation is the regulatory body responsible for the overall planning and development of Hulhumale.
- The construction sector in Maldives is regulated by Construction Industry Development Department (CIDD) under the purview of Ministry of National Planning & Infrastructure (MNPI) while the local authorities such as Male City Council, Ministry of Housing, HDC and FDC are responsible to grant approvals/permissions to the contractors for designs & construction of buildings.
- Male Planning Regulations released by the Ministry of Housing and Infrastructure is the main legislation followed for approval of buildings in Male. The Male city council permits the construction of building only if the drawing submitted for approval are according to the regulations. The regulations do not cover energy efficiency aspects such as thermal performance of facades, glazing ratios, daylight etc. However, certain criteria such as projection of cantilever portion from the building, setback distances, ventilations and lighting, height of building are important from the point of view of energy efficiency and will be taken into consideration in the development of Building EE guidelines.
- Maldives has Tropical Monsoon (Koppen- Geiger) or warm and humid climate with two main seasons- Dry and Wet season. This climate is characterized with average temperature of about 29 °C & high humidity throughout the year. Based on Climate Analysis, the following passive & low energy strategies shall be effective to achieve better thermal comfort and reduce air conditioning load of the building:
 - Building Form and Orientation to reduce heat gains
 - Solar Shading of all facades and windows
 - Natural and Cross Ventilation
 - Providing Natural Daylight in buildings
 - Reduce Internal heat gains using efficient lighting and HVAC equipment
 - Reduce window to wall Ratio
 - High performance Envelope
 - Roof Insulation
 - Renewable Energy Harness
- Maldives imports all its construction materials for the building construction & crude oil for its energy demand which is a significant portion of its import bill. Major Construction materials imported are cement and aggregates, base metals, wood, finishing materials and construction hardware. Major imports are from India, China, Singapore and UAE. About 41% of construction material is imported from

India followed by UAE, Malaysia, Singapore and China. There is an import regulation for construction material, but it does not cover any energy efficiency aspects.

- The commonly used building material is masonry bricks, cement, wood & it was found that the typical U-value (Thermal transmittance) of the walls & roof is approx. between 2-2.6W/m² K due to which there is large amount of heat transfer between the indoor & the outdoor environment. Thus, buildings need to be designed with appropriate insulation to reduce heat gains.
- It was observed in the assessment that the material regulations in the construction sector is primarily focused towards the quality and safety of the structures and not on the energy efficiency aspects. The development of building EE guidelines presents an opportunity to integrate energy efficiency measures. The integration of energy efficiency measures in the current construction practices will help to significantly reduce the energy demand.
- The growth in the real estate sector has also fueled the increase in the consumption of energy & water in the region which was evident in the energy & water consumption pattern analyzed. A 19% increase in the number of electricity connections was observed in Hulhumale from 2016 to 2017, whereas in Male, the increase is about 4% from 2016 to 2017. 59% of the energy is consumed in Residential buildings followed by 29% in Commercial buildings, 12% in Government buildings, and nearly 0.3% to 0.43% in Hotels and guesthouses in the years 2016 and 2017.

The average EPI of various buildings is summarized below:

Table 18: Average energy consumption and EPI in 2016 and 2017, Male

Total Average Annual Energy Consumption of Male in 2016 and 2017				
Parameters	Residential	Commercial	Government	Hotels and Guest Houses
Total Electricity Consumption in 2016 and 2017 (MWh)	305480	150151	62132	1553
Total number of connections	53511	13799	1188	146
Average Energy Consumption per connection in 2016 and 2017 (kWh)	5708	10880	53680	11716
Energy Performance Index EPI Range (in kWh/sq.m/ year)*	47-378	63 - 405	67-540	38-331

*EPI Range is based on sample of buildings whose consumption and built up area data was available.

Table 19: Average energy consumption and EPI in 2016 and 2017, Hulhumale

Total Average Annual Energy Consumption of Hulhumale in 2016 and 2017				
Parameters	Residential	Commercial	Government	Hotels and Guest Houses
Total Electricity Consumption in 2016 and 2017 (MWh)	38507	18927	7832	281
Total number of connections	6819	2086	73	108
Average Energy Consumption in 2016 and 2017 (MWh)	5.6	9.1	134.5	2.6
Average Energy Consumption in 2016 and 2017 (kWh)	5621	9058	134528	2597
Energy Performance Index EPI Range (in kWh/sq.m/ year)	60-257	52-428	26-109	61-705

*EPI Range is based on sample of buildings whose consumption and built up area data was available.

The energy performance index (EPI) of existing building stock in Male and Hulhumale is higher than that of the modern buildings, which adopt best practices in building design and energy efficiency. Opportunities to improve the building design and construction of Maldivian building stock to reduce their EPI will be identified to achieve energy efficiency in building sector and reduction in GHG emissions.

- Although, the Maldivian government through Maldives Energy Authority department has taken few steps towards reducing the energy imports such as increasing the share of renewable energy in the current energy source basket & is working towards developing star labelling programs for the energy efficient appliance to reduce the energy demand, but it is necessary to augment such efforts by bringing in energy efficiency at the design stage of the building.

7. 2nd Stakeholder Workshop

The 2nd stakeholder consultation was organized in SHE building, Male on 20th January, 2020 which was well attended by representatives of various ministries in Maldives. The stakeholder consultation was aimed at discussing the findings of the local condition assessments of buildings in Male and Hulhumale that covered the following aspects:

- Prevailing regulatory and policy ecosystem in the building sector of Maldives and how the energy efficiency guidelines can seamlessly integrate with the current regime
- Existing design and construction practices such as buildings orientation and layout, materials, glazing, thermal and visual comfort systems and others
- Energy and Water consumption analysis of various building typologies

The objective of the stakeholder consultation was to strengthen the findings of the local conditions and to identify any further critical aspects to have a holistic approach for developing energy efficiency guidelines. The stakeholder consultation further presented an opportunity for the PwC team to discuss the methodology, expected outcomes from the detailed building energy assessment that was scheduled to be the next task of the assignment, along with support required from stakeholders for the same.

The list of attendees, agenda and key discussion points of the stakeholder consultation is presented in the next sections.

7.1.1. List of Attendees

The list of attendees along with their designation and organization is presented below.

Table 20: List of attendees of the stakeholder consultation workshop

Attendees	Designation & Organization
Mr. Mohamed Inaz	Project Manager, ME
Ms. Fathimath Raufa Moosa	M & E Officer, ME
Mr. Mohamed Saif	Principle Architect, HDC
Ms. Mariyam Irasha Najeeb	Asst. Architect, MNPI
Ms. Fathimath Fizna Yusoof	MEA
Ms. Shara Mauroof	MEA
Mr. Haikal	MNU
Mr. Rajeev Ralhan	Executive director, PwC
Ms. Sanyukta Pande	Senior Associate, PwC
Mr. Akash Vajpai	Sr. Associat, PwC
Ms. Aishath Ahmed	Building services engineer, Riyan pvt.ltd
Ms. Mariyam Irasha	Architect, Riyan Pvt. ltd

7.1.2. Agenda for the Stakeholder Consultation

The agenda was prepared before undertaking the mission, and Ministry of Environment's support was sought in scheduling the meetings with relevant contact persons. The final agenda for the mission is presented below.

Table 21: Agenda of the stakeholder workshop

0830 - 0900	Registration	
Inaugural Session		
0900 - 0920	Recitation of Holy Quran	
	Opening Statement by the Ministry of Environment	
0920 - 0945	Tea/Coffee break	
Session 1: Development of energy efficiency guidelines for buildings- Overview of Local Conditions and Building systems		
0945 - 1045	Energy Efficiency Building Guideline – an introduction	PwC
	Overview of Maldives Construction Industry – Construction practices, building codes, regulatory framework and future initiatives (estimated 15 mins)	CIDD, MNPI (tbc)
	Planned development of Hulhumale’	HDC (tbc)
	Overview of proposed approach and methodology for the development of EE guidelines and Climate Analysis	PwC
	Overview of design and construction practices, building materials and key findings	Riyaan and PwC
	Comments and feedback from Stakeholders	Stakeholders
Session 2: Energy and water usage patterns in Male’ and Hulhumale’		
1045 - 1200	Energy and Water sector in Male’ and Hulhumale	Riyan
	Analysis of Building Electricity Consumption for Male’ and Hulhumale	PwC
	Comments and feedback from Stakeholders	Stakeholders
	Analysis of Building Water Consumption for Male’ and Hulhumale	PwC
	Key Points to be addressed for developing energy efficiency guidelines	PwC
	Comments and feedback from Stakeholders	Stakeholders
1200 - 1300	Lunch	

7.1.3. Photographs of the Stakeholder Consultation Event

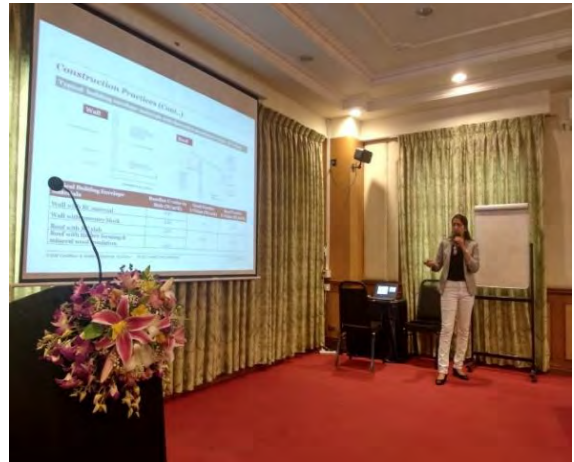


Figure 80: Overview of findings of local condition assessment by PwC



Figure 81: Discussion with stakeholder



Figure 82: Image of stakeholder consultation held on 20 January ,2020

7.1.4. Key Discussion Points from the Stakeholder Consultation

- The discussion was initiated by Mr Inaz, Project Manager, ME, by greeting the participants followed by a quick overview on the importance of energy efficiency during design and construction of buildings.
- Mr. Inaz, said electricity consumption in Male is increasing at a rate of 9-11% every year and during hot seasons, **energy is supplied inefficiently which increases the expenses on the government's budget. He added that every year 1 billion MVR is allocated as subsidy for supplying electricity in government's budget.** He continued that Maldives is heavily reliant on diesel supply for electricity generation and only 7.7% of the total electricity generation is renewable energy. Moreover, the buildings are not designed to **operate energy efficiently. Also, people opt for cheaper inefficient AC's which apparently in long run cost more** due to high energy consumption and associated energy cost. Therefore, Ministry of Environment is undertaking efforts that are aimed at creating awareness so that people adopt energy efficient practices.
- He further added that energy efficiency guidelines for buildings, that are developed as a part of this assignment, encourages energy efficient designs such as energy efficient building materials or use of natural ventilation design to lower the energy consumption. Stakeholders of the industry are integral to **the development of this energy efficiency guideline which will ultimately help Maldives' government to reduce energy expenditure.**
- He concluded by saying that reduction in energy consumption can increase the bottom line of the businesses especially resorts and guest houses and mentioned that government is aiming 21 MW of solar power generation along with other renewable technologies such as sea waves or hydrogen for electricity generation for reducing energy costs. Post this, PwC team presented their findings of the local condition assessment which was followed with open discussion.

Key outcomes from the discussions are:

8. Detailed Building Energy Assessment and Occupancy Survey

Post the 2nd Stakeholder workshop, PwC team conducted a detail energy assessment of various buildings in Maldives during 21-31 January, 2020 . The detailed energy assessment was carried out through walkthrough assessment with a structured set of questionnaire and with instruments to measure temperature, lux level distribution, that targeted at supplementing the existing information on the design and construction practices, thermal comfort and lighting systems in use, as well gather more information on the building operation and management practices with regard to energy and water usage. Additionally, an occupancy survey was undertaken for the government and commercial buildings that provided crucial information about the performance of the overall building and its workspace on air quality, thermal comfort and lighting quality from the building occupants. PwC team also collected energy and water bills while undertaking the assessment. The detailed assessment methodology is illustrated in Figure 83.

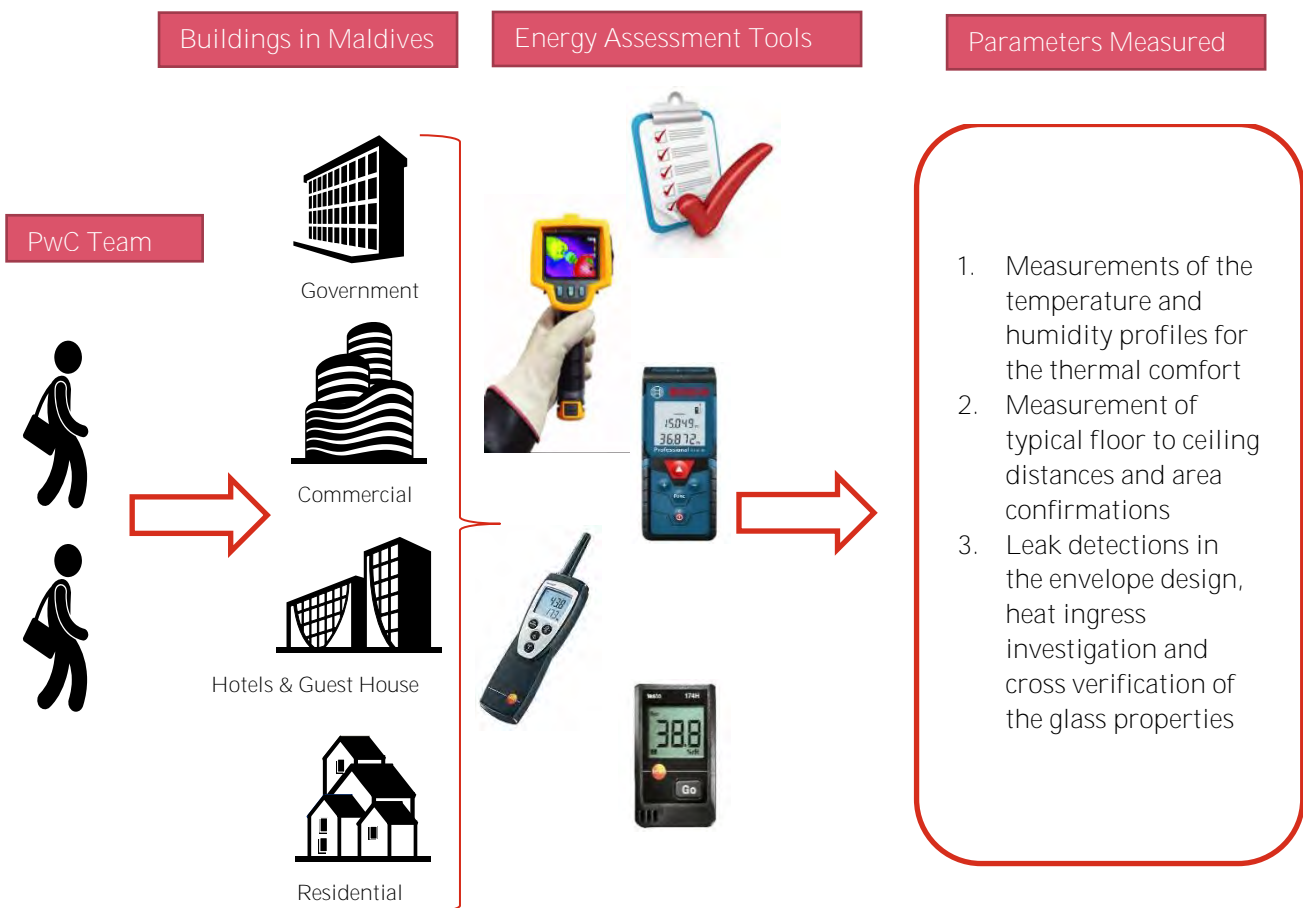


Figure 83: Building Energy Assessment Methodology

The assessment aimed at achieving following objectives:

- Validation of the findings of local conditions assessment
- Identification of low cost or no cost energy conservation measures in the buildings

- Identification of major or minor changes through retrofitting of existing buildings
- Carryout energy simulations using the computer software in the next phase of the assignment, using the data obtained from the assessment to identify appropriate energy efficiency strategies

The above objectives would ultimately help in developing an energy efficiency guidelines with effective building design, construction and operation strategies for the buildings in Maldives.

A total of 19 buildings, covering each typologies as identified in the local condition assessment across Male and Hulhumale was shortlisted, in consultation with Ministry of Environment and the same is given in Figure 84.

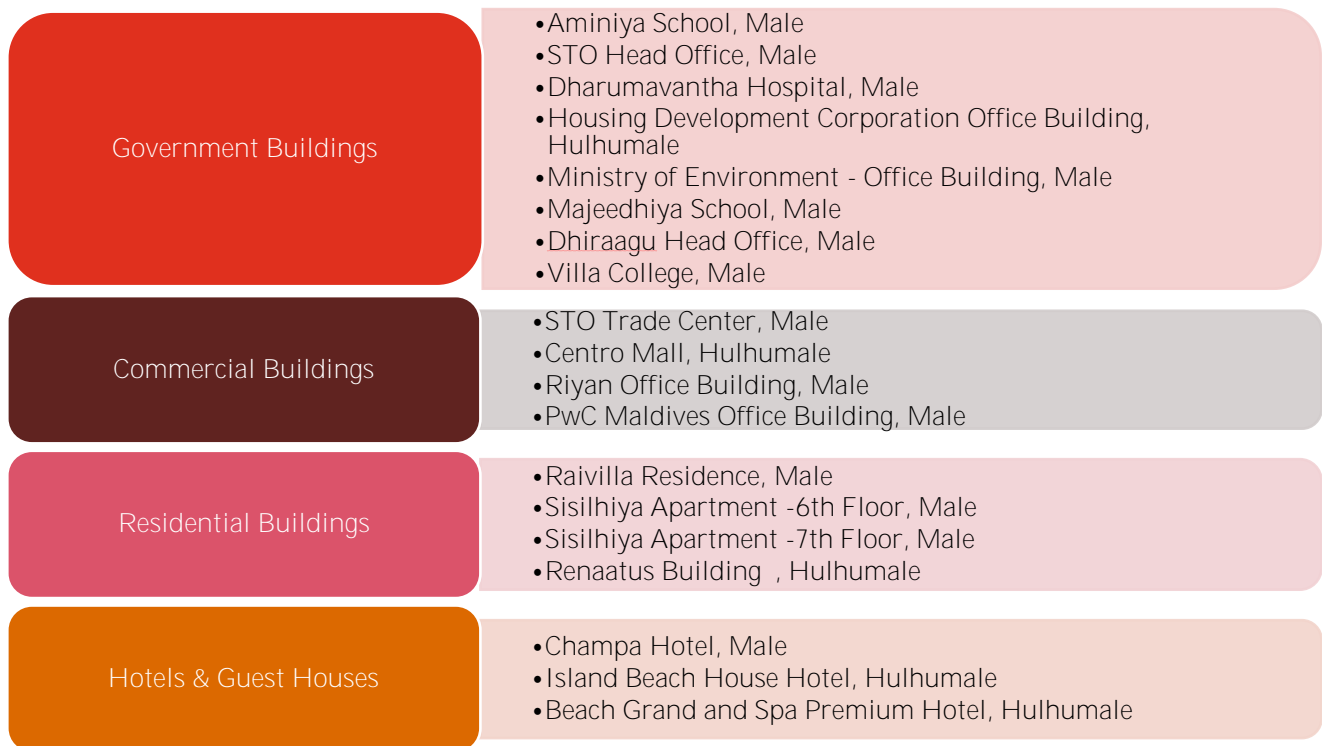


Figure 84: List of buildings that were assessed in the mission

Few snapshots of the assessment carried out by the PwC team is given in the Figure 85.



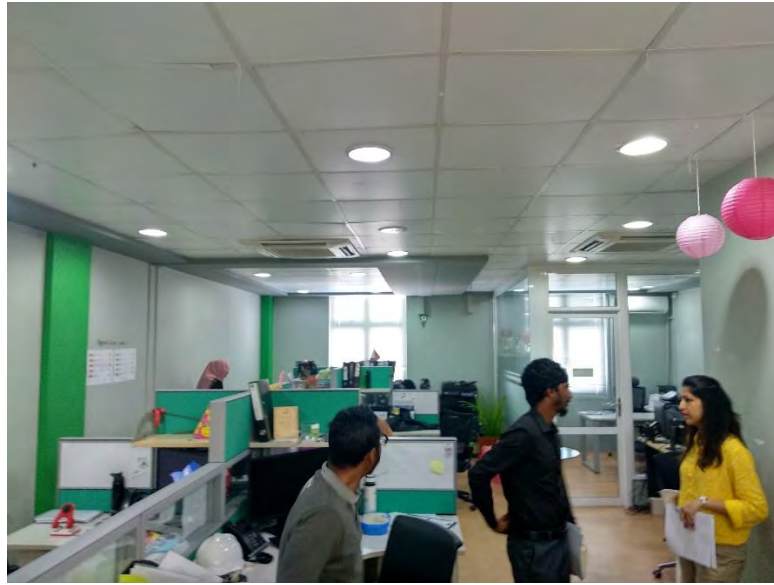


Figure 85: PwC team carrying out detailed assessment of the buildings

The information and data obtained from the detailed energy assessment, occupancy survey of the is provided in the next sections.

8.1.1. Detailed Energy Assessment Data

As mentioned earlier, the detailed energy assessment of 19 buildings across Male and Hulhumale was conducted using questionnaire that were asked to building owners/managers along with temperature and lux level measuring instruments. The questionnaire was prepared carefully with long list of qualitative and quantitative questions that covered various facets of buildings based on its typology/usage pattern to identify the existing building design and construction practices along with type of lighting and thermal comfort system and usage pattern. The questionnaire covered following topics/parameters:

- Building Information: Purpose of the building and its built-up area, construction year, no. of floors etc.
- Building Design: It included the orientation and layout of the building with respect to the sun movement along with the amount of natural ventilation and daylight received.
- Building Envelope/ Façade: It included the materials used for construction of walls and roofs and window to wall ratio. It also included the type of glazing used
- Type of thermal comfort and artificial lighting system employed and their operation pattern
- Details of automated control systems for lighting and thermal comfort systems
- Details of onsite-renewable energy systems
- Details of water fixtures and water consumption

The technical parameters such as capacity and type of the air-conditioning systems, lighting system, type of glazing on the windows, construction material, window to wall ratio and others where the technical knowledge of the respondent was limited, were filled by the PwC team from the visual inspection. The typology wise data obtained from the energy assessment of the buildings are presented below while the questionnaire used for the assessment is provided in the annexure 1.

Government Buildings:

1) Ministry of Environment, Office Building, Male



Figure 86 – Front View (East) of the building



Figure 87 – Image showing North and South sides of ME building with adjoining buildings on both sides

Building Information

City & Year of Construction	Male, 2009
Area (in sq. Meter)	1496
No of Floors	5
Number of Occupants	305
Building Operational Hours	8 am to 10 pm, 85-90 % occupancy during (8 am - 2 pm -6hrs) while 10-15% from 2 pm -10 pm
Connected Load	NA
Power Backup	Solar
No of Energy meters	4
No of Water Meters	4

Building Design

Orientation:

The building has good orientation as longer facades of the building are facing North South Orientation. However, adjacent buildings on North and South side are too closely placed which have an impact on the daylight and shading of the lower floors.

Layout:

The building has a rectangular shape. The office spaces have a mix of cellular and open plan layout. Service Core and washrooms of the building are facing North Façade. Workspaces are oriented on South, East and West façade.

Daylight:

Workspaces located on upper floors receive good daylight. However, workspaces located on lower floors rely mainly on Artificial lighting (Figure 89)



Figure 88– Image showing good daylight levels in workspaces located near the external window

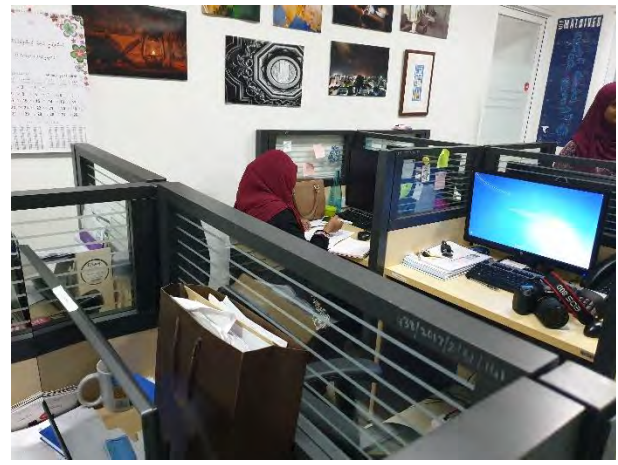


Figure 89– Image showing usage of Artificial lighting in workspaces located on lower floors.

Building Envelope

Building Façade:

Window to wall ratio and shading

The building has a high Window to Wall Ratio of 50%. Windows are shaded on the East façade by virtue of the façade design (Recessed windows).

Glazing

High glazing area leads to excessive solar gains inside the building, leading to usage of internal blinds in the office spaces. Also, single glazing is used in the building

Walls, Roof Material & use of insulation

No insulation is provided on the walls or Roof.

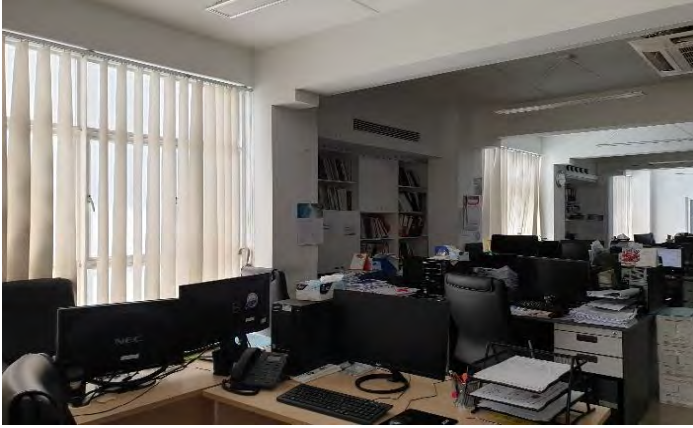


Figure 90 – Image showing usage of Internal blinds in Workspaces



Figure 91 – Image showing usage of Internal blinds in Conference rooms



Figure 92– Adjacent building white Tin roof reflects high amount of glare inside the building



Figure 93– Image showing high amount of glazing in Conference Rooms leading to heat buildup and glare inside the conference room.

Lighting

Artificial Lighting:

The building uses LED lighting ranging from 7 W to 24 W. There are no lighting controls installed in the building. It was observed that the occupants (specifically on 2nd floor) use optimum artificial lighting. They get enough daylighting at their work station.

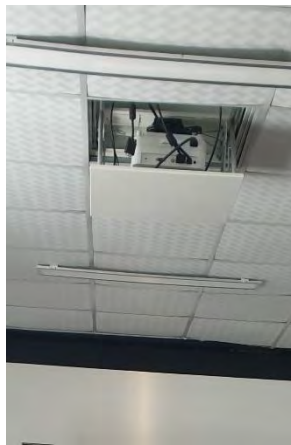


Figure 94– Image showing LED lighting installed in the building

Thermal Comfort System and Building Operation

The building uses unitary air conditioners (mix of high wall and cassette ACs). Originally, the building was installed with air cooled chillers but later the building owner choose to opt for unitary air conditioning systems in building due to mold and fungus in chilled water.

Air Conditioning:

The air supply ducts are in place in the building, however the system is not in operation. The ACs are not star rated. The capacity of ACs range from 0.75 TR to 2.5 TR. Setpoint temperature of ACs is set at 24 degree C. The occupants are well aware to keep the temperature at 24 degree C. The relative humidity in air conditioning spaces were in the range of 55% to 60%



Figure 95– Image showing high wall unitary air conditioners



Figure 96– Image showing cassette air conditioners



Figure 97– Image showing non-operational air ducts in the building due to mold and fungus problems in chilled water.



Figure 98– Image showing set-points of 25 deg C set in the workspaces. Awareness on high setpoint is issued by Energy Department.



Placement of outdoor units generates a lot of heat which prevents the building users to operate the window or open the blinds.

Figure 99– Image showing outdoor units of adjacent buildings.

Renewable Energy

Solar Panels are placed on the roof of the building.



Water Efficiency

Plumbing Fixtures:

Taps are provided with motion sensors. However, No low flow fixtures are installed in the washrooms.

Building Performance

Energy Performance Index (EPI) -kWh/m ² /year	83.80
Water Consumption per Capita (m ³ /person)	1.77

2) Aminiya School, Male



Figure 100 – Aminiya School building

Building Information

City & Year of Construction	Male, 2018
Area (in sq. Meter)	NA
No of Floors	12
Number of Occupants	2630 (2400- Students & 230 Staff)
Building Operational Hours	School Timings 6.45 am -12.30pm - Morning School 12.30pm -5.30pm - Afternoon School Offices - 6:45 am -6:45 pm (12 hrs)
Connected Load	NA
Power Backup	NO
No of Energy meters	2
No of Water Meters	3

Building Design

Orientation:	Linear building has a North South orientation. Longer facades of the building facing North and South orientation. Adjacent building on the South side is closely placed which impacts the daylight and shading of the lower floors.
Layout:	Classrooms on south side and corridor on North side. Classrooms have windows on both sides for light and ventilation.

Daylight:



Figure 101– Image showing low daylight levels in classrooms located near the external window

Classrooms on lower floors rely on Artificial lighting. Staffrooms and 50% classrooms do not get natural daylight due to overshadowing with surrounding building.



Figure 102– Image showing usage of Artificial lighting in classrooms located on lower floors.

Building Envelope

Building Façade:

Window to wall ratio and shading

The building has a high Window to Wall Ratio of 50%. Windows and front side of the building is covered with perforated facades for privacy from adjacent building which blocks the natural daylight. Curtains are also present to block Glare

Glazing

Single glazing with Aluminum window

Walls, Roof Material & use of insulation

150 mm Concrete Masonry block Wall. No insulation is provided on the walls or Roof.



Figure 103 – Image showing usage of Internal blinds in office area of the school



Figure 104– Image showing high window to wall ratio

Lighting

Artificial Lighting:



The building uses T 5 lights. There are no lighting controls installed in the building.

Use of lighting is minimum in classrooms. However offices use lights in day time as well.

The building has exterior Mercury Lighting



Figure 105– Image showing T 5 lights installed in the building

Thermal Comfort System and Building Operation

Air Conditioning:

The building uses unitary air conditioners (split Acs) for the staff rooms and multi purpose room. All classrooms are naturally ventilated. Some classrooms open windows to get natural breeze during class timings. The ACs are not star rated. The relative humidity in air conditioning spaces were in the range of 55% to 60%

AC is operational throughout the day from 6.15am to 8pm in Offices. Classrooms are Naturally ventilated with fans leading to thermal discomfort for majority of students.



Figure 106– Image showing high wall unitary air conditioners in staff rooms

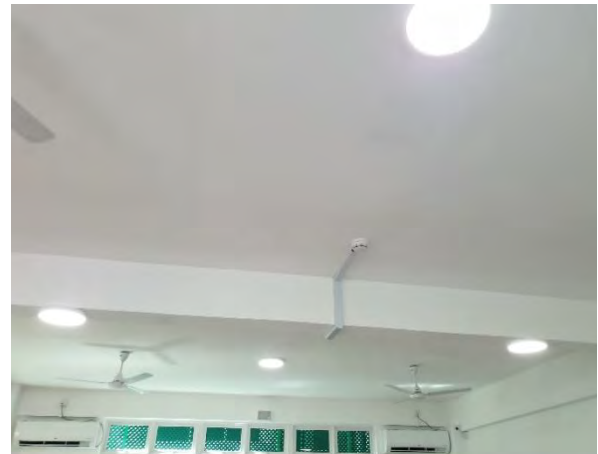


Figure 107– Image showing natural ventilation in the classrooms

Renewable Energy

No

Water Efficiency

Plumbing Fixtures:

No low flow fixtures are installed in the washrooms.

Building Performance

Energy Performance Index (EPI) -kWh/m²/year

NA

Water Consumption per Capita (m³/person)

NA

3) STO Head Office, Male



Figure 108 – STO Head Office building

Building Information

City & Year of Construction

Male

Area (in sq. Meter)

3284

No of Floors

G+ 7

Number of Occupants

NA

Building Operational Hours

8 am – 4 pm (8 hrs)

Connected Load

150 kW

Power Backup

NA

No of Energy meters

1

No of Water Meters

2

Building Design

Orientation:

Elliptical Building with facades facing all north and south orientations.

Layout:

Open Plan layout with service core located centrally. Workspaces are facing North orientation overlooking the sea.

Daylight:

The building receives too much daylight. No Artificial lighting are used during daytime

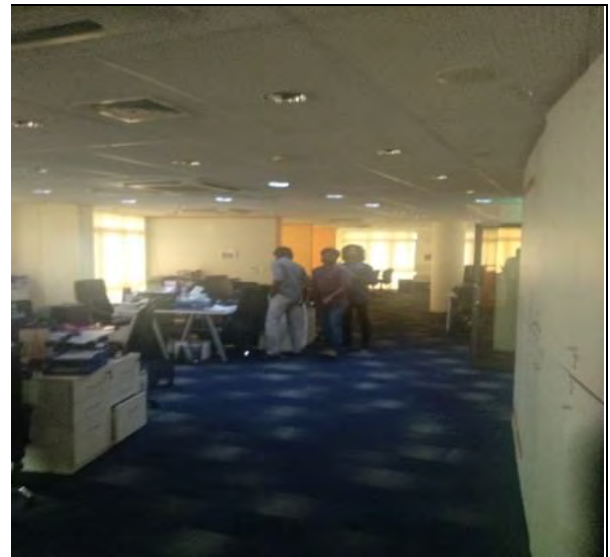
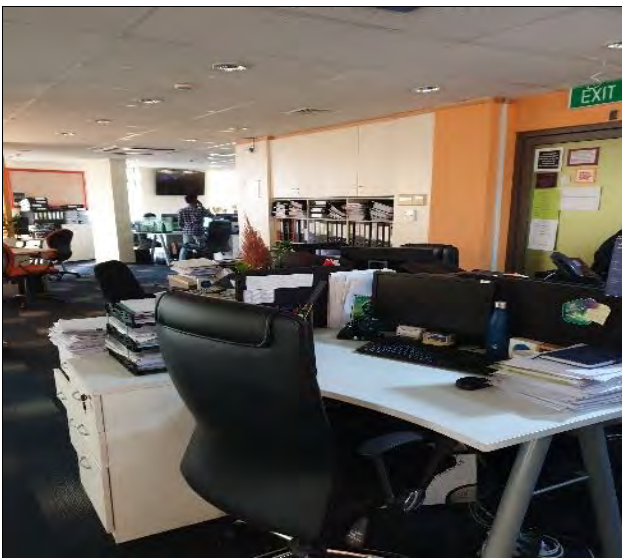


Figure 109– Image showing good daylight levels in workspaces located near the external window

Building Envelope

Building Façade:

Window to wall ratio and shading

The building has very high Window to Wall Ratio. Single glazing provided in the windows with PVC frame. Windows are mostly unshaded

Glazing

Single glazing with reflective glasses

Walls, Roof Material & use of insulation

cement blocks for walls. No insulation is provided on the walls or Roof.



Figure 110 – Image showing usage of Internal blinds in office area of the school



Figure 111– Image showing high window to wall ratio

Lighting

Artificial Lighting:

The building uses LED (10 Watt). There are Occupancy Sensor installed in Staircase of the building.

All office spaces uses artificial lighting. They use blinds and does not take daylight in day time

The building has exterior bulbs for lighting

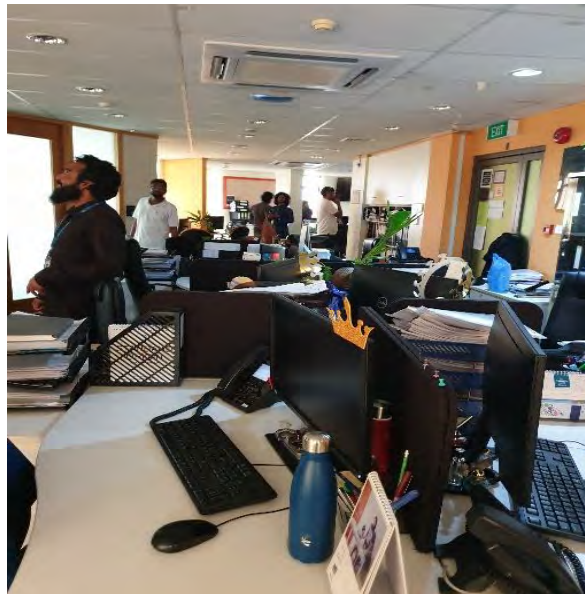


Figure 112– Image showing T5 lights installed in the building

Thermal Comfort System and Building Operation

Air Conditioning:

The building uses energy efficient Hitachi VRF (variable refrigerant systems). The system is recently installed and commissioned by Hitachi. Advantages of VRF are being availed by building occupants. Set points are maintained at 24 degree C. Also in less occupied areas, the control of

indoor units are done by maintenance and operation team. The ACs are star rated. The relative humidity in air conditioning spaces were in the range of 55% to 60%. Placement of outdoor units is strategically good. ODU are placed on roof and the heat is not being absorbed by any other nearby building

Building operates at a setpoint of 24 deg C. Blinds are pulled up during the day to receive natural lighting.

Building operates at a setpoint of 24 deg C. Blinds are pulled up during the day to receive natural lighting.

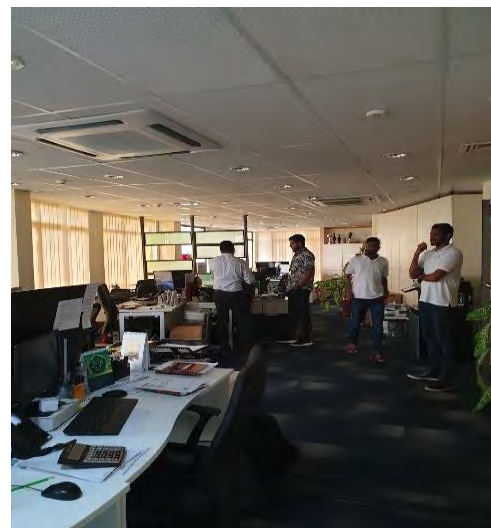


Figure 113– Images showing VRV system in the building

Water Efficiency

Plumbing Fixtures:

No low flow fixtures are installed in the washrooms.

Building Performance

Energy Performance Index (EPI) - KWh/m²/year

46.50

Water Consumption per Capita (m³/person)

-

4) Dharumavantha Hospital, Male



Figure 114 – Front View of the building

Building Information

City & Year of Construction

Male, 2019

Area (in sq. Meter)

NA

No of Floors

25 Floors but only 7 floors are operational

Number of Occupants

100 (50 Staff + 50 patient room)

Building Operational Hours	24 hrs
Connected Load	3 MW but using 400 kW
Power Backup	2 – 2 MW Diesel Genset & Battery (UPS)
No of Energy meters	2
No of Water Meters	1

Building Design

Orientation:

Building comprises of various departments serving various functions. Reception and Waiting rooms are oriented towards South side of the building,

Layout:

Rectangular building layout with window opening on all 4 sides (east, west, south & north side) of the building

Daylight:

Indoor spaces such as waiting areas, reception, corridor, consultation rooms are mainly using artificial lighting throughout the day.



Figure 115– Image showing low daylight levels in reception area



Figure 116– Image showing usage of Artificial lighting in the common area .

Building Envelope

Building Façade:

Window to wall ratio and shading

Glass building with extremely high- 100% window to wall ratio. No shading is provided on external facades.

Glazing

Windows: Double Glazed Unit - 12mm-6mm-12mm tinted Blue

Walls, Roof Material & use of insulation

150 mm Concrete Masonry block Wall, Roof is made of concrete slab with no insulation. No insulation is provided on the walls or Roof.



Figure 117 – Images showing usage of double-glazed window with Internal blinds in common area

Lighting

Artificial Lighting:

The building uses LED for both interior and exterior lighting. There are Occupancy Sensor installed in Staircase of the building.

Most of the spaces uses day light and less use of artificial light. However office space uses artificial lights

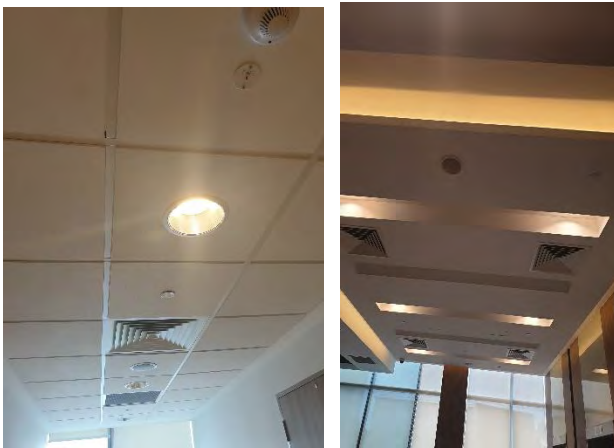


Figure 118– Images showing LED lighting installed in the building



Figure 119– Image showing use of day lighting in conference area

Thermal Comfort System and Building Operation

Air Conditioning:

The building uses highly efficient water cooled central air conditioning system (400 TR Daikin). Although the building is not 100% operational, but the operational areas (3 floors) are being air

conditioned by this system. Since the building is newly constructed the systems are working well.

The relative humidity in air conditioning spaces were in the range of 55% to 60%

BMS system is installed in the building which monitors the HVAC system, Lighting, Fire and Elevator system. All manual controls are provided on lighting



Figure 120– Image showing Chiller Plant Room



Figure 121– Image showing Daikin 400 TR water-cooled Chiller

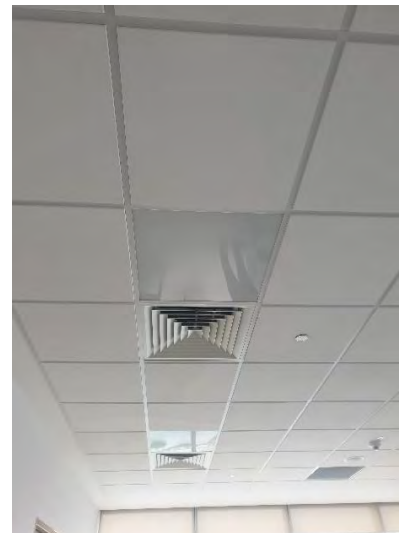
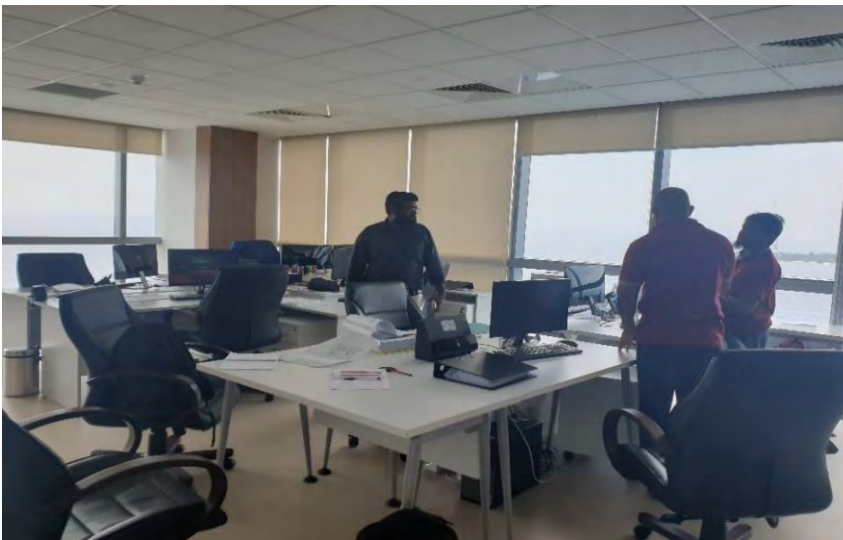


Figure 122– Images showing indoor AC units

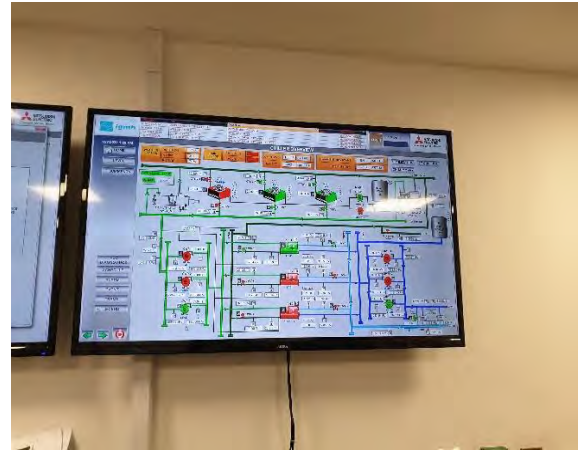


Figure 123– Images showing Building Management System (BMS)

Renewable Energy

No

Water Efficiency

Plumbing Fixtures:

Dual Flush fixtures used in toilets



Figure 124– Image showing dual fixtures

Building Performance

Energy Performance Index (EPI) -kWh/m2/year

-

Water Consumption per Capita (m3/person)

-

5) HDC, Hulhumale

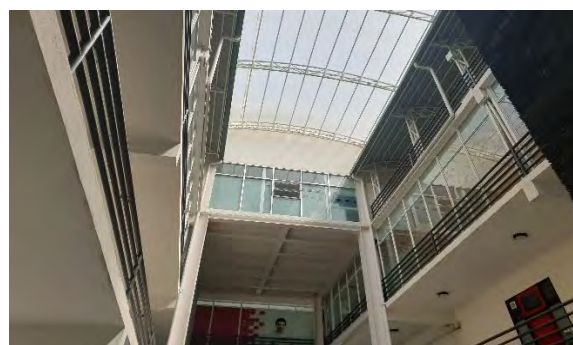


Figure 125 – Front View of the building

Building Information

City & Year of Construction	Hulhumale, 2004-05
Area (in sq. Meter)	3326
No of Floors	4
Number of Occupants	250
Building Operational Hours	8 am to 3:30 pm
Connected Load	NA
Power Backup	NA
No of Energy meters	4 (Separate meter for each office)
No of Water Meters	4

Building Design

Orientation:	Longer facades are oriented towards East and West orientations.
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Layout:

The building has a courtyard layout. 2 rectangular blocks with naturally ventilated courtyard in the middle

Daylight:

Indoor offices mainly rely on Artificial lighting throughout the day. Blinds are down throughout the day due to Glare issues in the building leading to no natural daylight.

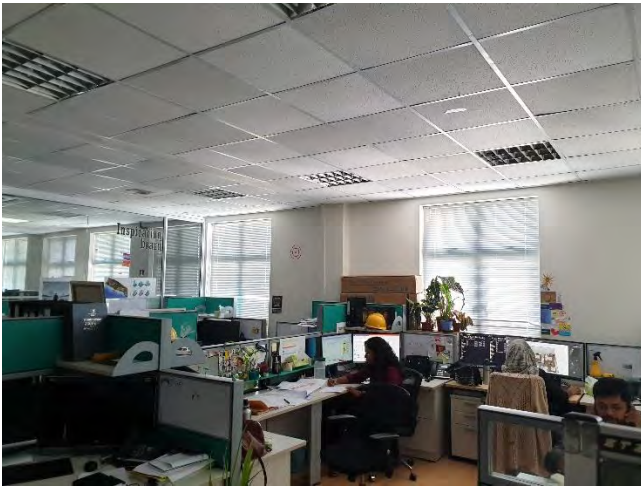


Figure 126– Image showing use of blinds to reduce the glare



Figure 127– Image showing usage of Artificial lighting in the indoor offices .

Building Envelope

Building Façade:

Window to wall ratio and shading

Building has low Window to Wall Ratio of 15%. Shading is not designed as per orientation leading to Glare during afternoon hours.

Glazing

Single glazing with Aluminum frame

Walls, Roof Material & use of insulation

150 mm Concrete Masonry block Wall. Roof is made of steel structure with no insulation



Figure 128 – Use of single glazed windows

Figure 129 –Image showing low window to wall ratio

Lighting

Artificial Lighting:



Figure 130– Image showing LED lighting installed in the workspace

The building uses LED for both interior lighting. There are no lighting control systems.

Optimum use of day lighting in operational hours



Figure 131– Image showing use of day lighting in conference area

Thermal Comfort System and Building Operation

Air Conditioning:

The building uses ceiling and wall mounted non-star rated split air conditioners.

Occupants follows the guidelines for keeping the set point at 24 degree C. At few spaces the occupants does not use AC

The relative humidity in air conditioning spaces were in the range of 50% to 60%

Common areas of the building are naturally ventilated such as corridors, cafeteria, courtyard etc. Energy saving reminders are installed in office areas to switch off lights, air conditioners and other electrical equipments.



Figure 132– Image showing wall mounted AC in workspace



Figure 133– Images showing wall mounted AC in cabins & its specification



Figure 134– Image showing naturally ventilated and use of daylight in cafeteria



Figure 135– Image showing energy saving reminders are installed in workspace areas

Renewable Energy

No

Water Efficiency

Plumbing Fixtures:

No low flow fixtures observed in the building

Building Performance

Energy Performance Index (EPI) -kWh/m2/year

274.14

Water Consumption per Capita (m3/person)

-

6) Majeediyya School, Male



Figure 136 – Front View of the building

Building Information

City & Year of Construction	Male, 95 years old
Area (in sq. Meter)	136.3
No of Floors	G+3, G, G+2
Number of Occupants	1680 (1500- Students & 180 Staff)
Building Operational Hours	6 am -6 pm (12 hrs)
Connected Load	NA
Power Backup	NA
No of Energy meters	5
No of Water Meters	8

Building Design

Orientation:	The building comprises of various blocks. Old school block is 100 years old. 2 New blocks have been added which are rectangular with longer facades facing North, South and East orientations.
Layout:	Main classrooms and offices are oriented North and East. The main playground is also shaded by virtue of building orientation and landscape.
Daylight:	The classrooms and offices mainly rely on artificial lighting throughout the day



Figure 137– Image showing landscaping and shading provided by trees in the low height blocks



Figure 138– Image showing usage of Artificial lighting in the classrooms

Building Envelope

Building Façade:

Window to wall ratio and shading

Trees are effective in shading the facade and low height building blocks. Building has high window to wall ratio with no effective shading on the external facade. Curtains are provided in classrooms to cut the excess glare.

Glazing

Windows: Single glazing with Aluminum frame

Walls, Roof Material & use of insulation

200 mm masonry wall, coral stone wall (old building).
Timber framing on roof (new building)



Figure 139 – Use of curtains in classrooms to avoid glare



Figure 140 –Image showing high window to wall ratio

Lighting

Artificial Lighting:

The building uses mix of LED (18 W), T5 & T8 lights for interior lighting. There are no lighting control systems. The building uses Mercury (4 * 400 W) for exterior Lighting. Use of lighting is minimum in classrooms. However offices use lights in day time as well.



Figure 141– Image showing use of artificial lighting in office area during daytime



Figure 142– Image showing use of artificial lighting in classrooms

Thermal Comfort System and Building Operation

Office spaces, principal cabin and staff rooms are having non star rated split Acs ranging from 1 TR to 2 TR.

Air Conditioning:

All class rooms are naturally ventilated. However, fans are provided in the class rooms to provide thermal comfort

The relative humidity in air conditioning spaces were in the range of 50% to 60%



Figure 143– Image showing wall mounted AC in staff room

Figure 144– Images showing fans in classrooms

Renewable Energy

No

Water Efficiency

Plumbing Fixtures:

No low flow fixtures observed in the building

Building Performance

Energy Performance Index (EPI) -kWh/m²/year

138.42

Water Consumption per Capita (m³/person)

-

7) Dhiraagu Head Office, Male



Figure 145 –View of the building

Building Information

City & Year of Construction

Male, 2012

Area (in sq. Meter)

1300.64

No of Floors

8

Number of Occupants

400

Building Operational Hours

8 am to 4: 30 pm (9 hrs)

Connected Load

NA

Power Backup	2 – 1 MW Diesel Genset & Battery (UPS)
No of Energy meters	1
No of Water Meters	3

Building Design

Orientation:	The building has a square form with equal exposures on all orientations.
Layout:	The building has an open plan layout for workspaces. However, the building has a very deep floor plate and high occupant density.
Daylight:	Due to very deep floor plate of 35m by 15m, workspaces do not get any natural daylight throughout the day.

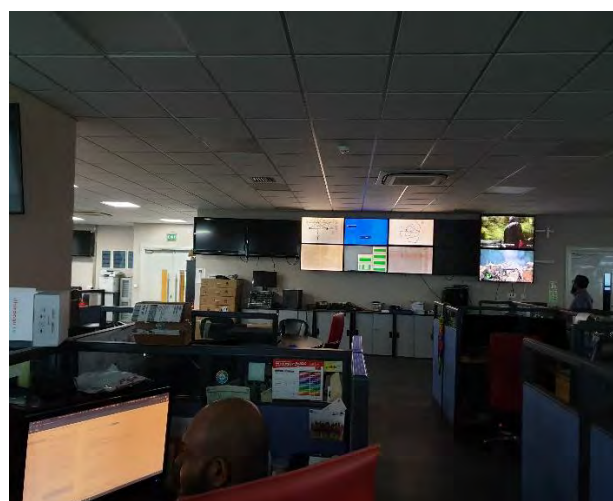
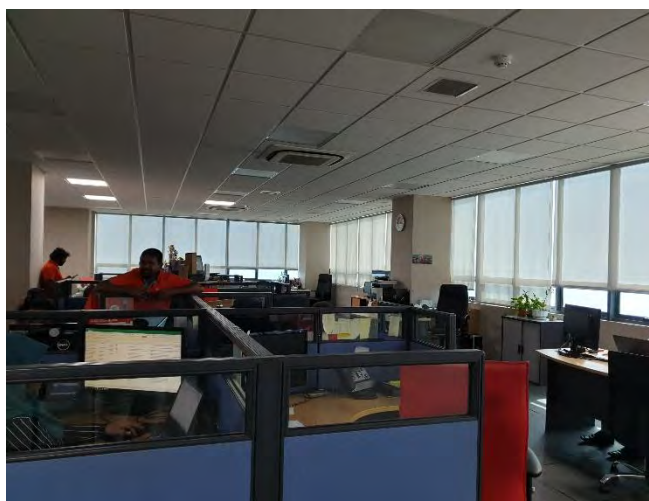


Figure 146– Images showing low daylight in workspaces

Building Envelope

Building Façade:	
Window to wall ratio and shading	High WWR of 60% average. Variable (South-70%, West 80-90%, North-10% & East 30%). High WWR is provided in unfavourable orientations.
Glazing	Glare issues were observed in the workspaces leading to usage of blinds. Single glazing with Aluminum frame
Walls, Roof Material & use of insulation	150 mm Concrete Masonry block Wall. Reflective paint along with insulation provided on roof



Figure 147 – Use high Window to wall ratio



Figure 148 –Image showing use of blinds to avoid glare

Lighting

Artificial Lighting:

The building uses 2 * 2 LED (18W & 24W) interior lighting. There are occupancy sensor in Corridors, Staircase & Toilets.

The building uses LED (200 W & 30W for Façade) for exterior lighting

Optimum use of day lighting in operational hours. However at many space artificial lighting is used due to deep floor plate

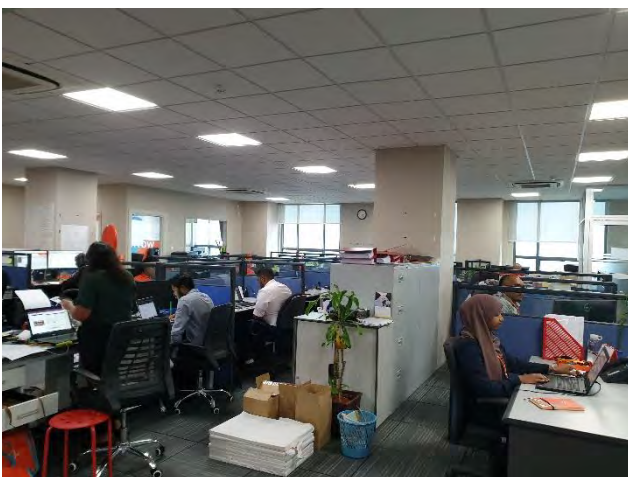


Figure 149– Image showing LED lighting installed in the workspace

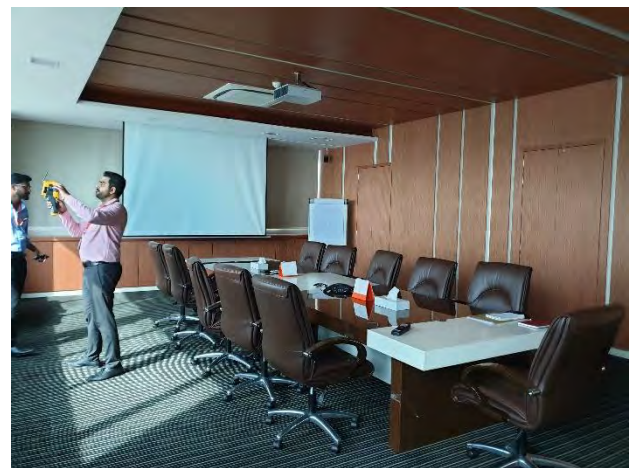


Figure 150– Image showing use of day lighting in conference area

Thermal Comfort System and Building Operation

Air Conditioning:

The office building uses energy efficient Daikin VRF air conditioning system.

All spaces maintain the set points as 24 degree C and follows this practice for energy efficiency.

The relative humidity in air conditioning spaces were in the range of 50% to 60%

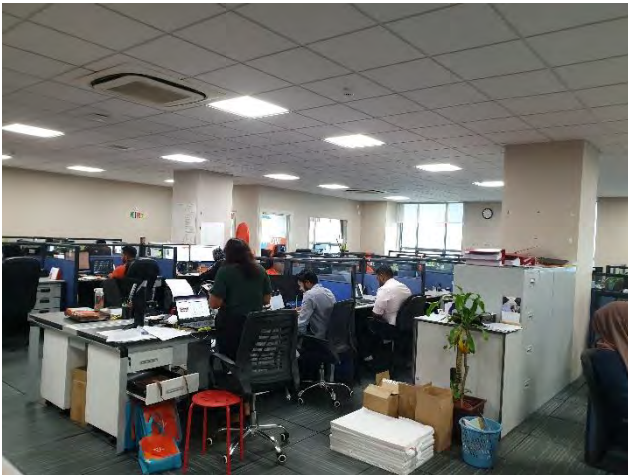


Figure 151– Image showing indoor ceiling mounted units of VRV system in workspace

Renewable Energy

No

Water Efficiency

Plumbing Fixtures:

Dual Flush fixtures used in toilets

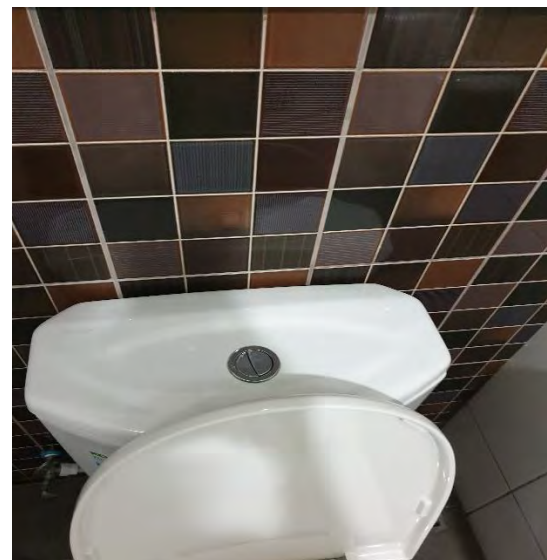


Figure 152– Image showing Dual Flush fixtures and faucets used in toilets

Building Performance

Energy Performance Index (EPI) -kWh/m2/year	298
Water Consumption per Capita (m3/person)	12.36

8) Villa College, Male



Figure 153 –View of the building

Building Information

City & Year of Construction	Male, 2013
Area (in sq. Meter)	11380.62
No of Floors	10
Number of Occupants	1130 (350- College Students, 650- Junior College & 130 Staff)
Building Operational Hours	8 am – 2 pm (High School) 4pm-10pm (College)
Connected Load	150 kW
Power Backup	NA
No of Energy meters	1
No of Water Meters	2

Building Design

Orientation:	Multiple Building blocks. New multi-story college block is oriented with longer facades facing East-West orientation
Layout:	Classrooms with open and naturally ventilated corridors overlooking a small central courtyard. Courtyards are well landscaped.
Daylight:	Few classrooms get natural daylight due to high windows.

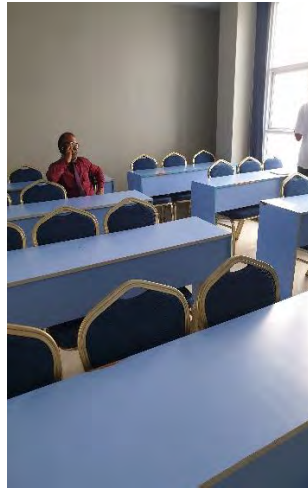


Figure 154– Images showing classrooms are designed for natural ventilation and daylighting

Figure 155– Image showing landscaping in the courtyard

Building Envelope

Building Façade:

Window to wall ratio and shading

Window to Wall Ratio of 60%. No shading is provided on external facade leading to Glare issues. Blinds are used in Classrooms which obstruct daylight and views. Glare issues were observed in the workspaces leading to usage of blinds.

Glazing

Tinted glass with aluminum & wooden frame is used.

Walls, Roof Material & use of insulation

Prefab Steel Construction for walls. No insulation on roofs. Solar panels help in shading of roof



Figure 156 – Images showing use of high Window to wall ratio and blinds to avoid glare

Lighting

Artificial Lighting:

The building uses LEDs for interior lighting. There are no exterior lighting and lighting controls.

Use of lighting is minimum in classrooms. However, offices use lights in day time as well.



Figure 157– Images showing LED lighting installed in the office area and computer lab



Figure 158– Image showing LED lighting in classrooms

Thermal Comfort System and Building Operation

Air Conditioning:

The building uses non-star rated split ACs (wall mounted) as well as VRF in the new block. The placing of outdoor units is at the roofs and heat of ODUs is not taken by any nearby building.

All ACs are being operated for 12-14 hrs even if the classrooms are empty as students want all the classrooms to be cool before they enter for lectures.

No ceiling fans are used in the classroom

The relative humidity in air conditioning spaces were in the range of 50% to 60%



Figure 159– Image showing wall mounted AC in the computer lab in old building

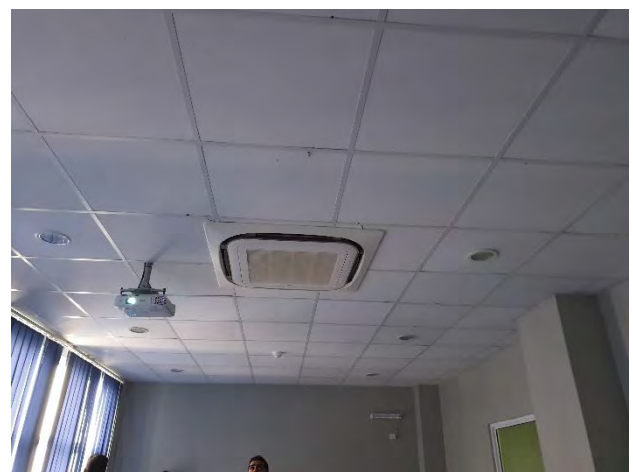


Figure 160– Image showing indoor ceiling mounted units of VRV system in new building

Renewable Energy

186 kW Grid Tied PV System is installed on the roof of the old building.



Figure 161– Images showing Solar PV panels on the roof of old building

Water Efficiency

Plumbing Fixtures: No low flow fixtures observed in the building

Building Performance

Energy Performance Index (EPI) -kWh/m²/year 220.25
 Water Consumption per Capita (m³/person) -

Commercial Buildings:

9) STO Trade Center, Male



Figure 162 –View of the building

Building Information

City & Year of Construction	Male
Area (in sq. Meter)	NA
No of Floors	5
Number of Occupants	Multiple occupants as spaces are rented to offices and shops
Building Operational Hours	7 am – 10 pm (15 hrs)
Connected Load	NA
Power Backup	NA

No of Energy meters	5
No of Water Meters	NA

Building Design

Orientation:	Trapezoid building with external facades facing all orientations.
Layout:	Offices on external facade, open corridor overlooking central courtyard
Daylight:	Insufficient daylight. All Workspaces mostly rely on Artificial lighting



Figure 163– Image showing trapezoidal structure of the building

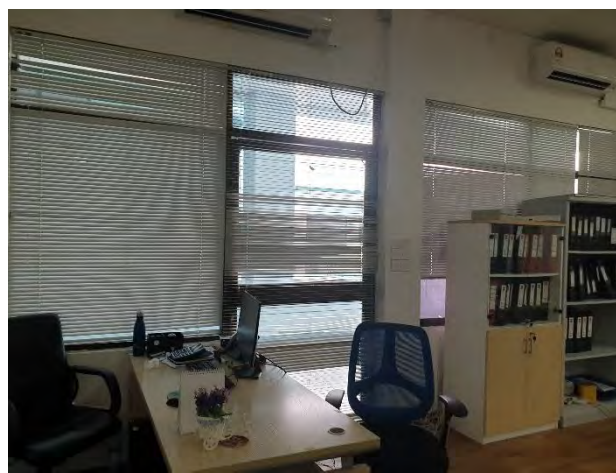


Figure 164– Image showing low daylight in the workspaces

Building Envelope

Building Façade:	
Window to wall ratio and shading	Window to Wall Ratio of 30%-40%. Facades are shaded due to projecting balconies on all internal and external sides of the building.
Glazing	Single glazing provided in the windows with tinted & aluminum frame.
Walls, Roof Material & use of insulation	Wall Material : 150 mm Cement block Wall. No insulation on roof

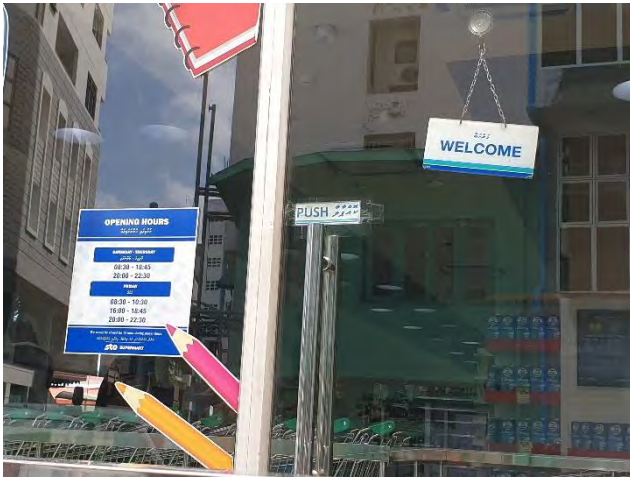


Figure 165 – Images showing single glazing on the windows



Figure 166 – Images showing shading by projecting balconies

Lighting

Artificial Lighting:

The building uses LED of 8 W & 80 W for offices while in Supermarket LED of rating 10W & 100 W is used . There no exterior lighting and lighting controls.

All office spaces uses artificial lighting. They use blinds and does not take daylight in day time



Figure 167– Image showing LED lighting installed in the supermarket

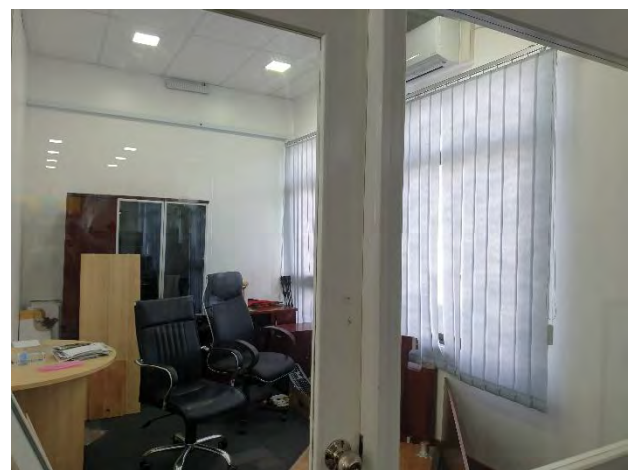


Figure 168– Image showing use of blinds and LED lights in the offices

Thermal Comfort System and Building Operation

Air Conditioning:

All the office space in the building have their own AC. They all are non star rated. Outdoor units are placed in the common area.

Super market is served by VRF system of Hitachi.

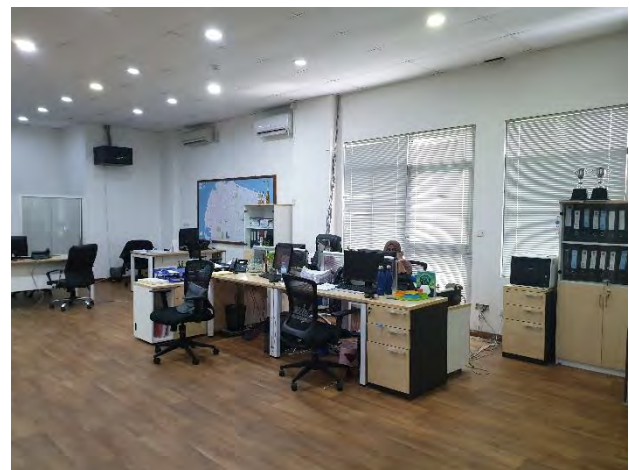


Figure 169– Images showing wall mounted AC in the offices



Figure 170– Images showing indoor ceiling mounted units and outdoor units of VRV system in supermarket

Renewable Energy

NO

Water Efficiency

Plumbing Fixtures:

No low flow fixtures observed in the building

Building Performance

Energy Performance Index (EPI) -kWh/m2/year

-

Water Consumption per Capita (m3/person)

-

10) Centro Mall, Hulhumale



Figure 171 –View of the building

Building Information

City & Year of Construction	Hulhumale, 2017
Area (in sq. Meter)	2000
No of Floors	4
Number of Occupants	32 shops but 25 shops operational
Building Operational Hours	7 am – 10 pm (15 hrs)
Connected Load	NA
Power Backup	NA
No of Energy meters	32 (25 currently operational)
No of Water Meters	9

Building Design

Orientation:	C shaped building block with longer facades facing north and south orientations. Most of the shops face north and south orientations
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Layout:

Shops with open and naturally ventilated corridors overlooking a central courtyard. Courtyards is shaded using fabric.

Daylight:

Most Shops do not receive natural daylight.



Figure 172– Image showing C shaped building block

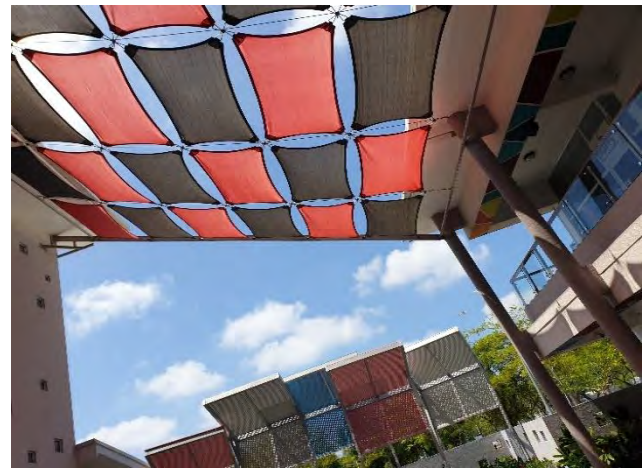


Figure 173– Image showing shading of courtyard using fabric

Building Envelope

Building Façade:

Window to wall ratio and shading

High Window to Wall Ratio. All shops have full glazing on external side. Shading is only provided on the east facade using external timber horizontal fins.

Glazing

Single glazing provided in the windows with tinted & aluminum frame.

Walls, Roof Material & use of insulation

Use of 150 mm Cement block Wall. No insulation on roof

Lighting

Artificial Lighting:

The building uses LED lightings.

Shops does not use day light. They need artificial lighting for their showrooms.



Figure 174– Images showing LED lighting installed in the one of the shop

Thermal Comfort System and Building Operation

The mall is having multiple shops and each shop has its own AC. Mostly all are split Acs.

The ACs are Non star rated split ACs

Air Conditioning:

Every shop has installed their own air conditioning system and has a seperate meter. Shop owners pay their own electricity bills. All lights and ACs are switched off during prayer timings when the shops are shut.



Figure 175– Image showing ceiling mounted AC in one of the shop

Renewable Energy

NO

Water Efficiency

Plumbing Fixtures: No low flow fixtures observed in the building

Building Performance

Energy Performance Index (EPI) -kWh/m2/year 119 (Retail Shop)

Water Consumption per Capita (m3/person) -

11) Riyan Office Building, Male

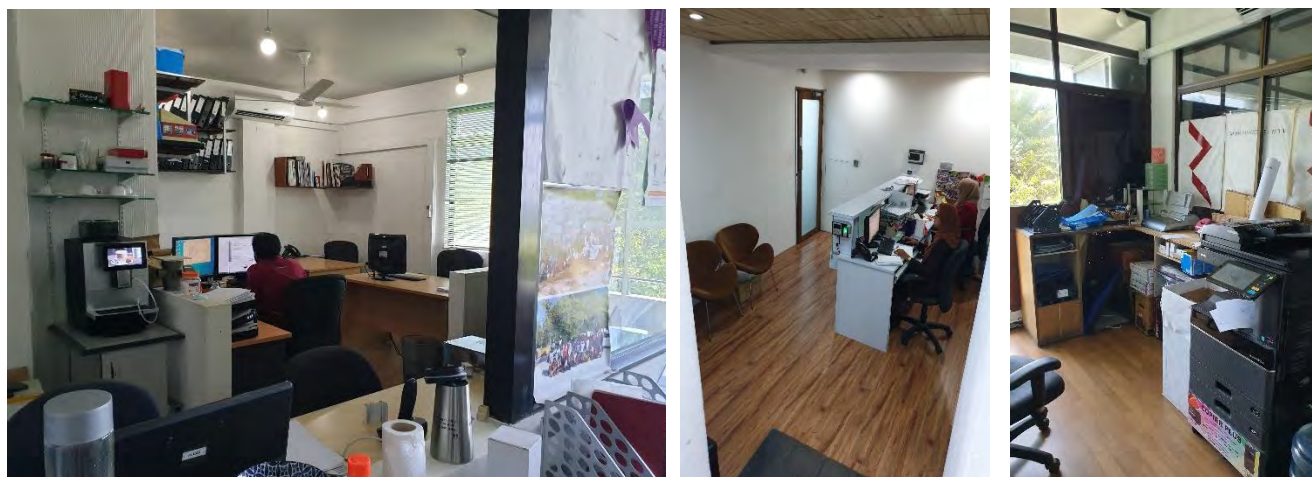


Figure 176 –View of the Office

Building Information

City & Year of Construction	Male, 2004
Area (in sq. Meter)	329
No of Floors	1
Number of Occupants	60
Building Operational Hours	8 am -5 pm (9 hrs)
Connected Load	NA
Power Backup	NA
No of Energy meters	3
No of Water Meters	3

Building Design

Orientation:	Window opening on 3 sides (west, south & north side) of the building
Layout:	Residence converted into commercial office. Mostly open plan layout in offices with high occupant density
Daylight:	Insufficient daylight in work spaces.

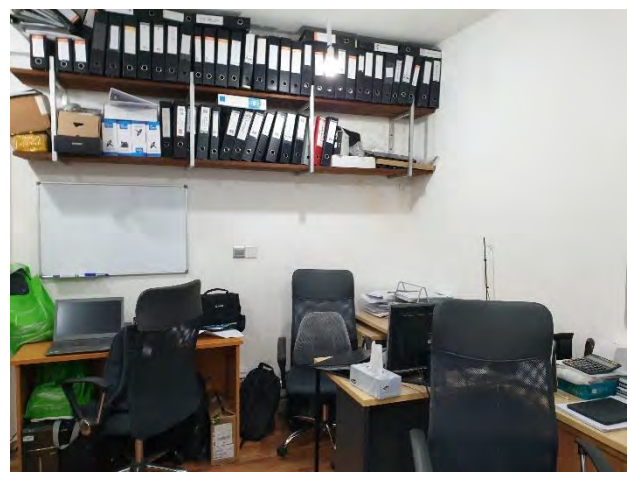


Figure 177– Images showing low daylight in the workspaces

Building Envelope

Building Façade:

Window to wall ratio and shading

Window to Wall Ratio of 15%-20%. No external shading on windows. Blinds are down throughout the day.

Glazing

Single glazing provided in the windows with some tinted & some non-tinted.

Walls, Roof Material & use of insulation

Wall Material : 150 mm Masonry block Wall. No insulation on roof

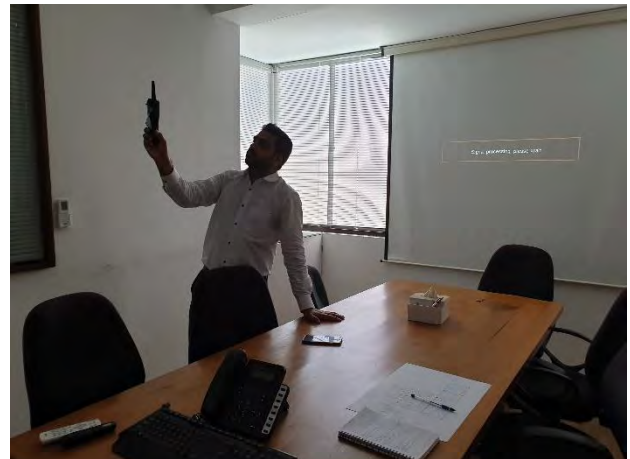


Figure 178 – Images showing low window to wall ratio and use of blinds

Lighting

Artificial Lighting:

The office uses LED (8 W, 11 W), and Tube lights There no lighting controls.

All office spaces uses artificial lighting. They use blinds and does not take daylight in day time



Figure 179– Image showing LED lighting installed in the office

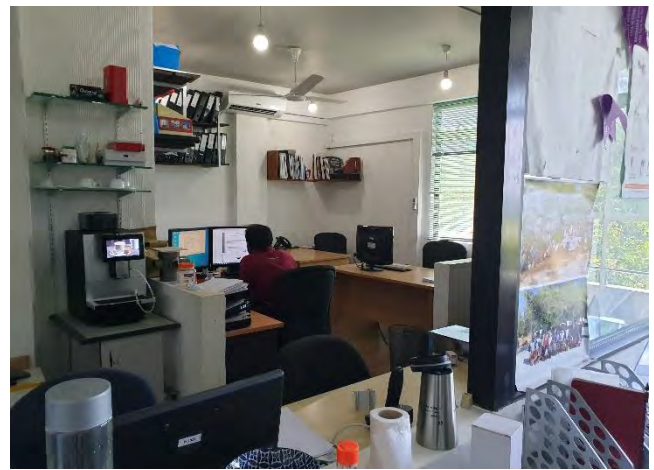


Figure 180– Image showing use of blinds and LED lights in the office

Thermal Comfort System and Building Operation

Entire office space is served by multiple split ACs and window ACs of capacities 1 TR & 1.5 TR respectively. The ACs are not star ated

Air Conditioning:

Set points are generally maintained at 20-22 degree C.

Air Conditioning and artificial lights operational throughout the day from 8am to 5pm.



Figure 181– Images showing wall mounted AC in the office

Renewable Energy

NO

Water Efficiency

Plumbing Fixtures: No low flow fixtures observed in the building

Building Performance

Energy Performance Index (EPI) -kWh/m²/year -

Water Consumption per Capita (m³/person) -

12) PwC Maldives Office Building, Male



Figure 182 –View of the Office

Building Information

City & Year of Construction	Male, 2008
Area (in sq. Meter)	297.3
No of Floors	1
Number of Occupants	30
Building Operational Hours	8 am to 5 pm (9 hrs)
Connected Load	NA
Power Backup	NA
No of Energy meters	2
No of Water Meters	2

Building Design

Orientation: Window opening on 2 sides (west & north side) of the building

Layout: Cellular layout on the outer facade and open plan layout in the center

Daylight:

Daylight is received in the cabins and conference room. Open plan layout does not receive daylight due to the layout

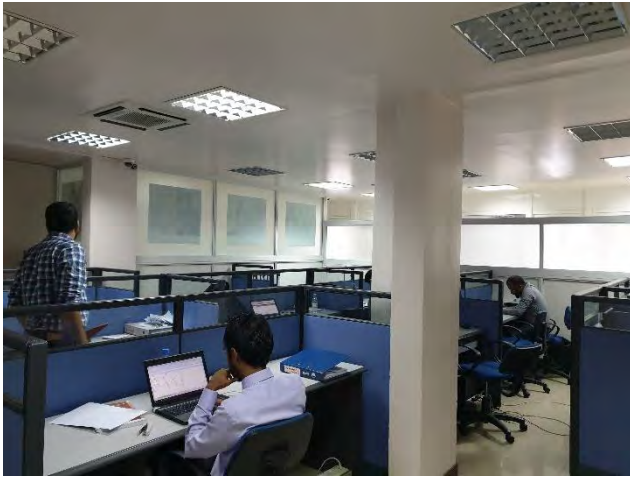


Figure 183– Image showing low daylight in the open layout workspaces

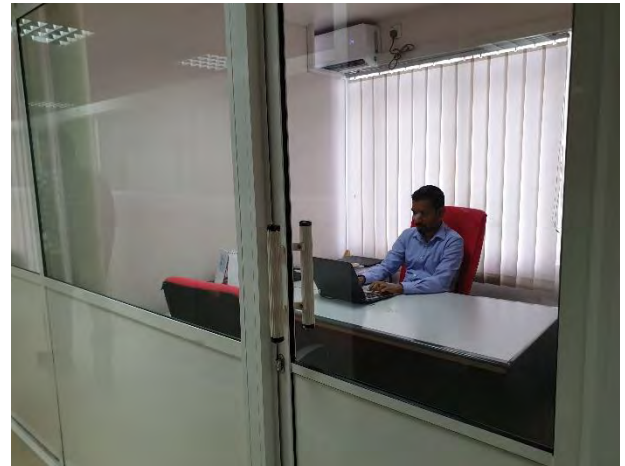


Figure 184– Image showing good daylight in the cabins



Figure 185– Image showing good daylight in the conference room



Building Envelope

Building Façade:

Window to wall ratio and shading

Window to Wall Ratio of 15%-20%. No external shading is provided. Blinds are down throughout the day obstructing daylight.

Glazing

Single glazing provided in the windows with Aluminum frame.

Roof Material & use of insulation

Walls,

Wall Material : 150 mm Masonry block Wall. No insulation on roof



Figure 186 – Images showing low window to wall ratio and use of blinds

Lighting

Artificial Lighting:

The office uses Fluorescent Tube Lights - T8 Phillips -18W . There no lighting controls.

All office spaces uses artificial lighting. They use blinds and does not take daylight in day time



Figure 187– Images showing Fluorescent Tube Lights installed and manual switches to operate lights in the office

Thermal Comfort System and Building Operation

Air Conditioning:

Entire office space is served by multiple non star rated split ACs and window ACs.

Set points are generally maintain at 20-22 degree C.

AC s are manually controlled.To maintain energy efficiency, not all Acs are operated at same time. Set points are generally maintain at 20-24 degree C.



Figure 188– Images showing wall and ceiling mounted AC in the office

Renewable Energy

NO

Water Efficiency

Plumbing Fixtures:

No low flow fixtures observed in the building

Building Performance

Energy Performance Index (EPI) -kWh/m2/year

118.21

Water Consumption per Capita (m3/person)

-

Residential Buildings:

13) Raivilla Residence, Male



Figure 189 –View of the Residential Building

Building Information

City & Year of Construction

Male

Area (in sq. Meter)	84
No of Floors	1, Apartment- 4bhk
Number of Occupants	6
Building Operational Hours	Weekdays - 7pm - 8am (13 hours) Weekends - 24 hours
Connected Load	NA
Power Backup	NA
No of Energy meters	1
No of Water Meters	1

Building Design

Orientation:	Window opening on 2 sides with balcony. The front side of the residence and 2 bedrooms have balcony and window openings towards North.
Layout:	Central living room with open kitchen. 4 Bedrooms with attached bathroom.
Daylight:	Good Daylight is received in living room. No daylight received in 2 bedrooms due to adjacent building.

Building Envelope

Building Façade:	
Window to wall ratio and shading	Window to Wall Ratio of 15%-20%. No external shading is provided.
Glazing	Single tinted glazing provided in the windows with Aluminum frame.
Walls, Roof Material & use of insulation	Wall Material : 200 mm Masonry external wall. Roof Material: 150 mm RC flat roof

Lighting

Artificial Lighting:	The residential apartment uses CFL- ceiling & wall mounted for lighting . There no lighting controls. Artificial Lighting is used mostly at night and on weekends
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Thermal Comfort System

Air Conditioning:	This residence does not have AC's and occupants use fans and natural ventilation for thermal comfort. The fans are not star rated Thermal discomfort is experienced by occupants as there is no natural cross ventilation.
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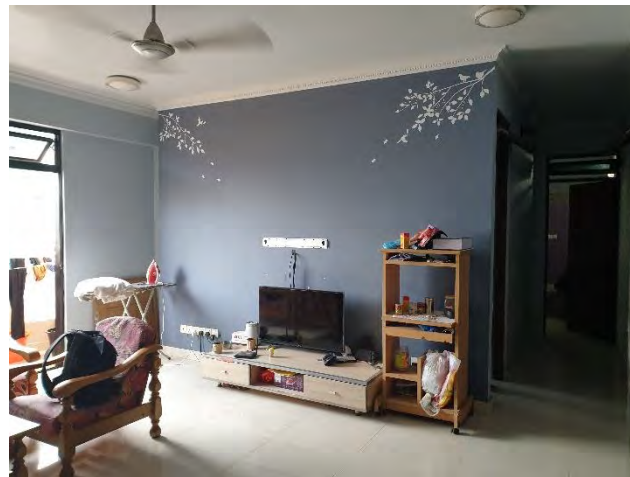


Figure 190– Image showing good daylight in the living room, ceiling mounted lightings and fans used for thermal comfort

Renewable Energy

NO

Water Efficiency

Plumbing Fixtures: No low flow fixtures and no hot water is provided

Building Performance

Energy Performance Index (EPI) -kWh/m²/year 37

Water Consumption per Capita (m³/person)

14) Sisilhiya Apartment (7th floor), Male

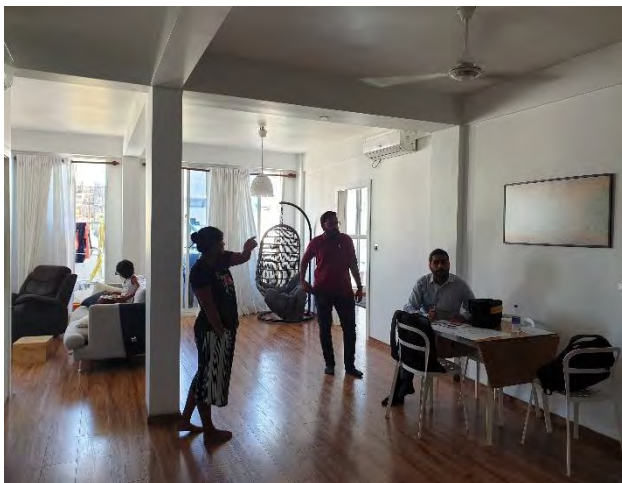


Figure 191 –View of the Apartment

Building Information

City & Year of Construction Male, 2016

Area (in sq. Meter) 140

No of Floors	1 (7th floor) , Apartment- 3 bhk
Number of Occupants	4
Building Operational Hours	24 hours
Connected Load	NA
Power Backup	NA
No of Energy meters	1
No of Water Meters	NA

Building Design

Orientation:	Square Apartment with exposed facades on 3 sides (North, East & West) & Balcony
Layout:	Central living room with open kitchen. 3 Bedrooms with attached bathroom. The layout enables effective cross ventilation throughout the day.
Daylight:	The entire apartment receives natural daylight throughout the day.

Building Envelope

Building Façade:	
Window to wall ratio and shading	Window to Wall Ratio of 15%-20%. High glazing ratio with No shading observed in Master Bedrooms. Recessed Windows of other bedrooms are shaded using a void.
Glazing	Single glazing provided in the windows with blue tinted and Aluminum frame
Walls, Roof Material & use of insulation	Wall Material: 200 mm Masonry external wall. No insulation on roof Plenty of daylight is available and penetrated in residence so they don't use artificial lighting in daytime



Figure 192 –Image showing good daylight in the bedroom



Figure 193 –Images showing recessed windows in the bedroom

Lighting

Artificial Lighting:

The residential apartment uses CFL- ceiling & wall mounted for lighting . There no lighting controls.

Plenty of daylight is available and penetrated in **residence so they don't use artificial lighting in day tim**

Thermal Comfort System

Air Conditioning:

The apartment is having non star rated split AC of capacities 1 TR and 1.5 TR in all spaces like living room, bedroom, common space etc.

However, it was observed that use of AC is very limited in day time

The building is naturally ventilated and comfortable during daytime using ceiling fans only and thereby no ACs and no artificial lighting is used.

AC are used for 5 hours during the night time with setpoint of 20-22 deg c along with ceiling fans.



Figure 194– Images showing lights and fans installed in the apartment



Figure 195– Images showing wall mounted ACs installed in the apartment

Renewable Energy

NO

Water Efficiency

Plumbing Fixtures:

No low flow fixtures observed in the apartment. Hot water provision using geysers

Building Performance

Energy Performance Index (EPI) -kWh/m2/year

-

Water Consumption per Capita (m3/person)

-

15) Sisilhiya Apartment (6th floor), Male

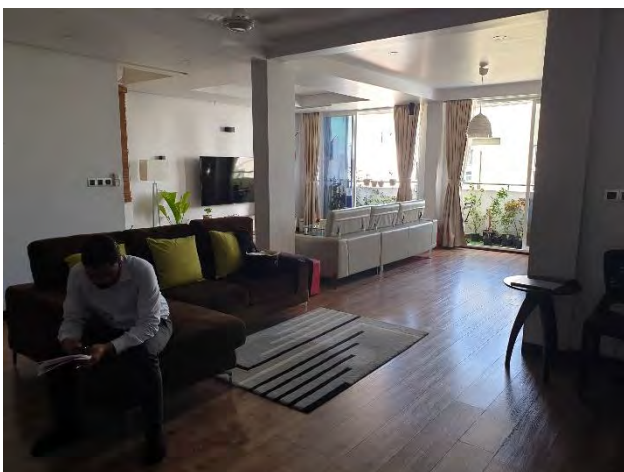


Figure 196 –View of the Apartment

Building Information

City & Year of Construction

Male, 2016

Area (in sq. Meter)

216

No of Floors	1 (6 th floor) , Apartment- 5 bhk
Number of Occupants	7
Building Operational Hours	24 hours
Connected Load	NA
Power Backup	NA
No of Energy meters	1
No of Water Meters	NA

Building Design

Orientation:	Rectangular Apartment with exposed facades on 3 sides (North, East & West) & Balcony
Layout:	Central living room with open kitchen. 3 Bedrooms with attached bathroom. The layout enables effective cross ventilation throughout the day.
Daylight:	Dining and Kitchen do not get natural daylight due to position of adjacent building. Rest all areas receive natural daylight throughout the day.

Building Envelope

Building Façade:	
Window to wall ratio and shading	Window to Wall Ratio of 15%-20%. High glazing ratio with No shading observed in Master Bedrooms. Recessed Windows of other bedrooms are shaded using a void.
Glazing	Single glazing provided in the windows with blue tinted and Aluminum frame
Walls, Roof Material & use of insulation	Wall Material: 200 mm Masonry external wall. No insulation on roof

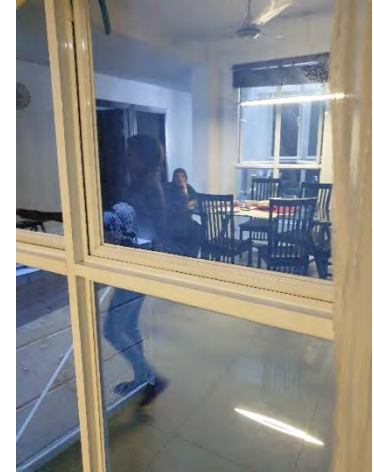


Figure 197 –Images showing good daylight in the bedroom and living room

Figure 198 –Image showing blue tinted glasses on the window

Lighting

Artificial Lighting:

The residential apartment uses CFL- ceiling & wall mounted for lighting . There no lighting controls.



Figure 199 –Images showing lighting system installed in the apartment

Thermal Comfort System

Air Conditioning:

The apartment is having non star rated split AC of capacities 1 TR and 1.5 TR in all spaces like living room, bedroom, common space etc.

However, it was observed that use of AC is very limited in day time

The building is naturally ventilated and comfortable during daytime using ceiling fans only and thereby no ACs and no artificial lighting is used.

AC are used for 5 hours during the night time with setpoint of 20-22 deg c along with ceiling fans.



Figure 200– Image showing fan installed in the apartment



Figure 201– Image showing wall mounted AC installed in the apartment

Renewable Energy

NO

Water Efficiency

Plumbing Fixtures:

No low flow fixtures observed in the apartment. Hot water provision using geysers

Building Performance

Energy Performance Index (EPI) -kWh/m2/year

-

Water Consumption per Capita (m3/person)

-

16) Renaatus Building (6th floor), Hulhumale

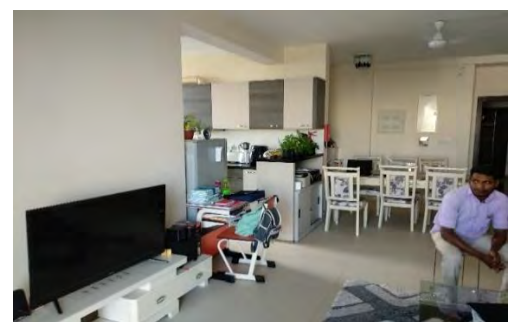


Figure 202 –View of the building

Figure 203 –View of the Apartment

Building Information	
City & Year of Construction	Hulhumale, 2018
Area (in sq. Meter)	130
No of Floors	1 (6 th floor), Apartment- 3 bhk
Number of Occupants	5
Building Operational Hours	24 hours
Connected Load	NA
Power Backup	NA
No of Energy meters	1
No of Water Meters	1

Building Design	
Orientation:	Window opening on 2 sides (East & South) & balcony. The ventilation of the flat is very good
Layout:	Central living room with open kitchen, 2 bedrooms with attached washrooms. The layout enables effective cross ventilation throughout the day
Daylight:	The openings from kitchen and living room provides sufficient daylight in the living room. One bedroom also receives sufficient daylight through out the day

Building Envelope	
Building Façade:	
Window to wall ratio and shading	Window to Wall Ratio of 15%-20%.
Glazing	Single glazing provided in the windows with tint and Aluminum frame.
Walls, Roof Material & use of insulation	Roof Material: Concrete block for roof

Lighting	
The residential apartment uses LED for lighting . There no lighting controls.	
Artificial Lighting:	Plenty of daylight is available and penetrated in residence so they don't use artificial lighting in day time

Thermal Comfort System	
------------------------	--

Air Conditioning:

The apartment is having non star rated split AC of capacity 1TR in all spaces like living room, bedroom, common space etc. Fans are also installed to achieve thermal comfort.

However, it was observed that use of AC is very limited in day time for common spaces. Children uses AC for 12-14 hours a day.



Figure 204– Image showing fan and wall mounted AC installed in the apartment

Renewable Energy

NO

Water Efficiency

Plumbing Fixtures:

No low flow fixtures observed in the apartment

Building Performance

Energy Performance Index (EPI) -kWh/m2/year

-

Water Consumption per Capita (m3/person)

-

Hotels and Guest Houses:

17) Champa Central Hotel, Male



Figure 205 –View of the building

Building Information

City & Year of Construction	Male, 1987 & 2003
Area (in sq. Meter)	5740.8
No of Floors	10
Number of Occupants	74 rooms with 80% occupancy plus 119 staff
Building Operational Hours	24 hrs
Connected Load	Na
Power Backup	195 KVA DG sets (Not operational)
No of Energy meters	11
No of Water Meters	NA

Building Design

Orientation:	Rectangular building block with longer facades facing North and South orientations. However, adjacent buildings are closely placed on all 3 sides (North, South and East)
Layout:	Doubly loaded corridor with rooms on both sides.

Daylight:

Natural daylight received in very few rooms. Many rooms do not have any windows or balconies for light and ventilation. No natural light received in corridors



Figure 206– Image showing good daylight in conference room

Building Envelope

Building Façade:

Window to wall ratio and shading

Window to Wall Ratio of 40%-45%. No shading is provided on windows. However adjacent buildings are very closely placed affecting daylight and shading.

Glazing

Windows: Single glazing provided in the windows with dark blue tint.

Walls, Roof Material & use of insulation

Wall Material: Concrete, masonry walls. Roof Material: 150 mm concrete slab roof

Lighting

Artificial Lighting:

The building uses LED (12, W, 18W, 25W & 7 W) for interior lighting. There are occupancy sensor and dim lighting sensor in Corridors, Staircase & Toilets.

The building uses LED (200 W & 30W for Façade) for exterior lighting

Hotel use lot of artificial lighting entire day. Since it's a hotel so operation of lighting can not be controlled. Lighting installed is already efficient technology

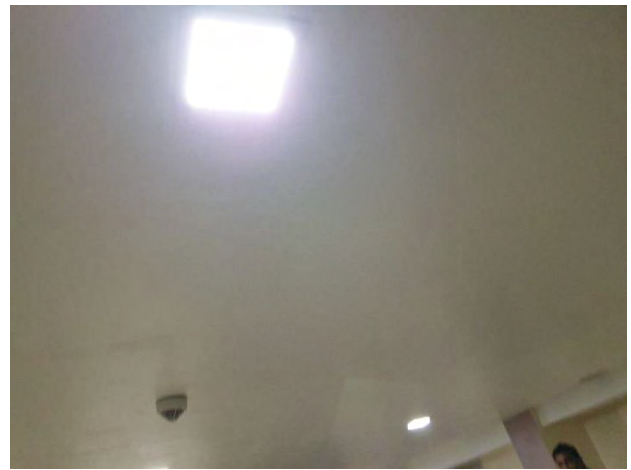


Figure 207– Image showing LED lighting installed in the building

Thermal Comfort System and Building Operation

Air Conditioning:

All guest rooms are having individual ACs of capacity 1 TR. Banquet areas is being served by 8 TR Daikin VRV system. Banquet is operational through out the year. Hotel records 70% as average occupancy per year. Offices, reception and restaurant are also served by Split ACs

The individual split ACs are not star rated

The hotel has high occupancy of almost 80% throughout the year. Due to limited provision of Natural ventilation, hotel guests use artificial lighting and air conditioners on throughout the time.



Figure 208– Images showing indoor ceiling mounted units of VRV system in the banquet areas

Renewable Energy

No

Water Efficiency

Plumbing Fixtures:

Dual flush fixtures observed in toilets. No low flow fixtures used in bathrooms.

Building Performance

Energy Performance Index (EPI) -kWh/m²/year

-

Water Consumption per Capita (m³/person)

-

18) Island Beach House Hotel, Hulhumale



Figure 209 –View of the building

Building Information

City & Year of Construction	Hulhumale, 2017
Area (in sq. Meter)	150
No of Floors	7
Number of Occupants	16 rooms with 80% occupancy
Building Operational Hours	24 hrs
Connected Load	NA
Power Backup	NA
No of Energy meters	12
No of Water Meters	11

Building Design

Orientation:

Rectangular building block with longer facades facing North and South orientations. However, exposed facades and building openings- windows and balconies are provided on East and West facade.

Layout:

Rooms are facing East and West side. All rooms are provided with windows for light and ventilation

Daylight:

Daylight is received in all hotel rooms.



Figure 210– Images showing good daylight in reception area

Building Envelope

Building Façade:

Window to wall ratio and shading

WWR is around 30%. No shading has been provided. Few Windows are partially shaded by virtue of Balcony on upper floors.

Glazing

Single glazing with blue tinted glass

Walls, Roof Material & use of insulation

No Data Available



Figure 211– Images showing shading provided by the balcony



Figure 212– Images showing blue tinted glass and optimal window to wall ratio

Lighting

The building uses LED for interior lighting. There are no lighting control systems.

Artificial Lighting:

Hotel use lot of artificial lighting **entire day**. **Since it's** a hotel so operation of lighting can not be controlled. Lighting installed is already efficient technology

Thermal Comfort System and Building Operation

All guest rooms are having individual ACs. Offices, reception and restaurant are also served by Split ACs

Air Conditioning:

The ACs are not star rated

The building has a naturally ventilated entrance lobby. No airconditioners are provided in the main lobby.



Figure 213– Image showing wall mounted split ACs in guest rooms



Figure 214– Image showing use of natural ventilation in the lobby area

Renewable Energy

No

Water Efficiency

Plumbing Fixtures:

Dual flush fixtures observed in toilets. No low flow fixtures used in bathrooms.

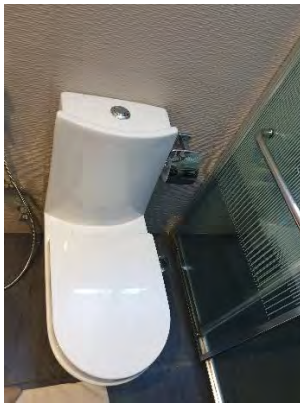


Figure 215– Image showing Dual flush fixtures



Figure 216– Image showing faucet in toilets

Building Performance

Energy Performance Index (EPI) -kWh/m2/year	359.46
Water Consumption per Capita (m3/person)	-

19) Beach Grand and Spa Premium Hotel, Hulhumale



Figure 217 –View of the building

Building Information

City & Year of Construction	Hotel
Area (in sq. Meter)	Hulhumale, 2016

No of Floors	176.5
Number of Occupants	4
Building Operational Hours	11 rooms with 70% occupancy
Connected Load	24 hrs
Power Backup	NA
No of Energy meters	NA
No of Water Meters	NA

Building Design

Orientation:	Rectangular building block with longer facades facing North and South orientations.
Layout:	Rooms are facing North and South side. Most Rooms are provided with windows for light and ventilation
Daylight:	Sufficient natural daylight is not received in all rooms.

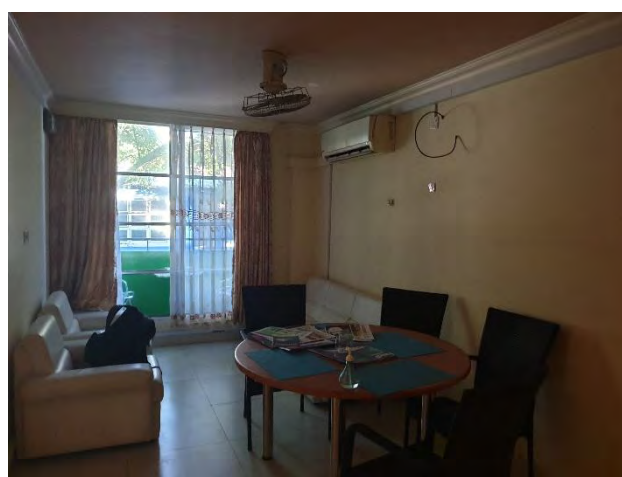
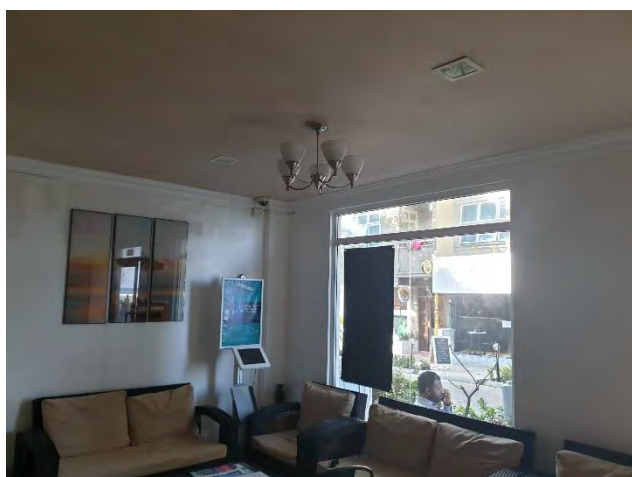


Figure 218– Images showing good daylight in reception area

Building Envelope

Building Façade:	
Window to wall ratio and shading	High window to wall ratio in bedrooms. Most windows are shaded by virtue of balconies. No shading is designed in other windows.
Glazing	Single Glazing with dark blue tint with Aluminum frame
Walls, Roof Material & use of insulation	Wall Material: Concrete. Roof is made of concrete slab



Figure 219– Image showing high window to wall ratio in rooms



Figure 220– Image showing blue tinted glass

Lighting

Artificial Lighting:

Mixed lighting - LED and CFL is provided in rooms. There are Occupancy Sensor in Staircase

Hotel use lot of artificial lighting entire day. Since it's a hotel so operation of lighting can not be controlled.

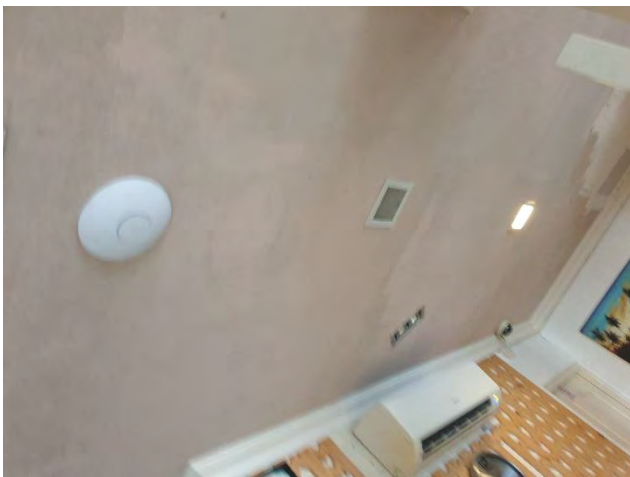


Figure 221– Image showing LED lighting installed in the reception area

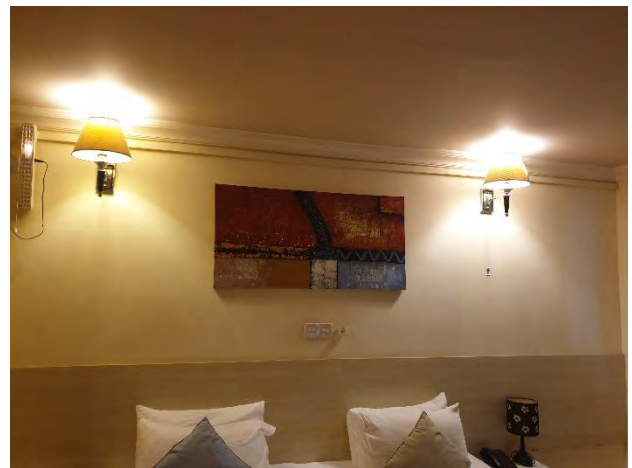


Figure 222– Image showing lighting installed in the rooms

Thermal Comfort System and Building Operation

Air Conditioning:

All guest rooms are having individual Acs. Offices, reception and restaurant are also served by Split ACs

The ACs are not star rated



Figure 223– Image showing wall mounted split ACs in reception area



Figure 224– Image showing wall mounted split ACs in guest rooms

Renewable Energy

No

Water Efficiency

Plumbing Fixtures:

Dual flush fixtures observed in toilets. No low flow fixtures used in bathrooms.



Figure 225– Image showing Dual flush fixtures



Figure 226– Image showing faucet in toilets

Building Performance

Energy Performance Index (EPI) -kWh/m2/year 280.48

Water Consumption per Capita (m3/person) -

8.1.2. Occupant Survey Results

To evaluate the overall performance of the building and its workspace based on the air quality, thermal comfort and lighting quality, occupant survey with the building occupants was undertaken in government and commercial buildings using the survey forms to gather requisite information. The survey forms were structured in the following manner:

- demographics information of the respondents that covered gender, age, working hours, years of services and their profession
- information on the workspace arrangement with respect to window and exterior wall of the building
- Satisfaction level on the air quality in the office space and its effect on task performed
- Satisfaction level on the thermal comfort in the office space and its effect on task performed
- Satisfaction level on the lighting quality in the office space and its effect on task performed
- Mode of controlling the thermal comfort and lighting in the office space

A total of 69 respondents took part in the survey from different government and commercial buildings and the occupant survey results are provided below. The survey forms used in the assessment is provided in annexure 2.

Demographic Information :

The results are provided in the below in Figure 227.

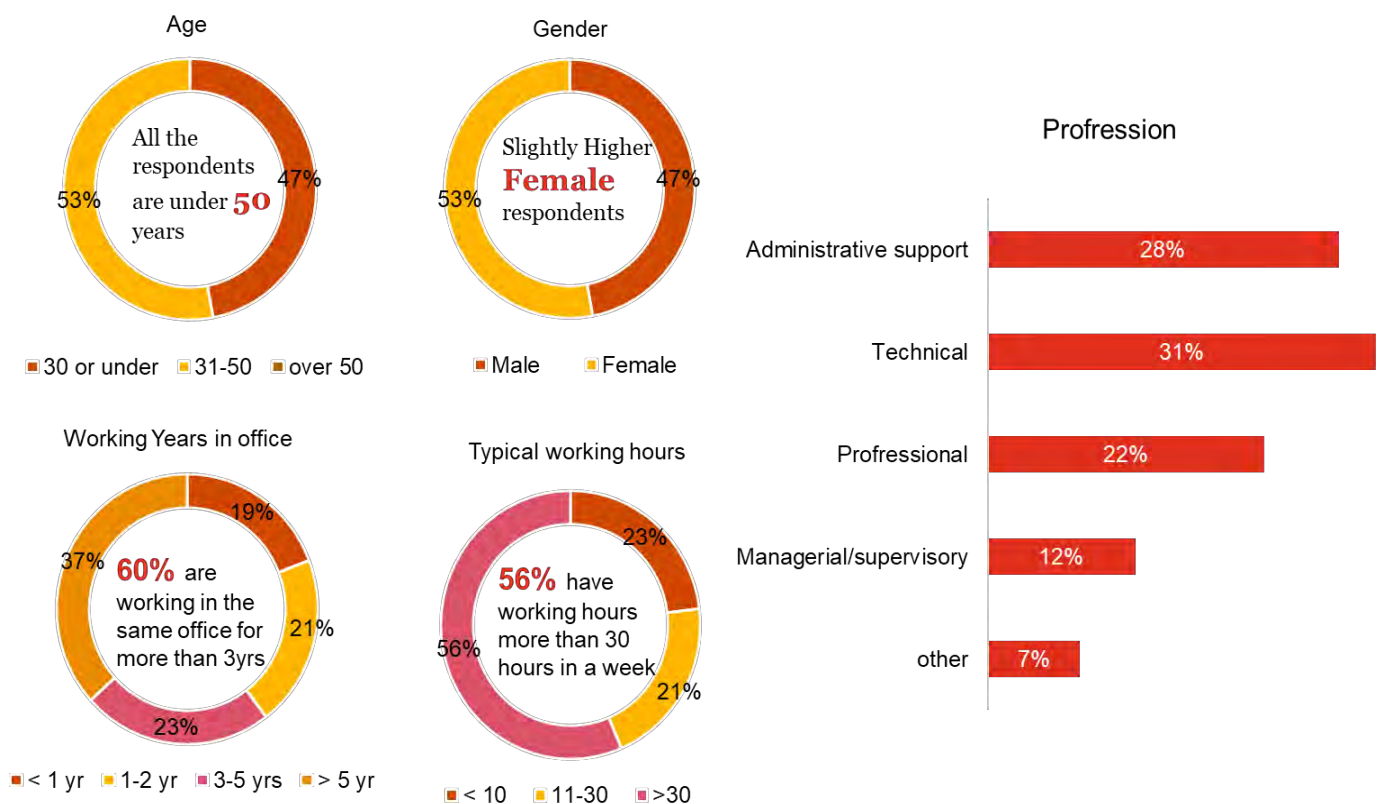


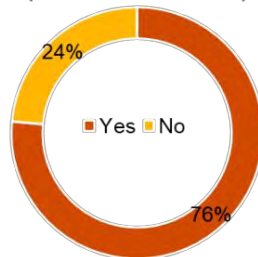
Figure 227: Demographic information from the survey

Personal Workspace Information :

The results are provided in the below in Figure 228.

Are you seated near an exterior wall?
(within 15 feet)

76%
Of the respondents are seated near an exterior wall



Are you seated near a window?
(within 15 feet)

63%
Of the respondents are seated near window

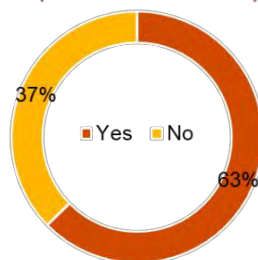


Figure 228: Workspace information from the survey

Air Quality Survey Results :

The results are provided in the below in Figure 229.

How Satisfied are you with the air quality in your workspace (stuffy/stale air or clean air)

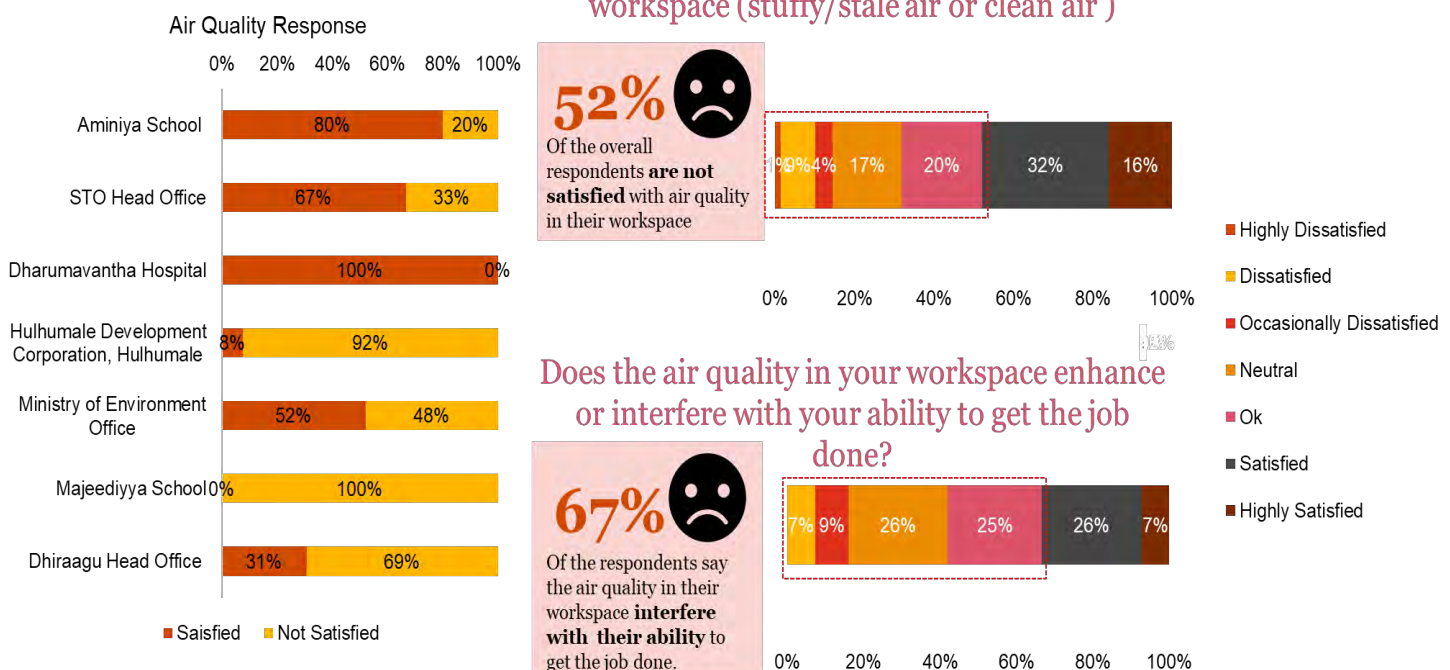
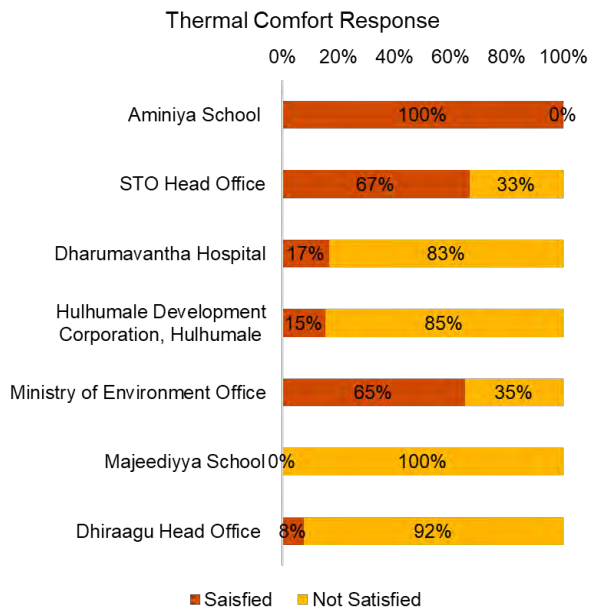
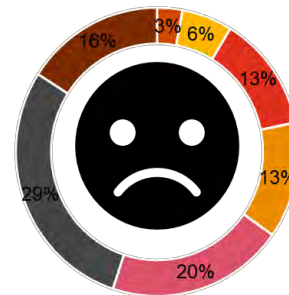


Figure 229: Air quality survey results

Thermal Comfort Quality Survey Results :
The results are provided in the below in Figure 230.



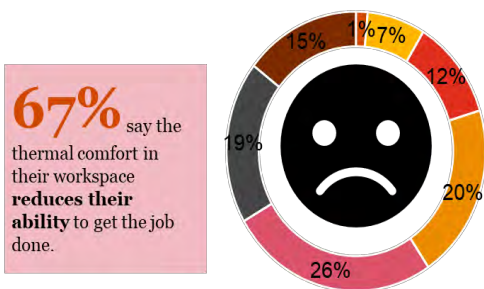
How Satisfied are you with the thermal comfort in your workspace



55% Of the overall respondents are not **happy with thermal comfort** in the workspace

- Highly Dissatisfied
- Occasionally Dissatisfied
- Ok
- Highly Satisfied
- Dissatisfied
- Neutral
- Satisfied

Does thermal comfort enhance or interfere with your ability to get the job done?



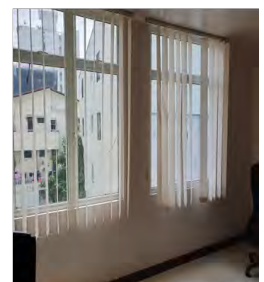
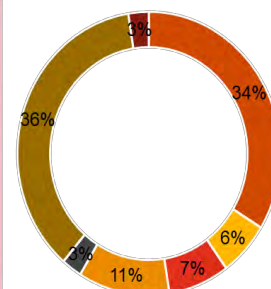
67% say the thermal comfort in their workspace **reduces their ability** to get the job done.

- Highly Dissatisfied
- Occasionally Dissatisfied
- Ok
- Highly Satisfied
- Dissatisfied
- Neutral
- Satisfied

List the means through which you personally adjust or control to achieve thermal comfort in your office space

36% Of the respondents say they have **no means** to achieve thermal comfort while

34% say they **adjust window blinds or shades** to achieve thermal comfort

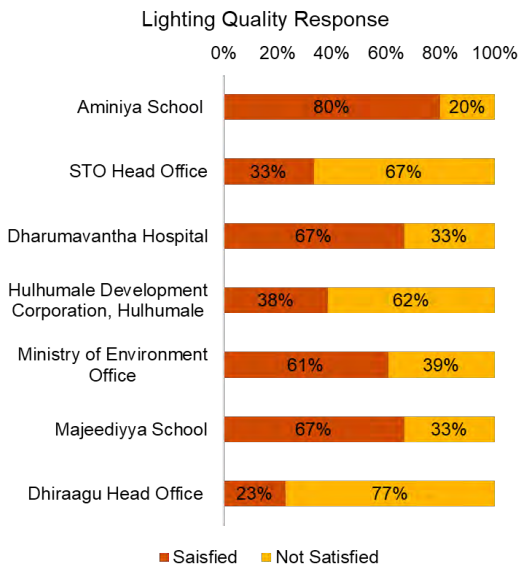


- Window blinds or shades
- Portable Fans
- Door to Indoor Space
- Door to exterior space
- Other
- Operable Window
- Adjustable air vent in wall or ceiling
- Air Conditioner
- None

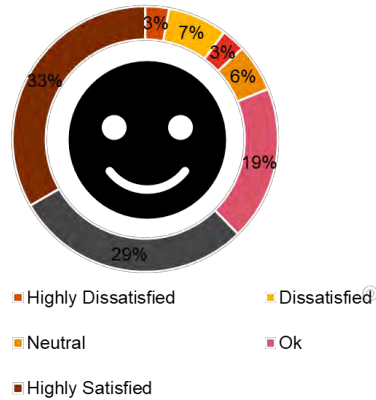
Figure 230: Thermal Comfort survey results

Lighting Quality Survey :

The results are provided in the below in Figure 231.

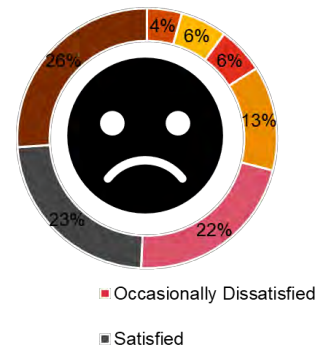


How Satisfied are you with the amount of light in your workspace



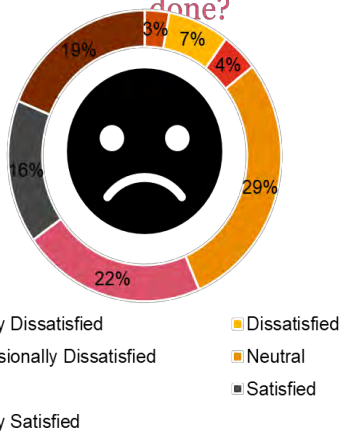
62% Of the over all respondents are **happy with amount of light** in the workspace

How Satisfied are you with the visual comfort of the lighting in your workspace



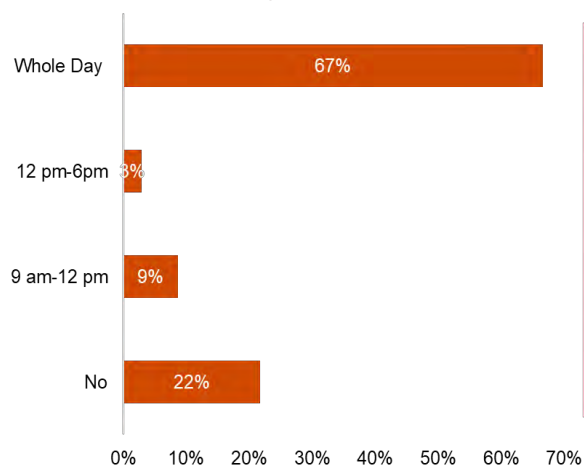
51% Of the respondents **feel visual discomfort** due to the lighting in the workspace

Does lighting quality enhance or interfere with your ability to get the job done?



65% say the lighting quality in their workspace **reduces their ability** to get the job done.

Do you get natural daylight in your office/workstation



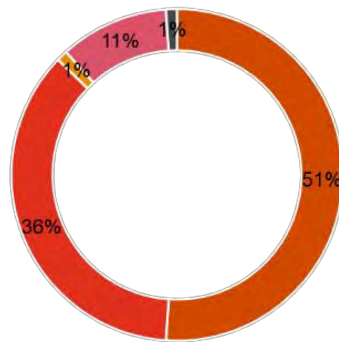
67% Of the respondents say they that their workspace get natural light **throughout the entire day.**

However 22% say that there is no natural light

Which of the following controls do you have over the lighting in your workspace

51%
Of the respondents say they **use light switch**

36% say they adjust window blinds or shades to control lighting in the workspace



- Light Switch
- Window blinds or shades
- None
- Light Dimmer
- Desk/Task Lights
- Other



Figure 231: Lighting quality survey results

Common issues faced by the building occupants in Government and Commercial Buildings: The results are provided in the below in Figure 232.

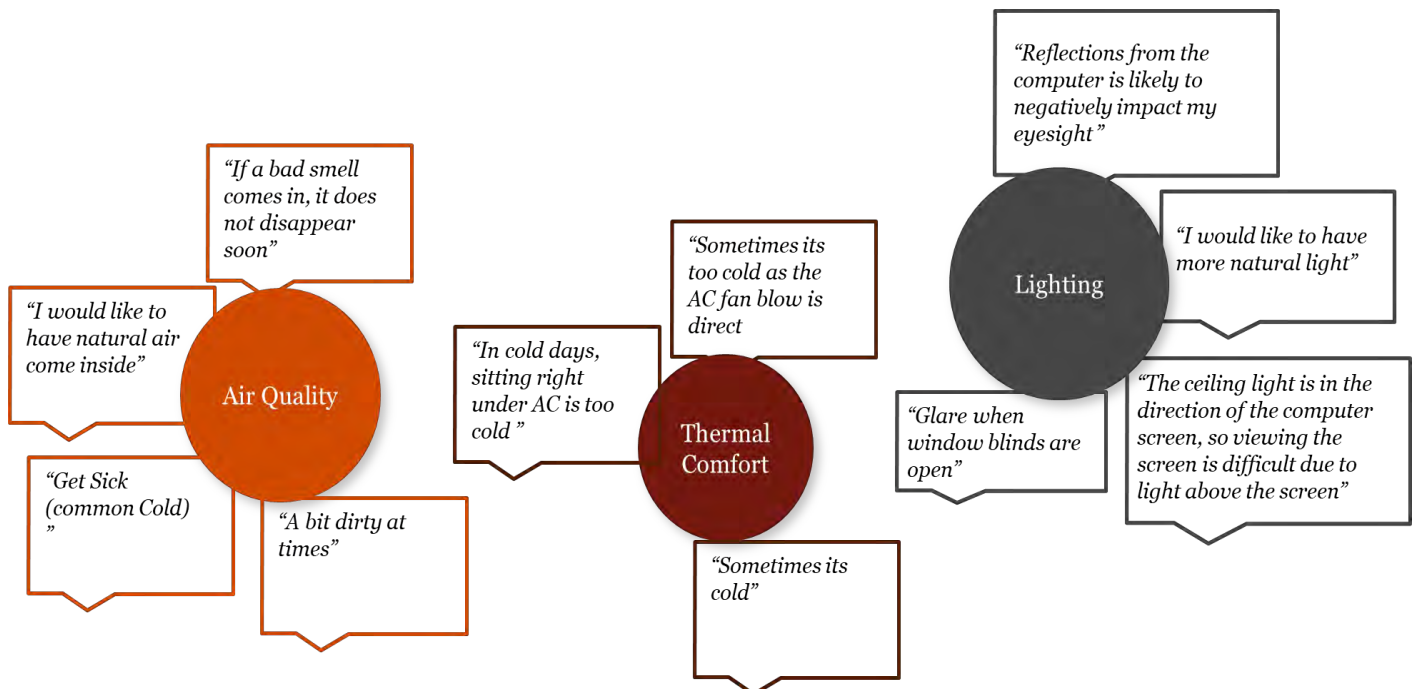


Figure 232: Common issues that the building occupants face

Overall performance of the building and its workspace:

The results are provided in the below in Figure 233.

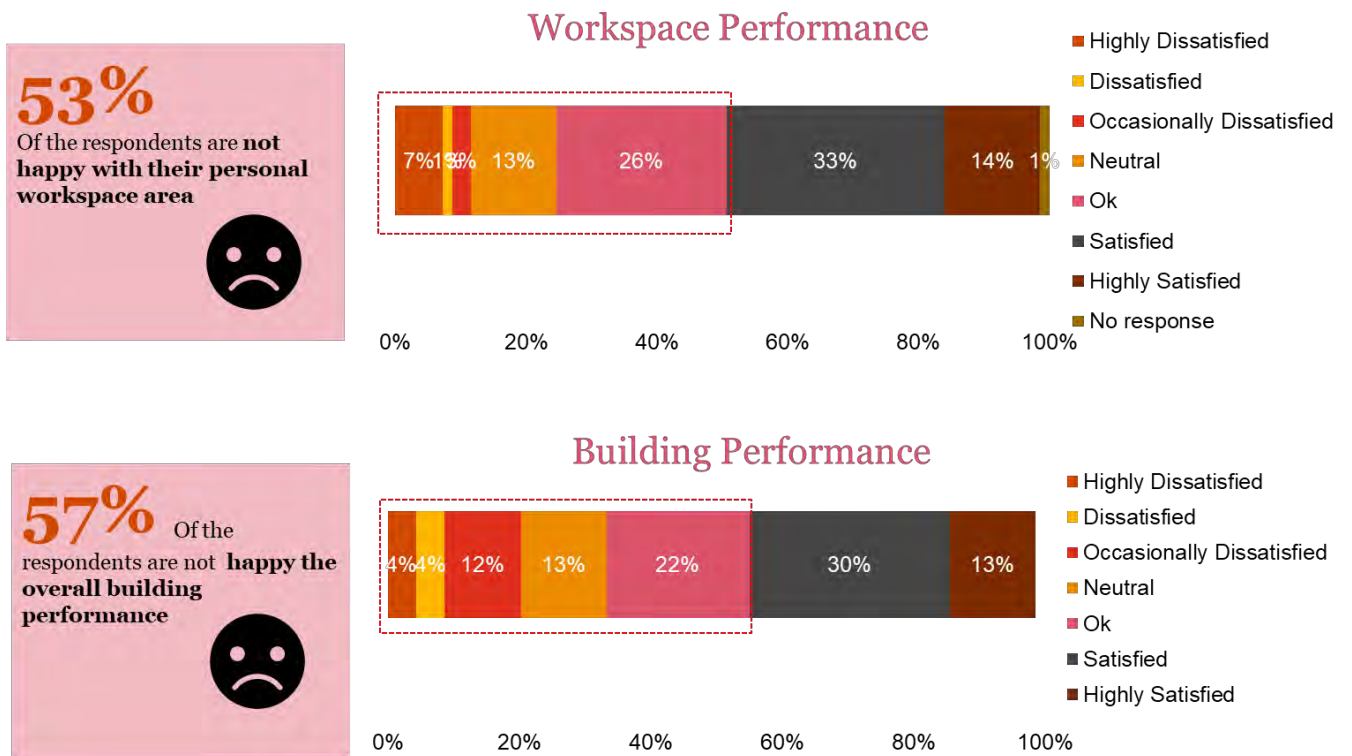


Figure 233: Overall building and its workspace performance

9. Outcome from the detailed energy assessment and occupancy survey

The detailed energy assessment of the buildings facilitated in-dept understanding of the building sector in Maldives. Some of the key observation gathered from the assessment of the buildings are:

- In Male, buildings are closely spaced due to scarcity of land and hence are oriented in random manner. However, even when the orientation was good, the closely spaced buildings impacted the natural daylight on the lower floors of the buildings.
- Most of the buildings have high window to wall ratio (50%-60%), single glazing with aluminum frame and no shading. However, as mentioned earlier, the closely spaced buildings provided shading to the lower floors of the buildings limiting natural day light.
- The high window to wall ratio with single glazing provided good daylight on the upper floor of the buildings but lead to excessive solar gains and glare inside the building. Hence, internal blinds were used to reduce the glare and heat gain.
- Some of the buildings use blue tinted glazing on the windows that effectively reduced the indoor heat gain, but it also limited the daylighting leading to use of artificial lightings for performing the required tasks.
- Concrete masonry blocks are common materials used for walls and roof construction in most of the buildings. There is no insulation provided on the roof, however, in some of the buildings the use of solar roof top provides the necessary insulation against solar radiation on the roof.
- Fewer buildings have provided landscaping for good air quality and ventilation
- Most of the buildings uses efficient LED for artificial lighting and use manual controls to manage the indoor lighting (lux) level. However, large and newer buildings like Dharumavantha Hospital in Male use automated control such as occupancy sensor for controlling the lighting as an energy conservation measure.
- Most of the buildings uses either wall mounted, or ceiling mounted split air conditioner for achieving the desired thermal comfort, but the air conditioners are non-star rated. However, some of the larger government and commercial buildings such as STO trade center (only Supermarket), Dharumavantha Hospital use efficient VRV or Chiller systems for the thermal comfort. Dharumavantha Hospital was the only building with building management system to control the chiller system.
- Most of the buildings operated air conditioner at a set point of 22 degree and below.
- Only one of the building (HDC office building) had energy conservation signs installed in their premises.
- On site renewable energy system, solar roof top in particular, was installed only in two government buildings (ME Office and Villa College). Some of the large buildings such as Champa Hotel or Dharumavanta Hospital uses diesel generating system or battery powered UPS for power back-up.
- None of the buildings use low-flow plumbing fixtures in the washrooms.
- The average Energy Performance Index (EPI) ranges evaluated from the annual energy bills collected during the detailed assessment as well as from the data shared by the stakeholders during local condition assessment for each building typologies is provided in Table 22.

Table 22: Average EPI ranges for building typologies in Male & Hulhumale

Average EPI range for the building typologies in Male & Hulhumale				
Parameters	Residential	Commercial	Government	Hotels and Guest Houses

Energy Performance Index EPI Range (in kWh/sq.m/ year)*	47-378	118 - 405	83.8-540	250-400
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*EPI Range was adjusted based on sample of buildings whose consumption and built up area data was available.

The assessment further helped in establishing a base case on the design, construction practices and current performance levels of the buildings in terms of air quality, thermal comfort levels and lighting quality in Maldives which will serve as input data to the computer software to carry out energy simulations for identifying appropriate energy efficiency strategies for the buildings. As mentioned earlier, the assessment also identified some of the immediate low-cost or no cost energy and water efficiency strategies that are applicable to the existing buildings in Maldives and these are as follows:

- Operating air conditioners at 25 deg or above set point
- Performing regular maintenance of mechanical and electrical equipment in the buildings so that they operate efficiently and keeping records of the same
- Installing energy conservation **signs such as “Switch-off Lights when not in use” and many such that** encourages occupants to adopt energy conservation practices.
- Ensuring complete insulation of the air-conditioned space and conducting regular checks
- Creating awareness on energy efficiency and conservation practices among all demographics of people
- Use of automated lighting controls such as occupancy sensors
- Replacing existing toilet fixture especially faucets with low flow fixtures and use of control systems
- Market Transformation to EE appliance: One of the point raised in the stakeholder engagement is that the temperatures in Maldives have been increasing year on year and as the economy grows, more and more people will have income level to afford air conditioner to achieve thermal comfort in the coming years. Therefore, the government must encourage the uptake of energy efficient appliances and create a policy ecosystem to drive out inefficient appliances. The Maldives government is already taken forward strides in **this aspect with “Strengthening Low Carbon Energy Island Strategies(LCEI)”** that encompasses projects like financing mechanism for EE appliance, Standards & Labelling of appliance, Life-Cycle Costing based public procurement that targets market transformation to EE appliances in Maldives.

However, some of the energy and water efficiency strategies that incur high capital cost were also identified and they are:

- Use of on-site renewable energy source for captive consumption wherever possible. Solar roof top being the most promising strategy
- Rainwater harvesting system
- Replacement of existing air-conditioners with EE alternatives

10. Way Forward

The assessments undertaken till date, provided vast information on the building sector in Maldives which will be used to develop an effective energy efficiency guidelines. In line with the consultative approach adopted for the assignment so far, PwC team will continue with following steps:

- **Conduct Energy Simulation :** The detailed energy assessment and occupancy survey established base case scenario for the all the existing building typologies which would serve as an input to the computer software to model these buildings and identify appropriate/optimal energy efficiency strategies for the buildings.
- **Initial Energy Efficiency Guideline Framework for Buildings and Stakeholder Consultation:** Initial framework of the energy efficiency guidelines will be developed and accordingly stakeholder consultation shall be organized to seek buy-in on the framework and identified energy efficiency and water strategies from the energy simulations. In amidst of COVID-19 and the associated challenges of travel ban, PwC team with support from Ministry of Environment shall conduct online consultation with maximum stakeholder participants.
- **Final Energy Efficiency Guideline for Buildings:** Once the feedback and agreement from the stakeholders on the energy and water efficiency strategies is received, the PwC team shall develop the final version of energy efficiency guideline and share the same with Ministry of Environment for final comments and revision.
- **Trainings on Energy Efficiency Guideline:** In parallel to drafting the final energy efficiency guideline, the team shall prepare training materials for the training programs on the same. The PwC team shall seek Ministry **of Environment's support to develop the training plan and conduct trainings once the COVID-19 crisis suffices.**

11. References

- Ministry of Environment and Energy Republic of Maldives- *Maldives Energy Policy & Strategy-2016*
- Ministry of National Planning & Infrastructure-Maldives *Statistical yearbook 2018*
- Ministry of Environment and Energy Republic of Maldives-*Electricity year book 2018*
- Ministry of Construction and Public Infrastructure- Construction Industry Development Section- *Maldives Nation Building Policy 1st Edition 2008*
- Ministry of Housing & Environment 2010- *Maldives National Energy Policy & Strategy*
- IFC World Bank Report -*Green buildings market intelligence*
- Mariyam Rashfa, Sept 2013, *Developments in the Construction Sector of Maldives*
- Flora Bernard, Thibault Ben Khelil, Vincent Pichon, Léo Tissot, Nov 2010, *The Maldives'2009 Carbon Audit*: Ministry of Housing and Environment
- Aminath Rasheed, 2012, *Optimizing Thermal Comfort through Passive Building Design in Maldives*, a thesis submitted to Department of Environmental Sciences & Policy of Central European University.
- Maldives Monetary Authority- <http://www.mma.gov.mv/> Website
- Ministry of Energy & Environment- <http://www.environment.gov.mv/v2/en/> -Website
- Ministry of National Planning & Infrastructure- <http://www.planning.gov.mv/MNPI%20EN/index.html> Website
- National Bureau of Statistics, Ministry of Finance & Treasury Male Republic of Maldives, 2014, *Population & Housing Census Statistical Release VI*
- Ministry of National Planning & Infrastructure, Data- *BUILDINGS AUTHORISED FOR CONSTRUCTION AND COMPLETED BY NUMBER AND FLOOR AREA IN MALE' 2010 - 2017*
- Housing Development Corporation- <https://hdc.com.mv/hulhumale/developments/>- website
- Translated documents- Material regulations, Construction Act, Maldives building Code
- Documents collected from local consultants- building typologies & common building material used, air conditioning systems etc.
- STELCO - Electricity Data
- MSWC- Water Data

12. Annexure 1: Detailed Building Energy Assessment Questionnaire

The following questionnaire was used for the detailed energy assessment of the buildings.

Building Overview (To be filled by Building Owner/Tenants)

Name of Owner (Optional)	
City	
Address (Optional)	
Type of building (Tick one of the below)	
<ul style="list-style-type: none"> • Residential Building <ul style="list-style-type: none"> ○ Individual house/office ○ An apartment in a building • Government Building • Commercial Building • Hotel or Guest House building 	
Floor Area/Apartment Area (in m ²)	
<ul style="list-style-type: none"> • More than 100 sq. m • Less than 100 sq. m 	
Number of floors occupied by Owner/Tenant	
Year of construction	
Owned or Rented	
Renovation	
Any change in wall, roof or glass of the building	
Year of renovation	
How many sides of your building is exposed or has window openings?	
1	
2	
3	
4	

Sample Template 1 for electrical load and electricity consumption of the buildings (To be filled by Building Owner/Tenants)

Consumer Name			
Area of the Building (in sq.m)			
Connected Load or Contract Demand (in kVA or kW)			
Electricity consumption from monthly Bill		in kWh	
January		July	
February		August	
March		September	

April		October	
May		November	
June		December	

External Wall type (Tick the correct option) <ul style="list-style-type: none"> • 230 mm RC Wall • 200 mm Masonry • Any other (please mention details of other type)
Roof type (Tick the correct option) <ul style="list-style-type: none"> • 150 mm RC Flat Roof • 200 mm RCC Flat Roof
Any insulation on roof/wall? (If yes then please provide insulation name and thickness in mm) <ul style="list-style-type: none"> • Timber Framing • Steel Truss & Rock wool insulation
Window type (Tick the correct option) <ul style="list-style-type: none"> • Single glazing • Double glazing
Glass (Tinted or Non-tinted)
Glass SHGC
Glazing U-Factor (W/m ² -°C)
Visible light transmittance (VLT)
Any overhang/shading on window
Window frame type (Tick the correct option) <ul style="list-style-type: none"> • Mild Steel • Aluminum, • PVC, • Wood or • Any other
Type of Windows (Tick the correct option) <ul style="list-style-type: none"> • Sliding • Side hung casement
% Window area to total wall area (Tick the correct option) <ul style="list-style-type: none"> • 5%-10% • 10%-15% • 15%-20% • 20%-25% • 25%-30%

Heating Ventilation and Air Conditioning (HVAC) and Hot Water & Pumping
Air Conditioning System <ul style="list-style-type: none"> • Central Plant • Unitary System
No. of Split ACs and their rating
No. of window ACs and their rating
Whether thermostats are installed in the zones where air conditioning is provided

Thermostats Temperature Set Point
Service Hot Water and Pumping
Daily hot water requirement of the building (Litres)
Type of service water heating system installed in the building
Capacity of system (Litres)
Efficiency of service water heating equipment

Lighting System
Internal Lighting
Total Lighting load (kW)
Is there a dedicated feeder for lighting?
Are meters installed to measure lighting consumption?
Type and wattage of lamps predominantly used (LED/FTL/CFL/MH)
Type 1
Type 2
Type 3
Type 4
Type 5
Type 6
Total lighting load
Lighting Controls
Are lighting controls used <input type="checkbox"/> Yes <input type="checkbox"/> No
If used, control type <input type="checkbox"/> Occupancy sensor <input type="checkbox"/> Time clock <input type="checkbox"/> Day light sensor <input type="checkbox"/> Building Management System (BMS)
Type of controls used for different spaces (Share controls details space-wise)
External Lighting
Type, Number of Lighting fixtures and operating hours used Type/Nos./Operating Hours
Type 1
Type 2
Type 3
Type 4
Type and wattage of ballasts (copper or electronic) used
Type 1
Type 2

Type 3
Type 4
Specify lamp efficacy of lighting for exterior building grounds luminaires (Lm/W)
Type 1
Type 2
Type 3
Type 4
Exterior lighting
Specify wattage of Exit signs
For exterior lighting: Wattage of lamp and ballast and number of fixtures
Electrical Power
Sanctioned load (kW / kVA)
Peak load in a year (kW / kVA)
Electricity tariff
Demand charges (per kVA)
Connected Load (kW) or Contract Demand (kVA)
DG/ GG Sets (kVA / kW)
Number
Capacity
Type of Fuel Used
Quantity of fuel used in liters per month
Transformers (kVA)
Type
Number
Capacity
Is automatic tap changer available
<input type="checkbox"/> Yes <input type="checkbox"/> No
Whether transformer test certificates are available (Transformer losses)
Capacitors
Number
Rating (KVA)
Whether Auto Power Correction Relay is installed
<input type="checkbox"/> Yes <input type="checkbox"/> No
Motors
Type
Number
Rating

Operational Details (For Residential Buildings)

Dwelling type (Tick the correct option)

- 1 BHK
- 2 BHK
- 3 BHK

- 4 BHK

Number of people living in the house	
Number of working members in the house	
Average number of AC operational hours in a day	

Operational Details (For Office/ Government Buildings)

Floor/Office	
Total Number of people working in the office	
Service Staff in the office	
Daily Office Timings	
Air Conditioners operational timings	

Operational Details (For Hotel/ Guest House Buildings)

Hotel Room	
Total Number of Rooms	
Average Occupancy of Hotel /Guest House	

Appliance details

Sr. No	Appliance	Count	Wattage	Sr. No	Appliance	Count	Wattage
1	Tube lights			10	AC: Living Room		
2	CFL/Bulbs/LEDs			11	AC: Other Room		
3	Television			12	Air Cooler		
4	Washing Machine			13	Kettle		
5	Laptops			14	Fans		
6	Geyser (Electric)			15	Microwave oven		
7	Refrigerator			16	Grinders		
8	Water pumps			17	Inverters (Y/N)		
9	Toaster			18	Others		

13. Annexure 2: Occupancy Survey Form

The survey forms that was used for the occupancy survey of the buildings is presented below.

BUILDING NAME:	OCCUPANT COMFORT SURVEY
<p>Floor:</p> <p>Department:</p> <p>Background</p>	
<p>1. How many years have you worked in this building?</p> <p><input type="checkbox"/> Less than 1 year</p> <p><input type="checkbox"/> 1-2 years</p> <p><input type="checkbox"/> 3-5 years</p> <p><input type="checkbox"/> More than 5 years</p>	
<p>2. How long have you been working at your present workspace?</p> <p><input type="checkbox"/> Less than 3 months</p> <p><input type="checkbox"/> 4-6 months</p> <p><input type="checkbox"/> 7-12 months</p> <p><input type="checkbox"/> More than 1 year</p>	
<p>3. In a typical week, how many hours do you spend in your workspace?</p> <p><input type="checkbox"/> 10 or less</p> <p><input type="checkbox"/> 11-30</p> <p><input type="checkbox"/> More than 30</p>	
<p>4. How would you describe the work you do?</p> <p><input type="checkbox"/> Administrative support</p> <p><input type="checkbox"/> Technical</p> <p><input type="checkbox"/> Professional</p> <p><input type="checkbox"/> Managerial/supervisory</p> <p><input type="checkbox"/> Other</p>	
<p>5. What is your age?</p> <p><input type="checkbox"/> 30 or under</p> <p><input type="checkbox"/> 31-50</p> <p><input type="checkbox"/> Over 50</p>	
<p>6. What is your gender?</p> <p><input type="checkbox"/> Female</p> <p><input type="checkbox"/> Male</p>	

Personal Workspace Location

1. In which area of the building is your workspace located?
(Will be marked on the building Plan)

East West North South

3. Are you seated near an exterior wall (within 15 feet)?

Yes

No

4. Are you seated near a window (within 15 feet)?

Yes

No

Please answer the below sections based on the Rating System mentioned below:

- | | |
|----------------------------------|------------------------|
| • -3 (Highly Dissatisfied) | • 1 (OK) |
| • -2 (Dissatisfied) | • 2 (Satisfied) |
| • -1 (Occasionally Dissatisfied) | • 3 (Highly Satisfied) |
| • 0 (Neutral) | |

Air Quality

1. How satisfied are you with the air quality in your workspace (i.e. stuffy/stale air, cleanliness, odours)?

(-3, -2, -1, 0, 1, 2, 3)

2. Overall, does the air quality in your workspace enhance or interfere with your ability to get your job done?

(-3, -2, -1, 0, 1, 2, 3)

3. Please describe any other issues related to the air quality in your workspace that are important to you.

Thermal Comfort

1. Which of the following do you personally adjust or control in your space? (Check all that apply)

- Window blinds or shades
- Operable window
- Portable fan
- Adjustable air vent in wall or ceiling
- None of the above
- Other

2. How satisfied are you with the temperature in your workspace?

(-3, -2, -1, 0, 1, 2, 3)

2. Overall, does your thermal comfort in your workspace enhance or interfere with your ability to get your job done?

(-3, -2, -1, 0, 1, 2, 3)

Temperature

If you are dissatisfied with the temperature in your workspace. Which of the following contribute to your dissatisfaction?

1. In dry season (Jan- April), the temperature in my workspace is:

- Often too hot
- Often too humid

2. In wet season (May-Dec), the temperature in my workspace is:

- Often too hot
- Often too humid

3. When is this most often a problem? (Check all that apply)

- Morning (before 11 am)
- Mid-day (11am - 2pm)
- Afternoon (2pm - 5pm)
- No particular time
- Other:

3. Please describe any other issues related to the temperature at your workspace that are important to you.

Lighting

1. Which of the following controls do you have over the lighting in your workspace?

(Check all that apply)

- Light switch
- Light dimmer
- Window blinds or shades
- Desk (task) light
- None of the above
- Other

2. How satisfied are you with the amount of light in your workspace?

(-3, -2, -1, 0, 1, 2, 3)

3. How satisfied are you with the visual comfort of the lighting (e.g. glare, reflections, contrast)?

(-3, -2, -1, 0, 1, 2, 3)

4. Overall, does the lighting quality enhance or interfere with your ability to get your job done?

(-3, -2, -1, 0, 1, 2, 3)

5. Do you get natural daylight in your Office/Workstation?

- No
- Between 9 am – 12 pm
- Between 12 pm – 6 pm
- Whole day

If you are dissatisfied with the lighting in your workspace. Which of the following contribute to your dissatisfaction? (Check all that apply)

- Too dark
- Too bright
- Not enough daylight
- Too much daylight
- Not enough electric lighting
- Too much electric lighting
- No task lighting
- Reflections in the computer screen
- Shadows on the workspace
- Other

6. Please describe any other issues related to lighting that are important to you.

Overall performance

1. All things considered, how satisfied are you with your personal workspace?

(-3, -2, -1, 0, 1, 2, 3)

2. How satisfied are you with the building overall?

(-3, -2, -1, 0, 1, 2, 3)

3. Any additional comments or recommendations about your personal workspace or building overall?
