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GGGI TECHNICAL REPORT NO. 2

Rapid Building Performance Assessment of Administrative Office Complex, Kigali, Rwanda

MARCH 2021

PART OF GGGI'S TECHNICAL REPORTS SERIES

1. Rapid Building Performance Assessment of Nyarugenge Pension Plaza Kigali, Rwanda 2020
2. Rapid Building Performance Assessment of Administrative Office Complex, Kigali, Rwanda 2021

Global Green Growth Institute
Jeongdong Building 19F
21-15 Jeongdong-gil
Jung-gu, Seoul 04518
Republic of Korea

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Estate Manager, AOC throughout the whole process.

Lead Authors: Dheeraj Arrabothu (Sr. Officer – Green Buildings)

Walkthrough Audit Team: Dheeraj Arrabothu (Sr. Officer – Green Buildings) and Inhee Chung (former GGGI Rwanda Country Representative)

Reviewers: Okechukwu Daniel Ogbonnaya (GGGI Rwanda Country Representative), Inhee Chung (former GGGI Rwanda Country Representative), Michelle DeFreese (Sr. Officer – Green Growth), Liliane Uwanziga Mupende (GCF NAP Project Coordinator), Jean Pierre Munyeshyaka (Sr. Associate – Green Urbanization)

Copy Editor: Pamella Birungi (Sr. Officer - Communication & Knowledge Management), Joyce Gatera (GGGI Rwanda Global Visiting Intern)

Publication Coordinator and Layout: Irene Isingizwe (Amasimbi creative Ltd.)

Visual Imagery: GGGI, The Ministry for the Environment, Land & Sea of the Republic of Italy (IMELS)

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ACRONYMS

ACP	Aluminum Composite Panel
AC	Air Conditioner
AOC	Administrative Office Complex
BTU	British Thermal Unit
CFL	Compact Fluorescent Lamp
DG	Diesel Generator
EUCL	Energy Utility Corporation Limited
EPI	Energy Performance Index
EEI	Energy Efficiency Index
EUI	Energy Use Intensity
EER	Energy Efficiency Ratio
GBMCS	Green Building Minimum Compliance System
GGGI	Global Green Growth Institute
GWP	Global Warming Potential
kW	Kilo Watt
kVA	Kilo-volt-ampere
kWh	Kilo-watt hour
LED	Light Emitting Diode
LPM	Litres Per Minute
LPF	Litres Per Flush
MININFRA	Ministry of Infrastructure
MINIJUST	Ministry of Justice
MOE	Ministry of Environment
ODS	Ozone Depleting Substance
PMO	Prime Minister's Office
RCC	Reinforced Cement Concrete
RFA	Rwanda Forests Authority
RURA	Rwanda Utilities Regulatory Authority
RSB	Rwanda Standards Board
RLRC	Rwanda Law Reform Commission
RWF	Rwandan Franc
SHGC	Solar Heat Gain Coefficient
SF	Solar Factor
SRI	Solar Reflective Index
Sq. m.	Square Meter
VRF	Variable Refrigerant Flow
VLT	Visual Light Transmittance
VVVF	Variable Voltage and Variable Frequency
W	Watt
WASAC	Water and Sanitation Corporation
WEI	Water Efficiency Index
WWR	Window to Wall Ratio

EXECUTIVE SUMMARY

In addition to the unprecedented growth in the global building sector, nearly two-thirds of the building area that exists today will still exist in 2050. Therefore, any transition to low carbon/ carbon neutral built environment must address both new construction and existing buildings. In order to achieve the target set by the Paris Agreement – to limit the rise in global average temperature to below the 2 degrees Celsius threshold – a significant increase in the rate of energy efficiency renovations in existing buildings and the generation and procurement of renewable energy (energy upgrades) is required.[1]

Energy use, water consumption and waste generation are the main components of resource use in public building operation. With the advancement of resource efficiency practices and technologies to reduce energy consumption, water consumption and better waste management, it is possible to cut down the operational costs significantly in the buildings without reducing the comfort and productivity of the building occupants and at the same time reduce the associated Green House Gas (GHG) emissions. This can normally be achieved by the building owners and managers by initiating a systematic assessment/ audit of their building, followed by implementation of cost-effective resource efficiency measures.[2]

The purpose of this report on 'Rapid Building Performance Assessment of Administrative Office Complex (AOC), Kigali, Rwanda' is to provide the Government of Rwanda, as the building owner, an opportunity to understand how their building is performing on key resource efficiency parameters (energy, water and waste) by benchmarking against similar facilities within comparable context, and suggest a list of recommendations for improvement and the associated climate actions and operational cost savings with an aim to convert the existing building into a green building.

Greening existing public buildings in Rwanda is a project initiated by the Global Green Growth Institute (GGGI) in 2020 with support from partners including the Ministry of Infrastructure (MININFRA), Rwanda Housing Authority (RHA), and Ministry of Environment (MoE), to improve the performance of existing public building stock in Rwanda based on green building parameters. The project is a scale-up of Rwanda Green Building Minimum Compliance System which is part of Rwanda Building Code 2019 and aims to provide pathways to green existing public buildings in Rwanda.

Summary of AOC Building Performance

The Energy Performance Index (EPI) of AOC based on monthly utility electricity consumption stands at approx. 36 $kWh/m^2/year$ and the Water Efficiency Index (WEI) based on monthly utility water consumption stands at approx. 0.47 $m^3/m^2/year$. For comparison purposes, the benchmark EPI for office buildings in a composite climate zone in India with less than 50% air conditioned built up area would receive 1 star label if the EPI falls between 80-70 $kWh/m^2/year$ and 5 star label (highest recognition) if the EPI is below 40 $kWh/m^2/year$. Similarly, in Singapore, the median value of WEI for Office buildings with water-cooled cooling tower (a

1 Extracted from https://architecture2030.org/existing-buildings-operation/
2 Modified and extracted from 2009 USAID ECO-III Project, Energy Assessment Guide for Commercial Buildings

type of air-conditioning system) is 1.1 m^3/m^2/ year. Although, the comparative benchmarking from a high level suggests that the building has low energy and water consumption, there are significant opportunities for AOC to reduce its energy and water consumption thereby reducing the operational expenditure and the associated GHG emissions.

Opportunities for Improvement

The resource efficiency of AOC falls under three fronts, namely energy, water and waste, and can be substantially improved by implementing the recommendations which would also help in reducing the associated GHG emissions from the building. The recommendations are classified under short-term and medium to long-term depending on when the cost reductions can be realized, payback period and the extent of interference to the day-to-day operations of the building. Below are some of the short-term recommendations taken from the complete list on Pg. 27:

Energy Conservation Measures

1. Replace all non-LED light fixtures with LED light fixtures.
2. Install occupancy sensors in washrooms, conference/meeting rooms and closed cabin spaces.
3. Install daylight sensors for spaces that have access to daylight especially workspaces close to the windows.
4. Encourage the occupants to make use of the openable windows in each office space to facilitate natural ventilation and take advantage of the ambient weather conditions to reduce the need for air conditioning.
5. Motivate occupants to turn off lights, air conditioners when they leave the office space. This can be encouraged through green awareness raising and energy conservation campaigns.

Water Conservation Measures

1. Ensure that the pumping equipment in the rainwater harvesting system are restored to start using the collected rainwater for landscape irrigation and cleaning applications.
2. Test the quality of water from the wastewater collection tanks before discharging. The testing will help to understand whether the treated wastewater is meeting the desired quality standard as prescribed by the Rwanda Standards Board (RSB).

Waste Management Measures

1. Encourage occupants to segregate waste at source by providing easily accessible colour coded bins in every office space and explore recycling opportunities to avoid the recyclable waste from being sent to landfill.

An attempt has also been made to showcase the savings potential, cost of implementation and simple payback period for some of the recommendations

INTRODUCTION

Background

The Ministry of Infrastructure (MININFRA) requested the Global Green Growth Institute (GGGI) Rwanda program to conduct a rapid building performance assessment of their new premises-namely the Administrative Office Complex (AOC). The AOC construction was completed in 2019 and has been occupied since 22 April 2019. The AOC hosts the Prime Minister's Office (PMO), the Ministry of Infrastructure (MININFRA), the Ministry of Justice (MINIJUST) and the Rwanda Law Reform Commission (RLRC). The AOC has a gross floor area of 15,700 sq.m with 7 storeys in the central wing and 5 storeys in each of the two wings.

Objective of the Assessment

The objective of the rapid building assessment is to take stock of the performance of AOC focusing on energy efficiency, water efficiency and waste management practices and the associated costs. This has been carried out by conducting a walkthrough audit followed by recommendations to promote efficient energy, water and waste management practices in existing government-owned public buildings with an aim to convert them into a green building.

Scope of the Assessment

The scope of the rapid building assessment is limited to evaluating the resource efficiency of the building on three parameters, namely energy, water and waste. The assessment does not focus on the structural integrity, emergency preparedness, or indoor environmental quality aspects of the building. The walkthrough audit of the PMO premises was not possible due to limited access, and information for this area was based on discussion with the Estate Manager.

Outcome of the Assessment

Improved energy, water, and waste management practices in Rwanda's existing government-owned public buildings.

Linkages to Existing National Green Building Initiatives

GGGI worked with Rwanda Housing Authority (RHA) and stakeholders to develop the Rwanda Green Building Minimum Compliance System (GBMCS) which was adopted as an Annex-3 of the Rwanda Building Code 2019. The green building minimum compliance system is applicable for new large-scale public buildings and major refurbishments of Category 4 and 5 and stresses on holistic building performance with focus on energy efficiency, water efficiency, environment protection, indoor environmental quality and green innovation.

Although Rwanda has relatively fewer large-scale existing building stock, there is an opportunity to improve building performance starting with public buildings (with government leading by example) so that the future building stock that will be built to meet Rwanda's development and urbanization target can draw valuable lessons.

Linkages to Global Program on Building Energy Efficiency led by GGGI HQ

GGGI HQ has developed a global program to mainstream energy efficiency standards of appliances and materials in new and existing buildings that would result in a significant reduction in energy consumption of buildings. Rwanda is part of the global program and the assessment of select existing public buildings such as AOC, will feed into the global output, with possibility of cross-country learning and information exchange through the program.

About Administrative Office Complex

The AOC is divided in 3 different parts: being the left wing, central wing and the right wing. The building is 32.4m in height-with 7 storeys in the central wing and 5 storeys in the left and right wing, and has a gross floor area of 15,700sq. m. The left wing hosts the Ministry of Justice (MINIJUST) and the Rwanda Law Reform Commission (RLRC), the central wing hosts the Prime Minister's Office (PMO) and the right wing hosts the Ministry of Infrastructure (MININFRA). The building is oriented along the North-West and South-East axis with longer sides of the building facing the east and west direction. The building has 1 partial basement floor that accommodates facilities such as an electricity transformer and distribution room, a firefighting room, a water tank and pump room, a server room and a control room with Building Management System (BMS). The building has a surface parking facility with parking spaces all around the building and constructed with grass paver blocks that help in increasing the permeability by percolating the rainwater and reducing the stormwater runoff compared to a paved surface. The building is operational 5 days a week, from 7 AM to 8 PM.

The building was designed to accommodate 1000 people, but approximately 400 people are currently working in the building. Furthermore, because of the ongoing COVID-19 restrictions, only 30% staff from each ministry were working from AOC on a rotational basis during the time of this audit. Once the building reaches the designed occupancy of 1000 people, the resource consumption will increase as well as the operational costs and the associated GHG emissions in the Business as Usual (BAU) scenario.

Facility Management of AOC

The building has a full-time estate manager hired by PMO and is supported by a team of full-time maintenance technicians from REAL Contractors Ltd. - which is a general maintenance company appointed by MININFRA to attend to electrical, air-conditioning, plumbing and general maintenance issues. The maintenance personnel

Photo 1: Outdoor shaded parking spaces on grass paver blocks

Photo 2: Part view of Administrative Office Complex

for air conditioners and elevators inspect AOC on a weekly basis. The various functions related to the management of the building are divided among the building owner and occupants and can be broadly classified as below:

- Rwanda Housing Authority (RHA) owns the building through the division in charge of Public Building Maintenance and Construction and take care of modifications of the building
- The management of the building is handled by the PMO and MININFRA
- The payment for utilities consumption (Electricity + Water + Fuel for diesel generators) is handled by MININFRA
- The contract of the building maintenance company is handled by the MININFRA Urbanization Division Manager
- The Estate Manager is under the PMO
- The general cleaning company is under the PMO

Types of Building Performance Assessments

There are three levels of building performance assessments. Each level is designed to meet specific needs of the building owner. For each level of assessment, the level of effort and expertise required differs. Each of the three types are briefly described below:

- Level 1 Assessment: Preliminary performance assessment; simple assessment based on available documents and information, physical inspection/walkthrough audit, and staff interviews to create a baseline and identify obvious energy efficiency, water efficiency and waste management measures which are easy to implement.
- Level 2 Assessment: Comprehensive performance assessment; thorough review of data, existing and newly gathered, to identify all energy saving, water saving and waste management measures and identify high potential measures for further investigation
- Level 3 Assessment: Detailed analysis of capital-intensive measures; also known as investment grade audit used to give a detailed

assessment of costs and benefits derived from energy conservation, water conservation and waste management measures

Level 1 Building Performance Assessment of AOC

GGGI team, comprising of the former Rwanda Country Representative and Sr. Officer – Green Buildings, conducted a Level 1 Assessment of the building which includes preliminary data gathering and walkthrough audit conducted on 26 August 2020. The objectives of the Level 1 assessment include:

- To determine the baseline of energy and water use, and waste generation
- To identify no/low cost measures for energy, water and waste reduction
- List down potential projects for further consideration and implementation

The specific activities conducted by GGGI team under the Level 1 assessment include:

- Development of Building Audit Walkthrough checklist (refer Annex 1)
- Determine building's total area and primary use
- Collect data based on a minimum of one year of utility bills (refer Annex 2 and 3)
- Brief walk-through survey of the facility to check the following:
    - Construction
    - Equipment
    - Operations and maintenance
- Meeting with building owner/facility manager, maintenance person, staff and occupants
- Develop energy, water use, waste generation and cost indices
- Identify and list low-cost/no-cost measures
- Identify potential capital projects for further consideration and possible implementation

AUDIT OBSERVATIONS

Architectural Observations

Building orientation

AOC is oriented along the North-West and South-East axis with longer sides of the building facing the east and west direction. Kigali is approx. 2 degrees South of Equator and the ideal building orientation should be for the longer sides of the building to be facing the North and South and for shorter sides to be facing the East and West to minimize direct sun exposure thereby reducing heat gain into the building. Also, the AOC plot had favorable conditions to orient the building most appropriately to reduce the direct heat gain, but it was a missed opportunity. Hence, interventions related to building orientation are not feasible.

Window to Wall Ratio (WWR)

WWR is defined as the ratio of the total area of the window or other glazing area (including mullions and frames) divided by the gross exterior wall area. The WWR is calculated with the following equation:

WWR (%) = $\sum$ Glazing area (m^2)/ $\sum$ Gross external wall area (m^2)

Finding the correct balance between the transparent (glass) and the opaque surfaces in the external façades helps to maximize daylight while minimizing unwanted heat transfer, resulting in reduced energy consumption. Windows generally transmit heat into the building at a higher rate

Photo 3: Administrative Office Complex on Google Maps indicating the building orientation

Photo 4: Part view of AOC right wing showing reduced WWR with recessed windows providing some form of shading

than walls do. In fact, windows are usually the weakest link in the building envelope as glass has much lower resistance to heat flow than other building materials. Heat flows out through a glazed window more than 10 times faster than it does through a well-insulated wall.[3]

From visual inspection, it was observed that the left and right wings of the building have optimum Window to Wall Ratio (WWR), but the central part has seemingly high WWR owing to the structural glazing as noted from the pictures below. Although, there is no baseline for optimum WWR as it also depends on the orientation of the façade, but generally a WWR of 20-40% may be considered optimum.

Shading Devices

Structural controls like 'external shading devices' are essential environmental controls that either obviate or greatly reduce the need for mechanical cooling by controlling heat gain through openings to maintain thermal comfort inside buildings. Along with glazing type and size of the window, shading devices are equally important in limiting heat gain from outside through radiation. External and internal shading devices can thus be used as an essential solution for achieving energy efficiency.[4]

Photo 5: Central part of AOC showing high WWR and no presence of shading devices

Photo 6: Recessed windows on the right wing of AOC

3 IFC EDGE User Guide
4 Extracted from https://nzeb.in/knowledge-centre/passive-design/shading/

The type of shading devices is also linked to the orientation of the building. In AOC, the predominant shading devices are recessed windows (almost 0.6m deep) which provide both horizontal and vertical shading. However, since the longer sides of the building face the east and west direction it becomes harder to effectively shade the windows thereby leading to tremendous heat gain especially from the western façade. Furthermore, it was observed that blinds were installed internally to cut down the excessive glare, which further indicates that the excessive daylighting, especially in offices located along the western façade and unwanted heat gain, is a concern among the occupants.

Building Envelope

AOC is a Reinforced Cement Concrete (RCC) structure with cement block as the main walling material and finished with a combination of Aluminum Composite Panel (ACP) Cladding, recessed fenestration on the left and right wings and structural glazing on the central wing. The fenestration is a tinted Double-Glazed Unit (DGU) window with a combination of fixed and awning windows. The building has a flat RCC roof with light coloured tiles on the rooftop. The total thickness of the wall assembly and roof assembly are unknown as the information was not available. Similarly, the U-value, Solar Heat Gain Coefficient (SHGC) or Solar Factor (SF) and the Visual Light Transmittance (VLT) of the DGU is unknown due to unavailability of technical specifications.

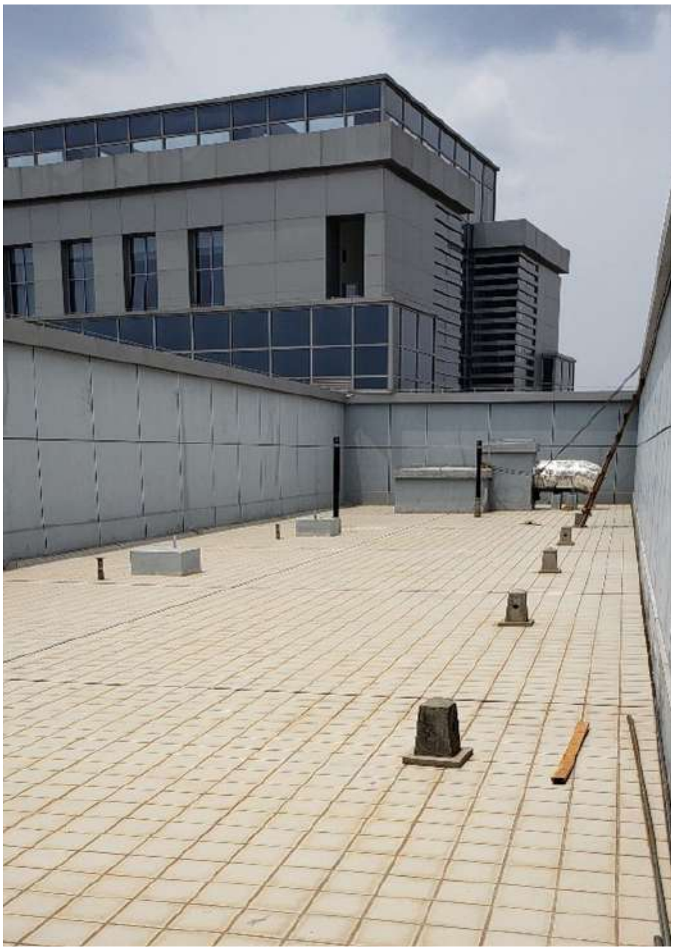

Photo 7: Light coloured tiles on the rooftop

Trends in Electricity Consumption

Thirteen months of monthly electricity consumption data/bill (from September 2019 to September 2020) were provided by the estate manager to analyze the trends in electricity consumption. Monthly electricity consumption in kWh (kilowatt hour) was provided and the

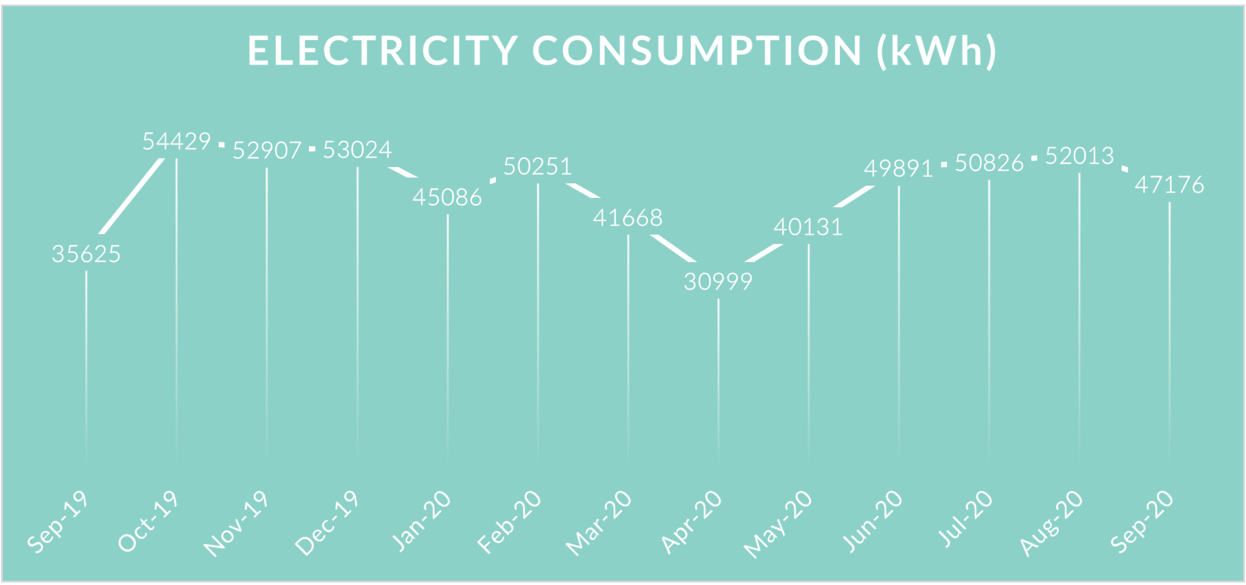

Figure 1: AOC Trends in electricity consumption

same has been plotted in the below chart. Based on the data, excluding March to May 2020[5], it is observed that the average monthly electricity consumption of AOC stands at approx. 50,622 kWh.

From the chart below, it is evident that during the months of March to May 2020 the electricity consumption was low due to the lockdown measures related to the COVID-19 pandemic. The lockdown was lifted on 4th May 2020 and the government offices resumed services with essential staff reporting to offices, followed by 30% of staff reporting to offices since 26th August 2020 while the rest continue to work from home. It can also be assumed that from June to September 2020, the graph does not represent the normal electricity consumption since only essential staff worked from office, but the electricity consumption gradually went up as the air-conditioning system was being installed in all offices and partly because of the long dry season from June to September.

It should also be noted that, in January 2020, the Rwanda Utilities Regulatory Authority (RURA) increased electricity tariffs for non-residential customers with a consumption greater than 100 kWh per month from 222 Rwf /kWh approx. to 255 Rwf/KWh, which is approx. 15% increase. Although the electricity bills for AOC could not be verified, we can assume that AOC's expenditure for electricity consumption could have increased starting February 2020.

Benchmarking the Electricity Consumption

The Energy Performance Index (EPI), also known as Energy Efficiency Index (EEI) or Energy Use Intensity (EUI), is a key metric used for benchmarking energy usage in commercial buildings. EPI is the total energy consumed in a building over a year divided by the total built up area expressed as kWh/m^2/year (read as kilowatt hour per square meter per year), it is considered to be the simplest and most relevant indicator for qualifying a building as energy efficient or not. Based on the past twelve-month cumulative utility electricity consumption and the built-up area the EPI for AOC was computed. The EPI for AOC based on monthly utility electricity consumption from October 2019 to September 2020 stands at approx. 36 kWh/m^2/year.

As a general practice, the EPI value should also include the annual electricity consumption from Diesel Generating (DG) sets in kWh, but since the information was not available, the EPI value including this crucial data could not be computed. The EPI value for AOC, if this information were to be included, could be further higher. Further, the EPI for AOC would have been higher if the building met 100% design occupancy of 1000 people. Also, the monthly electricity consumption from March to May 2020 has been considered in the EPI calculation, although the consumption was low owing to the COVID-19 pandemic lockdown measures. Otherwise, the EPI for AOC would have been higher if there was normal consumption. As a good practice, it would be good to compare the current EPI value with future EPI values to check the performance of the building.

For comparison purposes, the benchmark EPI for office buildings in a composite climate zone in India with less than 50% air conditioned built up area would receive 1 star label if the EPI fell between 80-70 kWh/m^2/year and 5 star label (highest recognition) if the EPI was below 40 kWh/m^2/year.

The present EPI value for AOC at 36 kWh/m^2/year - excluding electricity consumption from DG sets and considering the low monthly consumption from March to May 2020 - shows that the building has significant potential for reducing energy consumption, thereby further reducing EPI by promoting energy conservation measures.

Annual Green House Gas (GHG) Emissions

Based on the past 12-month electricity consumption data from October 2019 to September 2020, the annual indirect GHG emissions of AOC from grid supplied electricity is 170.5 tCO2e[6]. The direct GHG emissions from diesel generator sets could not be calculated as the data was not accessible.

5 Due to COVID-19 pandemic Rwanda enforced a complete lockdown from 22 March to 4 May 2020 and hence the electricity consumption of those months is not a true indicator of normal electricity consumption and has been avoided for calculation purposes

6 Excludes Scope 1 emissions from diesel generator sets. Rwanda grid-emission factor considered as 0.3 kgCO2/kWh.

Energy Consumption and management

Lighting Systems

Lighting Systems could be categorized as indoor and outdoor lighting systems. AOC has three types of indoor lights and one type of outdoor light.

Indoor Lighting

The Office Block has a combination of LED lamps in lobby areas and restrooms and 18W Fluorescent T8 Tube lights in office spaces. As per the estate manager, 70% of the lights are non-LED, but could be upgraded to LED resulting in significant energy savings.

Photo 8: LED light fixture in the lobby areas

Photo 9: Fluorescent tube fixture in corridor and office spaces

Photo 10: Fluorescent tubes in the corridor

Photo 11: LED fixtures in the lobby area

Outdoor Lighting

The building is equipped with LED based outdoor lighting system with timer control. Although the audit team could not verify the wattage of the light fixture - since it is LED based fixture - it is considered as energy efficient.

Photo 12: LED outdoor light

Air-conditioning System and Refrigerants

AOC has recently installed a Variable Refrigerant Flow (VRF) air-conditioning system for the offices in the left and right wings, with wall mounted indoor units that are connected to centralized outdoor units on the building rooftop. The central wing had an air-conditioning system since the inauguration, however the type of system could not be verified because of limited public accessibility. The building was initially designed to have AC for the central part only, with the left and right wings installing individual AC systems on a need basis and hence a provision had been made to conceal the outdoor units in the building façade (see photo below). However, since AOC has chosen a more efficient solution by installing VRF air-conditioning system, the façade is free of outdoor units except for few spaces where outdoor units can be observed. Additionally, the server room has its own dedicated AC system.

The following outdoor units were observed on the rooftop of the right wing and as per the estate manager, similar number of outdoor units are on the left wing.

- 5 units of LG make and rated cooling capacity of 114,600 BTU/hr. each.

Photo 13: West facade of AOC with provision of space for AC outdoor units

- 1 unit of Samsung make and rated cooling capacity of 84 kW or 286,619 BTU/hr.

Each wing has a total of 6 outdoor units installed on the rooftop and based on the technical specifications mentioned on the outdoor units, the total cooling capacity of the 12 outdoor units is calculated as 143 Refrigeration Tons (RT). The cooling capacity of the AC unit on the central part of the building is not known.

The ACs are used only on a need basis and the control remains with the occupants. However, as per the estate manager, the occupants sometimes forget to switch off the ACs before leaving office leading to wastage of electricity. A green education awareness campaign needs to be conducted to sensitize the occupants on energy savings.

Although the exact Energy Efficiency Ratio (EER) of the ACs could not be verified due to lack of product specifications, a quick web search based on the make (LG MULTI V 5 and SAMSUNG DVM S) proved the system to be energy efficient.

R-410A is the type of refrigerant used in the AC system. R-410A has zero Ozone Depleting Substances (ODS) and is considered as ozone friendly. The Global Warming Potential (GWP) of R-410A refrigerant is 2088 and is considered as high. As per the Kigali amendment to the Montreal Protocol - for which Rwanda is a signatory - high GWP refrigerants must be phased out/replaced with low GWP refrigerants.

Photo 15: Specification of the AC outdoor unit

Photo 14: Outdoor Units of air conditioning system on the building rooftop

Elevators

AOC has total of eight elevators, with one dedicated for VIPs in the PMO. During the walkthrough audit, it was not clear whether the elevators are equipped with Variable Voltage Variable Frequency (VVVF) drives which could help in energy savings.

Electricity Back-up System

AOC is equipped with two Diesel Generator (DG) power back-up systems of rated power 658 kVA each. Based on the model number and through a quick web search, it was observed that the rated fuel consumption of the generator is 209 g/kWh. The DG room is also equipped with a dedicated diesel tank and the maintenance team maintains a dedicated logbook to record the monthly fuel consumption of these generators. The record could not be verified by the audit team. Further, it is observed that there is a dedicated sub-metering system to record the electricity generated from the generators on a daily and monthly basis.

Sub-metering for Electricity Consumption

AOC is equipped with a low voltage switchboard for power distribution of a Schneider Electric make and product named BlokSet. During the walkthrough audit, it was observed that the switchboard had provisions to meter and monitor various end uses, such as internal and external lighting, air-conditioning system, rainwater harvesting pumps, firewater pumps, elevators and other major energy consuming equipments in the building. The building also has dedicated meters installed by the Energy Utility Company Limited (EUCL) for both the transformers.

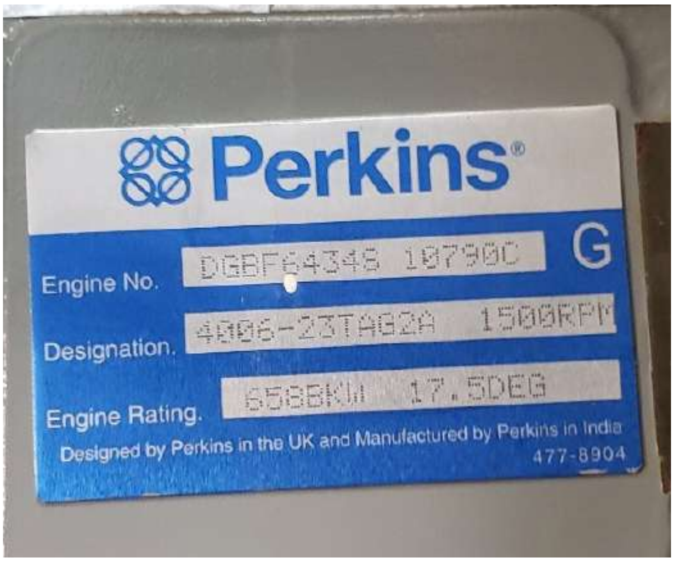

Photo 17: Specifications of the diesel generator

Photo 16: One of the 658 kVA Diesel Generator

The data from the various sub-meters has the potential to provide a more detailed analysis of building energy consumption. The first step is to break the building down into sub areas with similar activities and comparable major consumption patterns:

- Outdoor
- Office area
- Server room
- Common area

The second step is to identify the different energy uses. Typical energy use breakdown for a office building might include:

- Indoor lighting
- Outdoor lighting
- Cooling
- Elevators
- Pumps and motors
- Other (office equipment)

These breakdowns can then be used to select which energy uses in which areas need to be monitored. This informs the basis for developing an appropriate metering strategy and determining the associated performance metrics.

Photo 18: One of the EUCL Electricity Meter at AOC

Photo 19: Low Voltage (LV) switchboard for power distribution

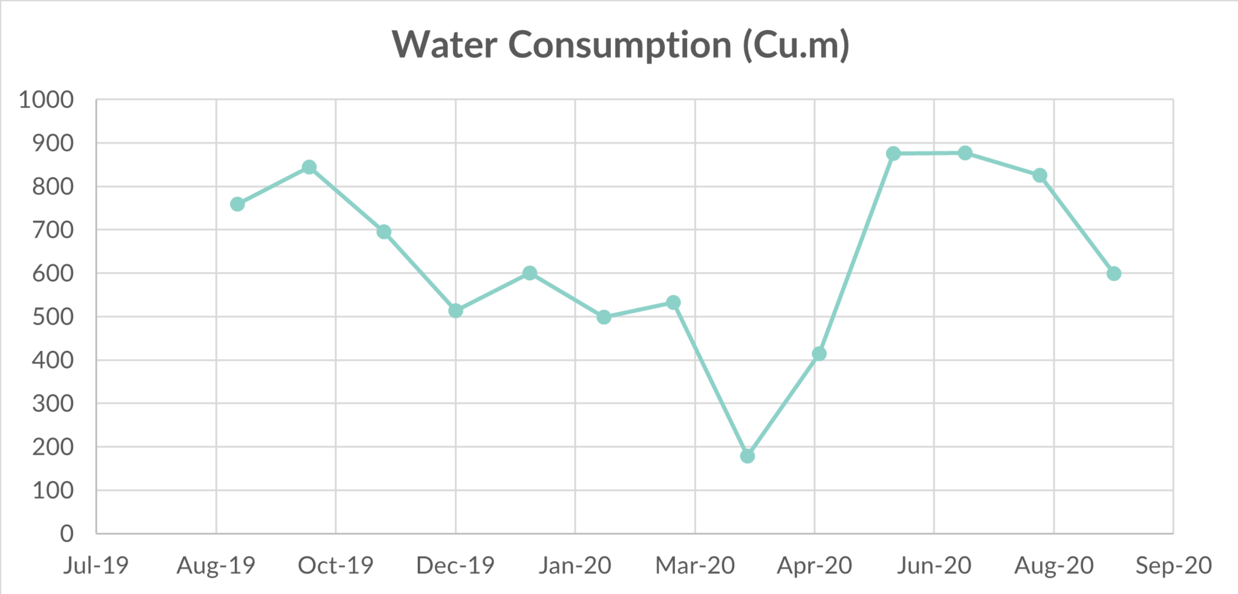

Figure 2: AOC trends in water consumption

Trends in Water Consumption

The monthly water consumption data from the utility provider Water and Sanitation Corporation (WASAC) was provided by the AOC estate manager and the same has been plotted on the above chart from September 2019 to 2020. The average monthly consumption stands at approx. 621 cu.m[7]. WASAC charges a flat rate of 895 RWF/cu.m of water consumption.

From the chart below, it is evident that during the months of March to May 2020, the water consumption is low because of the lockdown measures related to the COVID-19 pandemic. Since the lockdown has been lifted the water consumption has picked up and hit a peak of 876 cu.m in June 2020 - however it started going down again for reasons that are unclear.

Benchmarking the Water Consumption

The Water Efficiency Index (WEI) serves as the performance indicator for water efficiency and refers to the amount of water used per business activity indicator. Office buildings WEI reflect the amount of water used by an office building for its operations for each gross floor area annually.[8]

Office building WEI = Annual Water Consumption (cu.m/year)/ Gross Floor Area (m^2)

Based on the past twelve-month cumulative utility water and the built-up area, the WEI for AOC was computed. The WEI for AOC based on monthly utility water consumption from Oct 2019 to September 2020 stands at approx. 0.47 m^3/m^2/year.

The monthly water consumption from March to May 2020 has been considered in the WEI calculation, although the consumption was low owing to the COVID-19 pandemic lockdown measures. Also, the WEI for AOC would have been higher if there was normal consumption. Further, the WEI for AOC would have been higher if the building met 100% design occupancy of 1000 people. As a good practice, it would be good to compare the current EPI value with the future EPI values to check the performance of the building.

In Singapore, the median value of WEI for Office buildings with water-cooled cooling tower [a type of air-conditioning system] is 1.1 m^3/m^2/year. The median value of WEI for office buildings without water-cooled cooling tower could not be located.

Although the present WEI value for AOC at 0.47 m^3/m^2/year seems to be low, there are significant

7 1 cubic meter is equivalent to 1000 litres of water.
8 Extracted from https://www.pub.gov.sg/savewater/atwork/WaterEfficiencyBenchmarks#:~:text=For%20the%20office%20building%20sector,each%20gross%20floor%20area%20annually.

opportunities for further reducing the water consumption thereby reducing the associated costs.

Water consumption and management

Rainwater Harvesting

AOC has a rainwater harvesting system to capture the runoff from the building rooftop. The runoff from non-roof areas, such as pavement, parking and landscaping, is captured in the storm water drain system which is further diverted outside the building. Based on the dimensions of the collection tank, it is estimated that the underground rainwater collection tank could hold approximately 360 Cu.m. of water. Furthermore, the rainwater harvesting system is equipped with a filtration system to treat the harvested water before reusing it. The system was designed to use rainwater for landscape irrigation and cleaning applications. However, as per the estate manager, the rainwater pump room was submerged during the heavy rains in January 2020 leading to the damage of the rainwater pump and non-usage of collected rainwater for landscape irrigation and cleaning applications. It is important to ensure that the rainwater pumping system is restored and start using the collected rainwater to reduce dependence on WASAC water.

Photo 20: Rainwater level indicator installed outside the collection tank.

Photo 21: Rainwater filtration system.

Plumbing Fixtures

- Taps: The efficiency of the restroom washbasin taps could not be measured, but from visual observation, it was noticed that the taps are equipped with aerators to reduce the flow of water leading to conservation of potable water. According to the Rwanda Green Building Minimum Compliance System 2019, the baseline flow rate range for tap shall be 4 to 6 Litres Per Minute (LPM) at a reporting pressure of 3 bar or 43.5 psi.

Photo 22: Tap in Men's restroom

- Water Closets: Dual flush tank water closets were observed in the washrooms. From a water efficiency aspect, dual flush tanks are preferred with a baseline flush rate range of 4 to 4.5 Litres Per Flush (LPF) for full flush and 2.5 to 3 LPF for half-flush as per the Rwanda Green Building Minimum Compliance System 2019. The efficiency of the water closet mentioned on the top of the fixture is 4 LPF. It would be good to have signages in the washrooms to sensitize users to use part flush/full flush depending on the requirement and get the benefit of having dual flush tanks.

Photo 23: Dual flush water closet in Men's restroom

- Urinals: 10 urinals per floor are installed in men's restroom. The efficiency of the urinal is mentioned as 3 LPF. According to the Rwanda Green Building Minimum Compliance System 2019, the baseline flow rate range for urinal shall be 1 to 1.5 LPF.

Photo 24: Urinal in Men's restroom

As per the estate manager, a survey was conducted to check for any leakages in the plumbing fixtures and the piping system and it was noticed that there were no major leakage issues.

Wastewater Treatment Plant

AOC has a basic wastewater treatment plant that was designed to segregate the grey water and the black water in two separate tanks. However, during the walkthrough audit and based on the interaction with the estate manager, it was observed that the grey water tank, which was supposed to function as a soak pit, was constructed as a non-permeable tank with RCC lining leading to the tank getting filled up quickly and the regular need for emptying it. It should be noted that the building has this problem at 40% occupancy and the problem will be aggravated once the building reaches 100% occupancy. To solve this issue, AOC is constructing a soak pit filled with rubble and coarse stones, to disperse water back into the surrounding ground. However, it was not clear whether the wastewater quality will be checked before the water enters the soak pit as it has the potential to pollute the ground water.

Photo 25: Wastewater collection tanks

It would be good for AOC to upgrade/install a proper wastewater treatment plant to appropriately treat the wastewater, in order to meet RSB standard and lead by example. Further, a proper wastewater treatment plant is a good long-term investment that can meet the treatment needs once the building reaches 100% design occupancy of 1000 people.

Photo 26: Soak pit under construction

Sub-metering for water consumption

AOC is connected by piped water supply from Water and Sanitation Corporation (WASAC) and the consumption is measured through a water meter, as shown below. As per the estate manager, WASAC team confirmed that the water meter is working properly during a visit. However, no other water meters were observed to measure the water consumption for flushing and landscape irrigation.

Photo 27: Potable water meter

Waste Management

Waste segregation and management

During the site visit, it was observed that the collected waste can be predominantly classified into paper, cardboard, plastic, metal, and landscape trimming waste that was segregated and temporarily stored in a container in one of the corners of the premises [besides DG room]. As per the estate manager, a small quantity of organic waste is also generated from the Prime Minister's office. The segregated waste is collected by a waste collection company and is most likely sent to the landfill for disposal.

AOC can lead by example by measuring the annual amount of waste generated from the building, and tie up with recyclers and waste management start-up companies to ensure that the segregated waste (where possible) is recycled and does not end up in landfills. The organic waste (food and landscape waste) could be composted and converted into manure for landscaping.

Photo 28: Unsegregated waste

Photo 29: Dedicated space to store segregated waste

RECOMMENDATIONS

Short-term Recommendations

Short-term recommendations are those that can be immediately taken up by the AOC management to achieve quick results. Most of the recommendations are less capital-intensive, include no/minimal costs, and have a short payback period.

Energy Conservation Measures

1. Replace all non-LED light fixtures with LED light fixtures.
2. Install occupancy sensors in washrooms, conference/meeting rooms and closed cabin spaces.
3. Install daylight sensors for spaces that have access to daylight especially workspaces close to the windows.
4. Encourage the occupants to make use of the openable windows in each office space to facilitate natural ventilation and to take advantage of the ambient weather conditions, reducing the need for air conditioning.
5. Motivate occupants to turn off lights, and air conditioners when they leave the office space. This can be encouraged through green awareness and energy conservation campaigns.
6. Ensure that the door and windows are closed when the air conditioning is turned on.
7. Set the air conditioning temperature setpoint between 24 – 26 degrees C (as prescribed by the Rwanda Building Code 2019) so that people need not open the windows when the space becomes excessively cold.
8. Consider plantation of trees to shade the western facade. Well-placed trees in front of the west facade will reduce unwanted heat gain thereby reducing the cooling load on the air-conditioning and promoting biodiversity.
9. Put in place a monitoring system to monitor the various energy end uses. The monitoring system could leverage the enormous amount of metering data coming out from the switch board. A functional monitoring system can help determine the associated performance metrics of various energy end uses and drive energy efficiency.

Water Conservation Measures

1. Install signages in the restrooms to sensitize users on the usage of dual flush tanks.
2. Ensure that the pumping equipment in the rainwater harvesting system are restored to start using the collected rainwater for landscape irrigation and cleaning applications.
3. Test the quality of water from the wastewater from the soak pits before it gets discharged into the ground. The testing will help to understand whether the wastewater is meeting the desired quality standard as prescribed by RSB.

Waste Management Measures

1. Encourage occupants to segregate waste at source by providing easily accessible colour coded bins in every office space and explore recycling opportunities to avoid the recyclable waste sent to landfill.

Medium to Long-term Recommendations

Medium to long-term recommendations are those that require detailed studies to estimate the impact of implementing the measure, GHG emission reduction potential, the associated capital requirements, cost savings and payback period.

Energy Conservation Measures

1. Install anti-glare window film, which can reduce the amount of sunlight coming from windows especially on the east and western façade, without changing the building appearance.
2. The refrigerants used in the VRF system have high Global Warming Potential (GWP). Explore the usage of climate-friendly refrigerants in the air-conditioning systems.
3. Install 100 kW grid connected Solar PV plant on the building rooftop. A solar PV with Lithium-ion battery storage system can also be explored to store the excess electricity produced and reduce dependence on grid electricity. A feasibility study can be commissioned.
4. Upgrade the current outdoor LED lights to solar based LED outdoors lights.

Water Conservation Measures

1. Wastewater is currently treated by a basic treatment plant and it is not clear whether quality of the treated wastewater meets the RSB standard. Therefore, install a proper wastewater treatment plant to ensure that the wastewater generated is treated to meet the prescribed RSB standard and further explore reusing the treated wastewater for flushing and landscape irrigation applications.
2. Install sub-metering at various end uses such as treated wastewater consumption, water consumption for flushing and landscape irrigation.

Waste Management Measures

Engage with building occupants and maintenance crew to explore ways to reduce the most produced waste from the building, such as paper, packaging, etc.

Cross-cutting themes

1. Introduce green procurement rules to ensure all energy and plumbing equipment replacement in the building comply with the requirements of the Rwanda Green Building Minimum Compliance System 2019.
2. Develop a green education program to increase the awareness of facility management team, staff, and occupants on reducing energy and water use and better managing the waste.
3. Develop a regular capacity building program for the facility management team including technicians from the general maintenance company to improve the performance of the building. The training should be focusing on utility data management, conducting regular audits, strategies to green existing buildings and proper maintenance of equipment.
4. Install EV Charging Station in the parking area. As e-mobility is gaining traction in the country, MININFRA can lead by example by installing a charging station that would encourage the building occupants to explore electric mobility options for commuting to office.

Indicative Cost Benefit Analysis of Select Recommendations

S. No.	Description	Potential Savings	Cost to Implement	Simple Payback Period
1	Install a 100kW grid connected solar PV on the building rooftop (parking + office block). Approximately 6-7 sq.m of roof area would be required to install 1kW of solar PV.	16% energy cost savings Considering 11 hour of building operation on 240 working days per year	120,000,000 RWF Cost of 1kW grid connected solar PV = 1,200,000 RWF. For a solar PV with Lithium-ion battery storage system the (cost would be three times expensive compared to a grid-connected system.	5-6 years
2	Replace all 1740 18W Fluorescent T8 Tube lights in office spaces with 15W LED lighting	20% energy cost savings Considering 8 hour of lighting operation on 240 working days per year	27,840,000 RWF Cost of each 4 feet 15W LED Tube light 16,000RWF including holder.	10 years

ANNEXES

Appendix 1 – Building Audit Checklist

Form 1: General Building Information

No.	Item		Value
	Name of the Building		
	Year of Building Construction		
	Year of last innovation (if any)		
	Plot area (sq. m)		
	Building footprint (sq. m)		
	Permeable area (sq. m)		
	Non-permeable area (sq. m)		
	Building orientation		
	Numbers of habitable floors in the building		
	Number of basement/parking floors in the building		
	Area of the building (exclude parking, lawn, roads, etc.)	a. Total Built Up area (sq. m)	
		b. Carpet Area (sq. m)	
		Air-conditioned area (sq. m)	
		Non-Conditioned area (sq. m)	
	Working days/week (5/6/7 days per week)		
	Typical working hours of the building		
	Total numbers of employees working in the building		
	% of male employees		
	% of female employees		

Form 2: Building Energy Data Collection Form

No.	Item		Value
	Connected Load (kW) or Contract Demand (kVA)		
	Peak Demand or Maximum Demand Indicated (MDI) (kW)		
	Installed capacity: DG Sets (kVA or kW)		
	a. Annual Electricity Consumption, purchased from Utilities (kWh)		
	b. Annual Electricity Consumption, through Diesel Generating (DG) Sets (kWh)		
	c. Total Annual Electricity Consumption, Utilities + DG Sets (kWh)		
	Electricity Cost		
	a. Annual Electricity Cost, purchased from Utilities (Rwf)		
	b. Annual Electricity Cost generated through DG Sets (Rwf)		
	If not available, please provide the fuel consumed in the last 3 years and the unit cost of fuel		
	c. Total Annual Electricity Cost, Utilities + DG Sets (Rwf)		
	Installed capacity of Air Conditioning System	a. Centralized AC Plant (TR)	
		b. Packaged ACs (TR)	
		c. Window/Split ACs (TR)	
		Total AC Load (TR)	
		Type of refrigerant used in the AC system	
	Installed lighting load (kW)		
	Sub-metering of electricity consumption	Interior, common, and exterior area lighting (Yes/No)	

No.	Item		Value
		Air-conditioning system (Yes/No)	
		Wastewater treatment (Yes/No)	
		Renewable energy generation (Yes/No)	
		Power backup system (Yes/No)	
		Elevators (Yes/No)	
		On-site pumping for water storage (Yes/No)	
	Any electricity generation from On-site Renewable Energy system (Yes/No)		
	If Yes, Type of On-site RE system (Solar, wind etc.)		
	Annual electricity generation from On-site RE system (kWh)		
	Any heating/hot water or cooling generation from On-site Renewable Energy system (Yes/No)		
	If Yes, Type of On-site RE system (Solar water heater, solar cooling, etc.)		
	Annual heating/cooling generation from On-site RE system (kWth)		

Form 3: Summary of Connected Load / Equipment Inventory

No.	Details of Connected Load	Nos.	Watts/Unit	Total kW	Efficiency (COP/EER) only applicable to AC systems	Operating Hours
1	**Indoor Lighting**					
	Fluorescent Lamps					
	Incandescent Bulb					
	CFL					
	Halogen					
	Any other					
2	**Outdoor Lighting**					
	High-pressure mercury vapor (HPMV)					
	Metal Halide					
	Flood lights					
	Sodium vapor					
	Any other					
3	**Ventilation Systems**					
	Ceiling Fans					
	Wall-mounted Fans					
	Pedestal Fans					
	Air Purifier					
	Exhaust Fans					
4	**Air-conditioning**					
i.	Localized AC Systems					
	Window AC					
	Split AC					

No.	Details of Connected Load	Nos.	Watts/Unit	Total kW	Efficiency (COP/EER) only applicable to AC systems	Operating Hours
	Precision AC					
	Package Unit					
ii.	Central AC Systems					
	Chiller package					
	Condenser pump					
	Chilled water pump					
	Cooling Tower					
	Air Handling Unit					
5	**Office Equipment**					
	Printers					
	Photocopier Machines					
6	**Lifts**					
	Passenger Lift					
	Goods Lift					
7	**Pumps**					
	Water Pumps					
	Hydro pneumatic pumps					
	Sewage pumps					
	Wastewater treatment pumps					
8	**Uninterrupted/ stabilized power systems**					
	UPS					
	Voltage Stabilizer					

Form 4: Building Water Data Collection Form

No.	Item	Value
	Annual Water Consumption, purchased from WASAC (Kilo litres)	
	Annual Water Consumption, through any other sources of water (Kilo litres)	
	a. Bore hole	
	b. Collected rainwater	
	c. Treated wastewater	
	Total Annual Water Consumption, WASAC + Any other source (Kilo litres)	
	Annual Water Cost (Rwf)	
	Estimated hot water consumption in the year (kilo liters)	
	Source of hot water (electric/solar)	
	Rainwater harvesting (Yes/No)	
	If Yes, total capacity of rainwater harvesting storage (Kilo litres)	
	Available roof area to capture rainwater (sq. m)	
	Roof surface type (Flat roof/Metal roof/Tiled roof/Any other type)	
	Sub-metering of water consumption	
	a. Piped water supply (Yes/No)	
	b. Reuse of stored rainwater (Yes/No)	
	c. Treated wastewater consumption (Yes/No)	

No.	Item	Value
	d. Water consumption for flushing (Yes/No)	
	e. Water consumption for air-conditioning cooling tower make-up (if installed) (Yes/No)	
	f. Water consumption for landscape requirements (Yes/No)	
	Wastewater treatment plant	
	Annual wastewater generated that is treated in the treatment plant (kilo litres)	
	Is the quality of treated water monitored (Yes/No)?	
	Is the treated wastewater reused in the building?	
	If Yes, annual treated wastewater reused in the building (kilo litres)	
	Annual Waste generated from the building (Kgs)	
	Is the waste segregated at source (Yes/No)	
	If Yes, please specify the types that it is segregated into (Food, paper, plastic, e-waste, bio-medical, landscape etc.)	
	Is there a dedicated storage facility to store the segregated waste (Yes/No)	
	How is the recyclable waste handled in the building?	

Form 5: Building Waste Data Collection Form

No.	Item	Value
	Annual Waste generated from the building (Kgs)	
	Is the waste segregated at source (Yes/No)	
	If Yes, please specify the types that it is segregated into (Food, paper, plastic, e-waste, bio-medical, landscape etc.)	
	Is there a dedicated storage facility to store the segregated waste (Yes/No)	
	How is the recyclable waste handled in the building?	

Form 6: Building Envelope Data Collection Form

No.	Item	Value
	Building Orientation	
External Wall Assembly		
	Main walling material (Clay bricks, concrete blocks)	
	External finish (ACP cladding, Plaster, and paint)	
	Internal finish (plaster and paint, others)	
	Total thickness of the wall assembly (mm)	
External Roof Assembly		
	Type of roof (Flat/slope)	
	Main roofing material (concrete, clay tiles, metal roofing, others)	
	Internal ceiling material (gypsum tile, others)	
	Total thickness of the roof assembly (mm)	
Fenestration – Vertical Glazing (Windows)		
	Type of window (Fixed/Sliding/Louvered/casement/awning/clerestory)	
	Type of glass (clear, tinted, reflective, single glazing, double glazing)	
	U-value of the glass (if available)	

No.	Item	Value
	Solar Heat Gain Coefficient (SHGC) of Solar Factor (SF) of the glass (if available)	
	Visual Light Transmittance (VLT) of the glass (if available)	
	Glass brand and product number	
Shading Devices		
	Depth of shading device	
	Length of shading device	
	Typical height of window	
	Typical width of window	
	Any presence of blinds (Yes/No)?	

Appendix 2 – Monthly Electricity Consumption

Month	Electricity Consumption (kWh)
Apr-19	20182
May-19	17195
Jun-19	30980
Jul-19	Not Available
Aug-19	Not Available
Sep-19	35625
Oct-19	54429
Nov-19	52907
Dec-19	53024
Jan-20	45086
Feb-20	50251
Mar-20	41668
Apr-20	30999
May-20	40131
Jun-20	49891
Jul-20	50826
Aug-20	52013
Sep-20	47176

Appendix 3 – Monthly Water Consumption

Month	Electricity Consumption (kWh)
Apr-19	190
May-19	398
Jun-19	809
Jul-19	Not Available
Aug-19	1265
Sep-19	759
Oct-19	844

Month	Electricity Consumption (kWh)
Nov-19	695
Dec-19	513
Jan-20	600
Feb-20	499
Mar-20	532
Apr-20	178
May-20	414
Jun-20	876
Jul-20	877
Aug-20	825
Sep-20	599

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