# Electrical Energy Auditing in Electricity Distribution Network of Rwanda

Rurangwa Damas[1]

Atlantic International University, Hawai

[ID: UD59060SEN68084]

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## ABSTRACT

**The developing country like Rwanda faces High Electricity Distribution Losses within its Network. Electricity Power distribution utility in Rwanda is facing many problems like commercial loss due to various reasons including inefficiencies, and high technical losses. This has a very bad effect on the economic growth of our country. Power system losses in Rwanda comprises of technical losses, non-technical losses & revenue losses. So, there is a need of proper energy accounting and audit in the power distribution system that helps the Utility to compute the energy losses. This paper provides the methodologies used to carry out the proper energy audit including deployment of SMART meters at every Network Grid Object, strengthening the Network extensions, N-1,2…. For this, the calculation of technical losses for HT feeders, power transformers, and secondary distribution system using the SMART meter data approaches. Keywords: technical losses, non-technical losses, Load Imbalances, power transformers, loss load factor, HT feeder), secondary distribution etc.**

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# CHAPTER ONE
# INTRODUCTION

➢ *Background Information*

Rwanda Energy Group is a holding that was incorporated in 2014 to expand, maintain and operate the energy infrastructure in Rwanda through its two subsidiaries, i.e. the Energy Utility Corporation Limited (EUCL) a d the Energy Development Corporation Limited (EDCL).

The Group was developed from EWSA (Energy and water Sanitation authority that was combining both Energy and water activities in the country. The Government of Rwanda has undertaken reforms in the energy and water sector which have been developed by the separation of energy from water operations where by the main objectives being: 1) To have sector focused and efficient operations; 2) Attract more investment; 3) Improve planning and accountability; and 4) Increase access to services by the population to drive sector performance towards the targets envisaged in the the Second Economic Development and Poverty Reduction Strategy (EDPRS II) and other national goals.

To this end, Government adopted the corporatization model as a vehicle to implement the required reforms. The law repealing EWSA of January 31, 2014 paved the way for the creation of two corporate entities which were subsequently incorporated in July 2014 with 100% government shareholding.

The Rwanda Energy Group Limited (REG) and its two subsidiaries; The Energy Utility Corporation Limited (EUCL) and The Energy Development Corporation Limited (EDCL) entrusted with energy development and utility service delivery while the Water and Sanitation Corporation (WASAC) has the mandate to develop and operate water and sanitation infrastructure and deliver related services in the country.

The Rwanda Energy Group (REG) was incorporated to expand, maintain and operate the energy infrastructure in the Country through its two subsidiaries the Energy Utility Corporation Limited (EUCL) and the Energy Development Corporation Limited (EDCL). The object of creating these subsidiaries amongst others was to ensure focused attention to enhancing efficiency in utility operations on one hand and ensure timelier and more cost-efficient implementation of development projects on the other. The Energy Utility Corporation is the trading arm of the Group and has to serve diverse Rwanda's electricity customers including individuals and industries. In executing its mandate, the Company will strive to achieve optimized generation capacity, economic plant dispatch to meet short and long-term energy supply requirements, enhanced operational efficiency, improved customer service, network growth, and increased connections within the footprint of electrified area. Energy loss in the existing power system is the difference between energy input to the system and the energy billed on the consumption of consumers connected and these are un avoidable. In the present global picture, where there is a never increasing demand for energy, energy These loss raises concerns to the utility, society, as well as the country as a whole where it belongs to. It has significant economical, financial and societal impacts amidst the continuing global energy crisis.

Energy losses occur at different levels of the power system, namely in electricity generation, transmission and distribution. The Utility is implementing various strategies and measures to minimize these losses in power systems. Although these losses are un avoidable but it is essential to maintain losses at certain minimum levels.

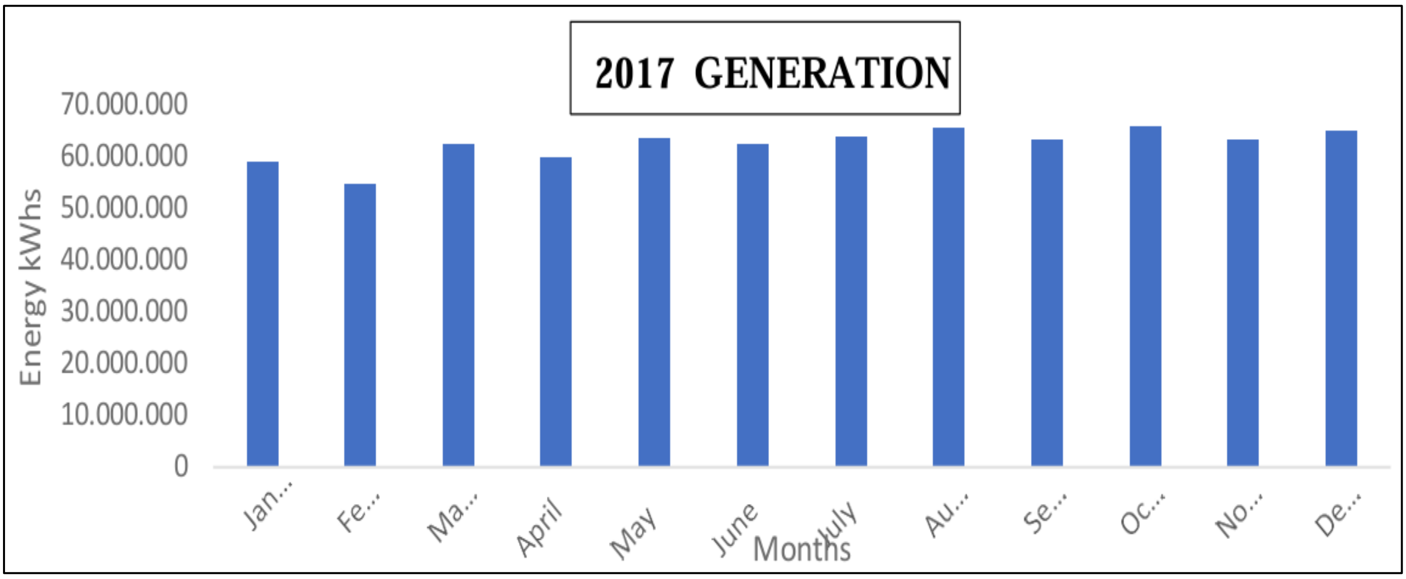


Fig 1 Electricity Generated in Year 2017

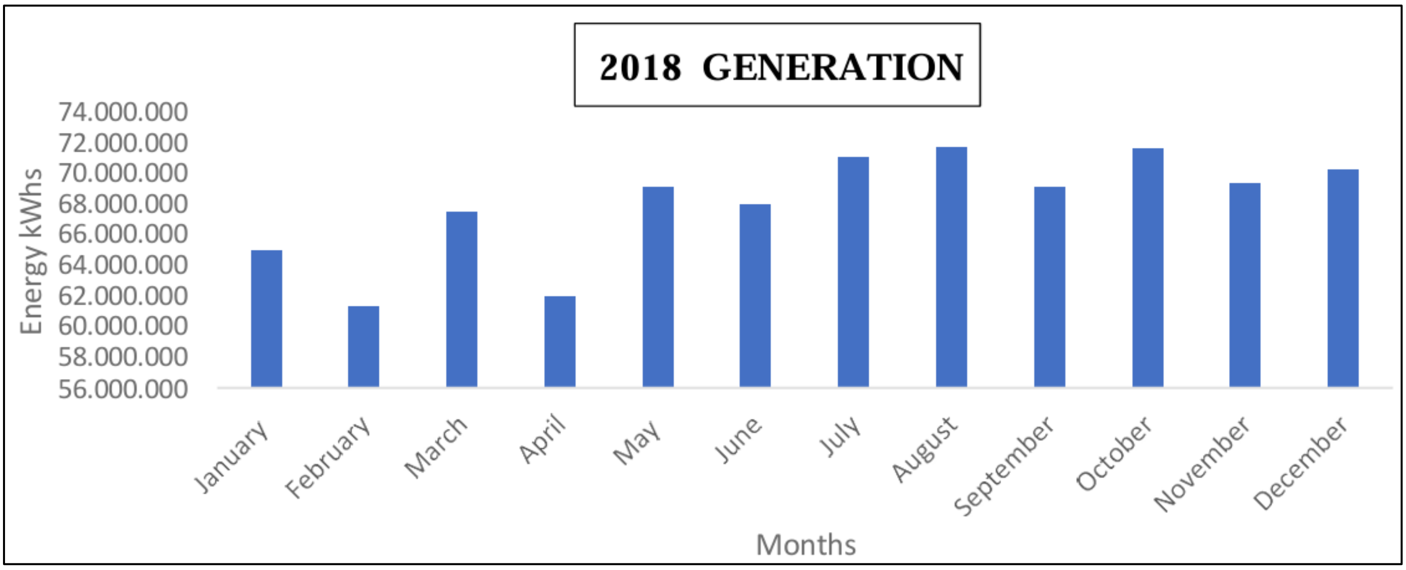


Fig 2 Electricity Generated in Year 2018

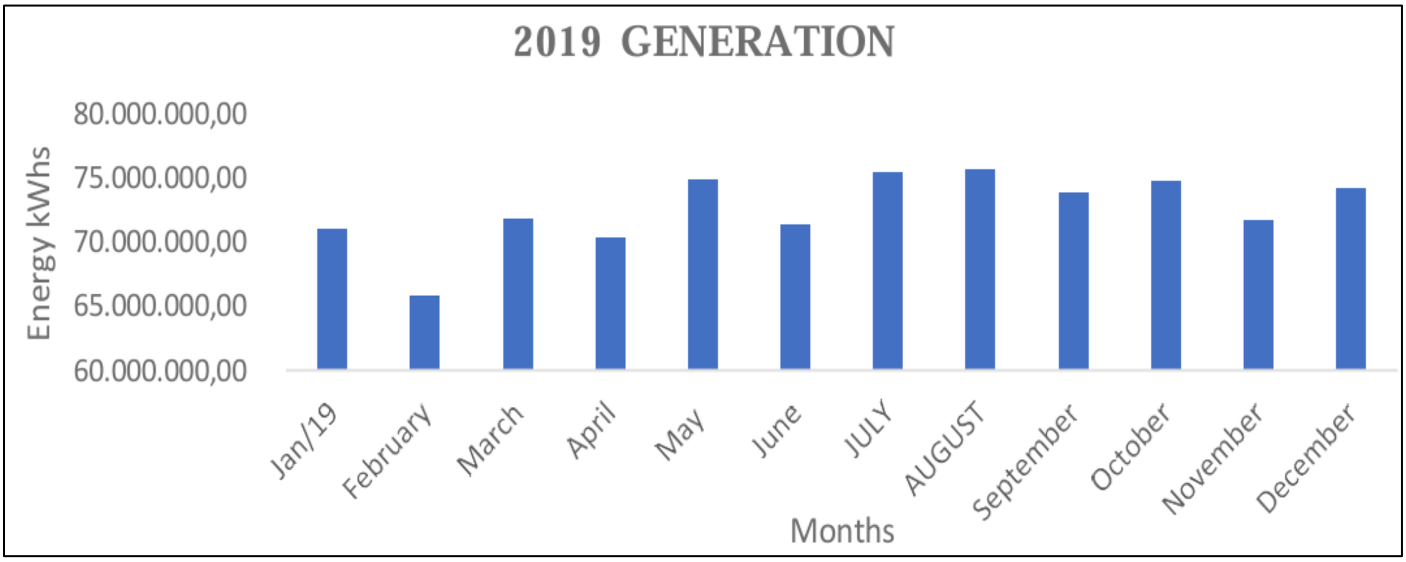


Fig 3 Electricity Generated in Year 2019

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# CHAPTER TWO
# DEFINITION OF THE INVESTIGATION (OR ISSUE)

➢ *Electricity Distribution System in Rwanda*

The Electricity Distribution in Rwanda is mainly at 30 kV as shown in the flow diagram below:

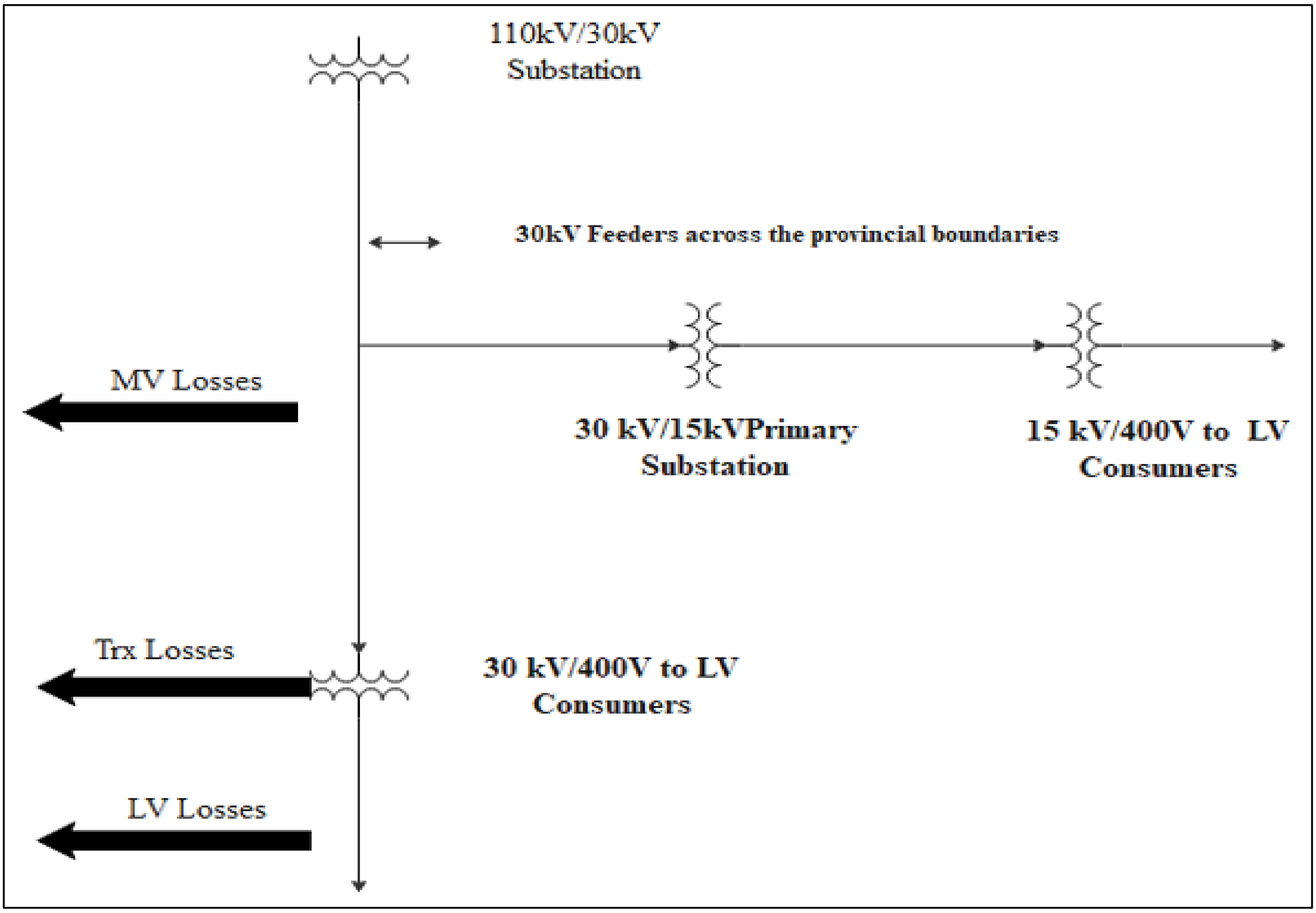


Fig 4 Energy Flow in the Distribution System

➢ *Distribution Losses*

Distribution losses can be segregated into the following components.

• *Technical Losses:*

These are inherently influenced by components and system designs. A list of such components in the local distribution system where power dissipation occurs is mentioned below.

- ✓ MV distribution lines
- ✓ Transformers supplying to low voltage heavy consumers
- ✓ Distribution transformers
- ✓ Low voltage distribution lines
- ✓ Consumer service lines
- ✓ Voltage regulators
- ✓ Capacitors
- ✓ Electrical burdens in metering equipment
- ✓ All other electrical devices necessary for the operation of the distribution system.

The losses in the power distribution lines, including service lines, are due to conductor loss. There are energy losses in electricity meters too. Further, higher level of harmonics in a distribution system also increases losses. Technical losses can be accurately computed provided the load conditions in the power system are known. Typically, load flow studies or network simulations are used to calculate technical losses.

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- *Non-Technical Losses (NTLs):*

NTLs are due to actions external to the power distribution system. NTLs are often unaccounted by utilities due to unavailability or lack of information. Hence, it is extremely difficult to have an accurate estimation of NTL in distribution systems. The general practice is to derive NTL after estimating technical losses. NTLs represent an avoidable financial loss for the utility. It is the amount of energy not billed but consumed. NTLs also reflect a social issue as the consumers who are accurately metered and billed are subsidizing those who do not pay for the electricity consumed. In general, NTL in the electricity distribution is high in countries where Gross Domestic Product (GDP) per capita is low. However, there are exceptions who have achieved very low levels of NTL irrespective of lower GDP per capita such as Thailand and Indonesia.

- *Electricity Theft:*

Electricity theft is defined as a conscious attempt by a person to eliminate or reduce the amount of money that he or she will owe the utility for electrical energy consumed. It is generally viewed as the major source of NTL by the electricity utilities worldwide. Two main forms of electricity theft can be identified, namely, directly connecting an unmetered load to a power line and tampering with the electricity meter in order to reduce, or stop recording the actual energy consumed. Illegal direct connections are mostly detected in rural and shanty areas.

- *Other Forms of Non-technical Losses:*

Whilst electricity theft is considered as the major form of NTL, the other forms of NTL are:

- ✓ Defective energy meters
- ✓ Un-metered connections
- ✓ Errors and delays in meter reading
- ✓ Arranging false meter readings by bribing utility staff
- ✓ Errors in billing
- ✓ Assessed meter readings
- ✓ Errors in estimation of technical losses

➢ *Economic Impact of Losses*

Energy losses represent losses in revenue for utilities. To recover costs involved in the supply of electricity and to fill the utility viability gap, costs of losses should be covered by paying users or by the Government via targeted output-based subsidies. Loss reduction and improvement on energy efficiency would partially cover the expected demand rise offsetting the need to increase the installed capacity. On the supply side, the impact on the utility to finance new generation capacity can be delayed or avoided if reduction in demand can be achieved by implementing good demand side management measures. The use of energy efficient compact fluorescent lamps (CFLs) in place of conventional incandescent lamps at large scale for domestic and other lighting applications is a typical example of such a demand side management measure.

➢ *Losses in Power Transformers*

Energy loss of a transformer depends on how it is loaded over a period of time. The following terms are important in understanding the energy loss of transformers:

- Load Loss Factor (LLF): This is the ratio Actual loss (kWh) during a cetain period to the loss at maximum current during that period
- Utilizationn Factor (UF): this is the ratio of Maximum Demand to the Rated Capacity

The average Loss of a power transformer is the total of its Iron and Copper Losses ie (LI+LC).

Instead of calculating the losses of individual transformers, a statistical method can be applied to approximately calculate the total loss of all the transformers under consideration. However, the following details of the transformers are required for the calculation.

- Capacity rating of each transformer
- Peak loading of each transformer
- Fixed and variable losses of the transformers of each rating
- Load factor

➢ *Sample Study on Low Voltage Network Losses*

Low voltage network supplies electricity to ordinary consumers. The ordinary consumers include those supplied under the domestic, religious, small scale industrial and general purpose tariff categories. Street lighting is also in the low voltage network. The share of ordinary consumer electricity sales is about 56% total electricity sales in the country. Table 16 shows the comparison of electrical energy consumption of the ordinary consumers and the low voltage distribution line lengths in the entire country and the provincial LV network.

- *Definition & Objectives of Electrical Energy Audit*

The fundamental goal of the Electrical Energy Audit is to minimise the electricity losses that might be present the course of transmitting and distributing electricity all the way to the end users. Once loses are reduced, the electricity tariffs might become affordable to the beneficiaries leading to the least cost and least environmental effect. One of the definitions of the Electrical Energy Audit is the judicious and effective use of Electricity to maximize profits (minimize costs) and enhance competitive positions. Another comprehensive definition is the strategy of adjusting and optimizing Electricity Usage, using systems and procedures so as to reduce electricity requirements per unit of output while holding constant or reducing total costs of producing the output from these systems.

The objective of this electrical Energy Audit is to achieve and maintain optimum Electrical energy procurement and utilisation, throughout the organization, to minimise electricity costs/waste without affecting production & quality and to minimise environmental effects.

- *Need for Energy Audit*

In any industry, the three top operating expenses are often found to be energy (both electrical and thermal), labour and materials. If one were to relate to the manageability of the cost or potential cost savings in each of the above components, energy would invariably emerge as a top ranker, and thus energy management function constitutes a strategic area for cost reduction. Energy Audit will help to understand more about the ways energy and fuel are used in any industry, and help in identifying the areas where waste can occur and where scope for improvement exists. The Energy Audit would give a positive orientation to the energy cost reduction, preventive maintenance and quality control programmes which are vital for production and utility activities. Such an audit programme will help to keep focus on variations which occur in the energy costs, availability and reliability of supply of energy, decide on appropriate energy mix, identify energy conservation technologies, retrofit for energy conservation equipment etc. In general, Energy Audit is the translation of conservation ideas into realities, by lending technically feasible solutions with economic and other organizational considerations within a specified time frame. The primary objective of Energy Audit is to determine ways to reduce energy consumption per unit of product output or to lower operating costs. Energy Audit provides a " bench-mark" (Reference point) for managing energy in the organization and also provides the basis for planning a more effective use of energy throughout the organization.

- *Problem of the Statement*

Electrical energy costs are soaring to the extent that this can lead to the population resorting to other alternatives or reduction in Electricity Consumptions in the Country. This can be a considerable risk if no measures are taken. Electrical energy audits are necessary to identify where Electricity is being wasted. Residential and and commercial properties account for around 40% energy Consumption and the rest 60% is for industrial, agriculture, and service sectors and carrying out an Electrical energy audit will help by revealing just how and where electricity is being wasted. With thousands of commercial energy customers nationwide, the audit will come out with the advice you on which methods are best used for reducing electricity waste and overall energy consumption.

An energy audit is an inspection survey and an analysis of energy flows for energy conservation. It may include a process or system to reduce the amount of energy input into the system without negatively affecting the output. Since Electrical energy is a very important thing in the economic growth of any country in all sectors. The living standard of country is directly related to per capita electricity consumption. Due to the economic growth of modern societies and to meet increasing electricity demand.

Generally, in an Input / Output system, losses are the difference between incoming and outgoing flows. In the case of an energy system, the incoming flow represents the energy injected or produced by the generation units and made available to consumers through a physical system of transmission and distribution. As for the outgoing flow, it can be assimilated to the energy consumed and actually paid. However, the complexity of the electrical energy system invites losses to be classified by sub-system (generation, transmission, distribution, invoicing) and by category (technical and non-technical losses). Physical subsystems constitute the set of energy networks as such thus, in generation and transmission subsystems, the losses incurred are intrinsically linked to their equipment and to their mode of operation. It is very evident that on the high-voltage side, fraud or other tampering is hardly possible. These losses are said to be purely technical.

On the other hand, the distribution subsystem has two (2) components, one of which is at medium voltage and the other at low voltage where by in these two (2) sets, the recorded losses are technical and non-technical. The most vulnerable and most accessible of these is the low- voltage component where more tampering are recorded, including fraudulent connections.

- *Description of the Problem*

Besides its Importance, Electrical Energy audit is an essential for any Rwanda Energy Group wishing to control its electricity usage as well as its operating costs.

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The annual report shows that REG has been incurring total losses ranging from 19 % to 21 % with an average for the year as a whole of 2019

It should be noted, however, that a review of the data used in calculating these losses identified anomalies that needed to be amended. As shown above the generated Energies are not read at real time basis and this leads to inaccurate computation of real Losses within the Network. In addition to inaccurate readings, during the computation of losses, the formula that is used allows some inaccuracies due to the fact the generation is being compared to sales instead of real Consumption in the same period as Generation.

The Low Voltage Distribution Network is operating in Imbalanced mode (i.e. the transformers are identified to face a lot of phase Imbalances), there is a need to balance the Phases on the Transformers with the Network. The weekly report shows that many transformers faces Phase imbalance rates that are above 5%. The chart below shows the behaviour of Phase currents from the chosen sample of the Transformer:

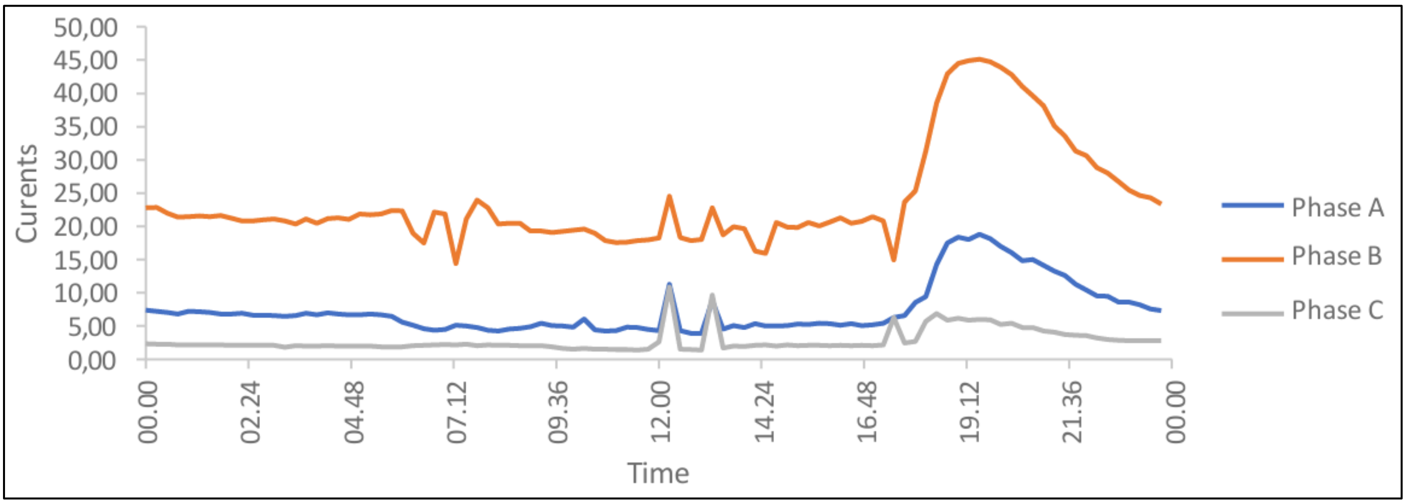


Fig 5 Transformer Curve Record

The Electricity Consumptions of most of the Customers of Rwanda Energy group behaves in a way that facilitates the losses like theft ie some customers tend to steal electricity hence contributing to a bigger T&D Losses, Low Power Factor that cause the Network to be stressed trying to overcome that reactive power from the clients. There is no means of monitoring the functioning of electricity meters to the extent that a meter might spend a lot of time malfunctioning i.e not registering all electricity being consumed by a client whereby it is found that all / part of consumed electricity is not billed and this contributes to the loses. Most of the customers tend to willing fully tamper the electricity meters and since there are no means of monitoring tamper alarms at all customers, this increases the frequency of unbilled energy in the system.

Distribution transformers are not located at load centre on the secondary distribution system. In most of case, distribution transformers are not located centrally with respect to consumers. Consequently, the farthest consumers obtain an extremity low voltage even though a good voltage levels maintained at the transformers secondary. This again leads to higher line losses. The reason for the line losses increasing as a result of decreased voltage at the consumers end. Therefore, in order to reduce the voltage-drop in the line to the farthest consumers, the distribution transformer should be located at the load centre to keep voltage drop within permissible limits.

Most of 15/ &30 KV and 400-volt lines are extended over long distances to feed loads scattered over large areas. Thus, the primary and secondary distributions lines are largely radial laid usually extend over long distances. The following results in high line resistance and therefore, high I2R losses in the line:

- Haphazard growths of sub-transmission and distribution system into new areas.
- Large scale rural electrification through long 15 &30kV and LT lines.

Also, the size of the conductors should be selected on the basis of KVA x KM capacity of standard conductor for a required voltage regulation but rural loads are usually scattered and generally fed by radial feeders whose conductor sizes are not adequate.

In most Low Voltage distribution loads, the power factor lies below 0.8 and a low power factor contributes towards high distribution losses. For a given load, if the power factor is low, the current drawn is high and losses proportional to square of the current will be more.

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Improper cable joints are found in the network and these ccontributes significant role towards increasing distribution losses. Poor Joining techniques cause the voltage reflections with in the network in a such a way that they would create voltage imbalances in the network hence Current imbalances might follow.

On the side of customers, most of the clients consumes more than the electricity being supplied to them that leads to higher deviation from the Consumed and supplied energy to some of the customers. In addition to Large consuming capacity, some customers experience Low Power factor that raises copper loses within the Network. The table1 below shows the examples of Customers with Power Factor below 0,9

Table 1 Customers with their corresponding Power Factor

| **Customer Name** | **Branch** | **Power factor** | **Period** | **No of Billed Days** |
|---|---|---|---|---|
| CATCHUP INVESTMENTS LTD CATCHUP | BUGESERA | 0,896223981 | 201912 | 31 |
| ABUSOL | BUGESERA | 0,724396419 | 201912 | 31 |
| KIGALI LEATHER | BUGESERA | 0,514784975 | 201912 | 31 |
| KIGALI LEATHER II | BUGESERA | 0,702032914 | 201912 | 31 |
| POURTRY EAST AFRICA LTD | BUGESERA | 0,8345181 | 201912 | 30 |
| EAST AFRICA EXCHANGE LTD | BUGESERA | 0,818283696 | 201912 | 31 |
| MAYANGE RICE | BUGESERA | 0,61547507 | 201912 | 32 |
| LAKE SIDE FISH FIRM | BUGESERA | 0,850409253 | 201912 | 31 |
| RWANDA BOTTLERS LTD | BUGESERA | 0,747579731 | 201912 | 31 |
| CONVENANT TREASURES RWANDA Limited | BUGESERA | 0,345819826 | 201912 | 31 |
| GLOBAL TRADING IMPEX LTD | BUGESERA | 0,790982529 | 201912 | 31 |
| ENVIROSERVE RWANDA GREEN PARK LTD | BUGESERA | 0,814318394 | 201912 | 31 |
| GASHORA GIRLS ACADEMY | BUGESERA | 0,85246664 | 201912 | 31 |
| BUGESERA WATER PARK | BUGESERA | 0,857021416 | 201912 | 31 |
| WASAC/POMPAGE RWAKIBIRIZI | BUGESERA | 0,845043715 | 201912 | 31 |
| WASAC/KANYONYOMBA WATER PUMPING | BUGESERA | 0,881984991 | 201912 | 31 |
| RUHUHA KUNDA UMURIMO Ltd | BUGESERA | 0,817363687 | 201912 | 31 |
| SUNBELT TEXTILES RWANDA LDT | BUGESERA | 0,576221411 | 201912 | 29 |
| SOSOMA INDUSTRY BUGESERA | BUGESERA | 0,736529888 | 201912 | 30 |
| TRINITAS GROUP LTD | BUGESERA | 0,606843203 | 201912 | 31 |
| TRIBU LTD | BUGESERA | 0,757409962 | 201912 | 31 |
| WASAC/PROJET A.E.P.BUGESERA | BUGESERA | 0,842742984 | 201912 | 31 |
| SHYAMA GGREGATES LTD | BUGESERA | 0,847998304 | 201912 | 28 |

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# CHAPTER THREE
# DYNAMICS OF THE ANTICIPATED SOLUTION

Electrical Energy Auditing in Rwandan Network will provide the vital information base for overall energy conservation program covering essentially energy utilization analysis and evaluation of energy conservation measures. It aims at: Identifying the quality and cost of various energy inputs, assessing present pattern of energy consumption in different cost centres of operations, Relating energy inputs and production output, Identifying potential areas of thermal and electrical energy economy, Highlighting wastage in major areas and Implementation of measures of energy conservation and realisation of savings.

The audit will determine the electricity consumption associated with the company and the potential savings associated with that consumption. It will help to reduce the dependence on foreign electrical energy sources as well as reducing environmental damage and pollution.

➢ *Methodology*

The Efficient electrical Energy Audit in the company will be accomplished by

- Identifying areas of improvement and formulation of energy conservation measures requiring no investment or marginal investment through system improvements and optimisation of operations.
- Identifying areas requiring major investment by incorporation of modern electricity efficient equipment and up-gradation of existing equipment.

➢ *The Electrical Energy Auditing Involved:*

- Collection of primary data & preliminary analysis of Electricity data: At this initial stage, data and information will be collected related to the present/current and past energy profile including the utilization on electricity with in the network. This data/information can be retrieved with the aid SMART Meters installed in the Network. The preliminary analysis of all collected data will lead to the identification of the annual trend and monthly fluctuation/variation of the total electricity energy consumption and Generation, which constitutes company's electrical energy profile. Initial energy data collected, will also lead to a first approximation on electricity consumption allocation in every area and sub-system of the network. This is a way to express the electricity balance of the network.
- Walking through the network to check on the Installation states of some of the equipment in the network: This will involve the qualitative of the Distribution Network to determine the appropriate sizing on the any existing electricity Infrastructure. This data registration will be coupled with instantaneous sampling measurements to apportion energy use and thus leads to the eelectricity balance within the network. This method once coupled with the previous one will lead to determination of energy saving potential with the use of tiding-up measures and simple inexpensive measures/actions that don't need economic payback assessment through relevant energy studies.
- On-site thorough Electrical energy Audit: This will involve the collection (from in-site measurements) and processing of data as well as a full examination of the installed infrastructures in the network which will trigger a thorough analysis. This procedure will also permit a sound techno- economical evaluation of one or more energy-saving approaches, with medium to high investments on specific systems, after a relevant study. This audit will be finalised with the presentation of all the energy saving proposals having the form of a summarized techno-economical report, which is composed by the Auditor and presented to the Company's Management for further decisions. This report will be part of my Final thesis for achieving a doctorate degree in Energy Audi and Management from Atlantic International University (AIU).

➢ *Typical Tools that will be Used in this Audit and Time Frames for Energy Audits in Various Applications*

Generally speaking, the typical requirements for carrying out an efficient Electrical energy audit in the company will be summarised can be summarised as:

- Staff with relevant knowledge/skills
- Time allocated to perform the tasks involved
- Technical equipment for any measurements eg SMART meters
- Financial assistance in the above areas and for the implementation of the recommendations
- Technical and operational information on Network performance.

The time taken to perform the mentioned Audit will depend on the availability of electrical energy data, the size of the site and the complexity of the systems. A walk-through audit will take only a few hours for a simple site for which information is readily available.

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➢ *Electrical Energy Audit: Types and Methodology.*

Electrical energy Audit is the key to a systematic approach for decision-making in the area of Electricity sector. It attempts to balance the total energy inputs with its use, and serves to identify all the energy streams in a facility. As it quantifies energy usage according to its discrete functions, it is as well an effective tool in defining and pursuing comprehensive electricity usage management programme.

- *The Type of Electrical Energy Audit to be Performed will Depend on:*

✓ Function and type of the facility
✓ Depth to which final audit is needed, and
✓ Potential and magnitude of cost reduction desired

- *Thus, Electrical Energy Audit was Classified into the Following Two Types*

✓ Preliminary Audit
✓ Detailed Audit

- *The Preliminary Involved the Following:*

✓ Establishing energy consumption in the organization
✓ Estimating the scope for saving
✓ Identifying the most likely (and the easiest areas for attention
✓ Identify immediate (especially no-/low-cost) improvements/ savings
✓ Setting a 'reference point'
✓ Identifying areas for more detailed study/measurement
✓ Preliminary audit used the existing, or easily obtained data

A Detailed Audit provided a detailed electrical energy project implementation plan for a facility, since it evaluates all major electrical energy using systems. This type of audit offerd the most accurate estimate of energy savings and cost. It considered the interactive effects of all projects, accounts for the energy use of all major equipment, and includes detailed electricity cost saving calculations and project cost. Since the energy Balance is one of the key elements of a comprehensive audit, During the audit, an energy Balance was considered by basing on an inventory of electrical energy using systems, assumptions of current operating conditions and calculations of electricity usage. This estimated use was then be compared to utility bill charges. Detailed auditing was carried out in three phases:

✓ Phase I - Pre-Audit Phase
✓ Phase II - Audit Phase
✓ Phase III - Post Audit Phase

✓ *Phase I -Pre-Audit Phase Activities*

▪ An initial study of the site was carried out as it is a condition for this phase.
▪ Initial Site Visit and Preparation was done. This took only one day and provided an opportunity to meet the personnel concerned.

- *During the Initial Site Visit, the Following Actions were Carried Out:*

✓ Discuss with the site's senior management the aims of the audit.
✓ Discuss economic guidelines associated with the recommendations of the audit.
✓ Analyse the major energy consumption data with the relevant personnel.
✓ Obtain the building plan drawings where available - building layout, steam distribution, compressed air distribution, electricity distribution etc.

- *Tour the Site Accompanied by the Electrical Engineer Staff from the Facility. The Main Aims of this Visit were:*

✓ To identify the main energy consuming areas/plant items to be surveyed during the audit
✓ To identify any existing instrumentation/ additional metering required.
✓ To decide whether any meters will have to be installed prior to the audit e.g. kWh, steam, oil or gas meters
✓ To identify the instrumentation required for carrying out the audit
✓ To collect macro data on facility energy resources, major energy consuming centers
✓ To create awareness through meetings/programme

✓ *Phase II- Detailed Energy Audit Activities*

Depending on the nature of data availability and access, the detailed studies to establish, and investigate, Electrical energy balances were easily carried out. Whenever possible, checks of facility operations were carried out over extended periods of time, at nights and at weekends as well as during normal daytime working hours, to ensure that nothing is overlooked. The audit report will include a description of energy inputs and product outputs by different categories of Electricity Consuming Equipment i.e. HVAC, Motors, Lighting, etc. and will evaluate the efficiency of each step of the manufacturing process. Means of improving these efficiencies will be listed, and at least a preliminary assessment of the cost of the improvements will be made to indicate the expected payback on any capital investment needed. The audit report will conclude with specific recommendations for detailed engineering studies and feasibility analyses, which must then be performed to justify the implementation of those conservation measures that require investments.

- *Below Shows the Flow Chart of a Detailed Audit Process Taken:*

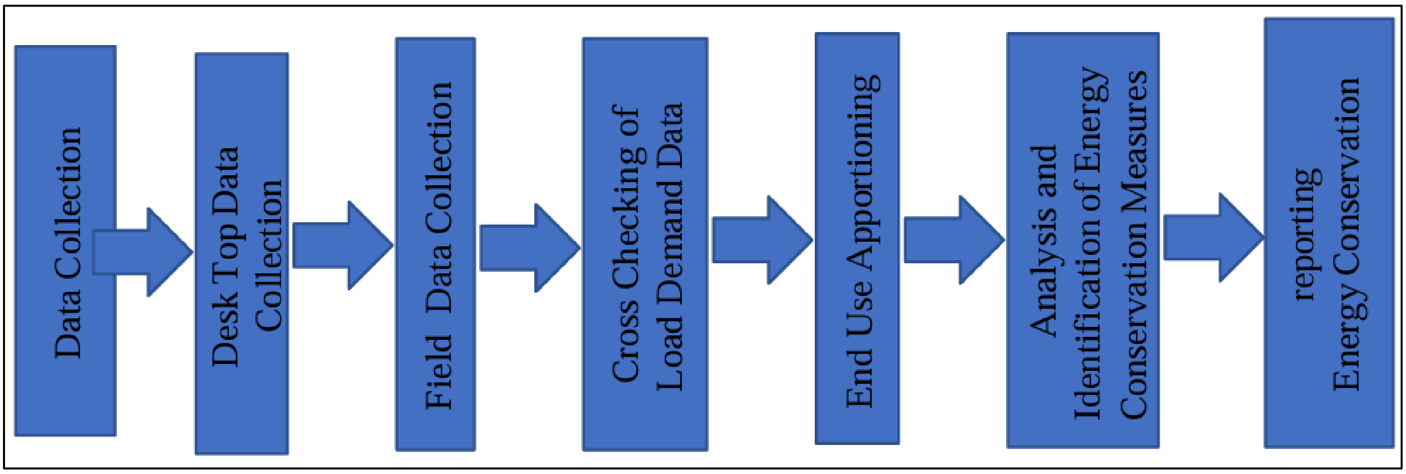


Fig 6 Flow Chart of a Detailed Audit Process

➢ *Data Collection*

Data were collected from the site either by moving there physically or using remote data collection through the Installed SMART meters. The collected data is then used to build a reliable picture of where and how much energy is being consumed as well as the cost of energy being used. Data collection was the most laborious tasks in the Electrical Energy Audit conducted.

➢ *Desktop Data Collection*

The purpose of desktop data collection was to minimize the field energy related data collection by using all available facility data. It was during the initial process that the audit forms were used to collect preliminary data where by the forms allowed me to understand the nature of the audited building and its areas to focus during the detailed auditing. The data collection through the form were used to estimate the time and resources required for the field data collection activity. Below are the forms that were used to collect the preliminary data:

Table 2 Preliminary Data Collection Form

| **Company Name & Address** |
| --- |
| Name, designation, telephone, fax no & email of |
| company's person in-charge |
| Name, telephone, fax no & email of registered |
| electrical energy manager |
| No. of staff |
| Operating hours (day, week, month) |
| Electricity tariff category |
| Building age |
| Building function |
| No. of blocks |
| Gross floor area (m2) |
| Percent of gross floor area that is air conditioned (%) |
| Server area (%) |
| Parking area that is enclosed (%) |
| Designed occupant load (please specify unit) |
| Actual occupant load (%) |

Table 3 Billing Data Collection Form

| **Month** | **Energy Use (kWh)** | **Rent (RWF)** | **VAT (RWF)** | **Sales (RWF)** | **Total Bill (RWF)** |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

Table 4 Lighting Desk Top Data Collection Form

| **Type of Light *:** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Level | Operation Hrs (hr/day) | Rated power kW (lamp+ ballast) | Total Number Installed | Place of use | Control system (manual/auto) | Remark | Please expand the table for other type of lighting(s) |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

Table 5 Lighting Field Data Collection Form (*If any Changes/Absence of Information During Desktop Data Collection)*

| **Type of Light□:** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Level | Operation Hrs (hr/day) | Power Measured kW Lamp + Ballast) | Loading Factor (%) | Place of use | Control system (manual/auto) | Average Lux Level | Remark | Please expand the table for other type of lighting(s) |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

T8/T5 fluorescent light, CFL, incandescent light, LED, etc

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

Table 6 Other Electrical Equipment Data Collection Form

| **Type of building electrical equipment □:** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Level | Operation hours (hr/day | Rated power kW | Quantity (nos) | Remark | Please expand the table for other type of building electrical equipment (s) | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

➢ *Field Data Collection*

The field Data Collection was carried out as a critical for:

- Complementing the missing data, which could not be found during the Desktop Data Collection process.
- Verifying the accuracy of Desktop Data.
- Understanding closely the building operations, energy wastages and building maintenance status.
- Carrying out the necessary field measurements required to establish main incoming load profile, major energy end-uses such as HVAC, lighting and others. Establishing actual building load apportioning

➢ *Cross Checking of Load Demand Data*

The accuracy of estimated end-use energy consumption might affect the accuracy of estimated energy savings of various ECMs. Therefore, for reliable estimate of the building and end-use energy consumption, the following approach was used:

- Use of the field data collected to estimate the building's total and end-use energy consumptions. Due to a number of assumptions used in this method, in particular the equipment loading and time usage factors, the accuracy in estimating the building total end-use energy consumption may vary depending on the loads measured. For instance, due to the predictable nature of lighting load, this method allows reliable determination of the building lighting load.
- Use of the appropriate data loggers to record the building and end-use load cycles. For example, recording typical daily load profiles of main incoming for seven (7) days, through SMART meter.

✓ *E.g. photocopying machine, fax machine, computer, printer, water dispenser, vending machine, lift, escalator etc*

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# CHAPTER FOUR
# OVERALL OUTCOMES

In order to carry out the efficient and purposeful electrical Energy Audit in Rwandan Network, several strategies were taken and among those were as follows:

- Installation of SMART meters on every Transformer in the Network
- Installation of SMART Meters on all Power Plants
- Piloting SMART prepaid meters on 1000 customers

These SMART meters are helping in retrieving the network consumption details like Transformer Imbalances, real-time distributed energy from transformers, real time generation, real time consumptions of prepaid customers etc.…

- *The Techniques that were Used During the Same Audit are Listed Below:*

- Reading all meters in the Network at the same time i.e at every beginning of each month at 00:00 midnight.
- Reading the phase unbalancing at the Transformer output on weekly basis
- Reading daily consumption of clients with SMART Prepaid Meters on real time basis.
- Reading the alarms caused by poor installations.

- *Load Imbalances:*

At present time, asymmetrical or unbalanced loads are experienced almost in all 0.4 kV distribution networks. The causes of this load imbalances is usually caused by domestic consumers, industrial consumers, etc. A balanced three phase system is characterized by the same module and voltage in all the three phases. During unbalanced operation mode, current is not equally distributed in the phases. Unbalanced operation modes in electrical networks are caused by the following reasons:

- Unequal loads in various phases,
- Partial operation of lines and other elements in the network,
- Different line parameters in different phases

It was found that most of the transformers in the Network are working in Unbalancing mode due to the fact that before any New connection of a customer, the loading of the transformer is not considered. Annex C shows the load Imbalances of most of the transformers which shows that Most of them are above 5% and this causes high Copper losses in Conductors. The Imbalances were found mostly to be caused by tapping a single-phase long extension lines from a three-phase line.

- *Estimation of Distribution Losses*

Basing on the demand, the energy loss was calculated given the following data:

- The total annual energy demand (677,87 GWhs) *ie for both residential and non- residential)*
- Peak Power Demad (152 MW)
- Installed Capacity ( 227 MW)
- Peak availability ( 176MW)
- Peak Power Loss ( 176-152 = 24 MW)

From the above data, the Load factor is he ratio of Total annual energy demand to the Peak Power Demand (= 677870/ 152 * 24 *365 = 0.51.

Since the loss of energy in any electricity network varies with time, A hypothetical time known as ‘Utilization time of losses’ or ‘UTL’ is defined such that losses during UTL with a continuous load equal to the peak power loss is the same as the loss with actual loading over the day. From the above data, UTL = $LF^2$ $(2+LF^2)$ *8760 divided by 1+2*LF. = ( 0.51^2 (2+0.51^2)*8760)/ 1+2*0.51=5150,6 Hrs/ year.

Therefore Energy Loss per year is estimated to be 24 * 5150,6/1000 GWhs = 123 GWh. Since the average Energy Input to the network is 810,8 GHws. The aannual energy loss as percentage of energy input to the nnetwork is 123/810.8 = 15 %.

- *Low Voltage Distribution Losses*

During the analysis of the losses with the help of the installed SMART Meters on all MV/LV Distributionn Transformers, a comparisonn was made between the energy being distributed into an area with the energy billed from the same area.

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Estimates were done on consumptions of clients using prepaid Meters by taking the average of their sales within a year as to minimie all possible errors that arises considering the following scenario:

- Some clients might buy electricity to be consumed for a long time to the extent that the units bought might also be used in more than one month.

- The challenge is that all Transformers are not yet covered except only two are covered at 100%

- *The Table 4 below Illustrates the Difference Between the Energy Distributed and Energy Billed for the Covered Ones:*

Table 7 Low Voltage Distribution Losses

| | **Branch Name** | **Distributed Energy (kWhrs)** | **Billed Energy (POST- PAID Customers)** | **Energy_Sold to Prepaid Customers (kWhrs) (Average of One year ie from June 2019 to June _2020)** | **Total Billed Energy** | **%ge LV Loss for June 2020.** |
|---|---|---|---|---|---|---|
| 1 | Huye | 1.183.150,60 | 517507 | 546974,3917 | 1064481,392 | 10,03% |
| 2 | Muhanga | 749.461,88 | 236.368,00 | 434.288,24 | 670.656,24 | 10,51% |

- *Methodology*

In order to find the electrical energy loss in the LV network selected, the methodology adopted is explained below.

- All the Transformers in Low Voltage network were obliged to be equipped with SMART Meters that are sending a 15 minute date to the central station.
- All the customers that are not on prepaid metering were bliged to have SMART meters sending a 15 miute data to the central station.
- In order to obtain the nearest to real Energy Cosumed by Prepaid Customers, their average sales within a year had to be computed.
- Ay the end of the month, the difference between the energy distributed from the Transformers and the energy billed from the customers supplied by the same transformers is computed and the result is the loss

- *Load Power Factor.*

The power factor is defined as the ratio of the active power (P) i.e the real power which is assumed in an AC circuit, and volt-amperes ie which is produced in the circuit when the waves of voltage or current are not in phase.

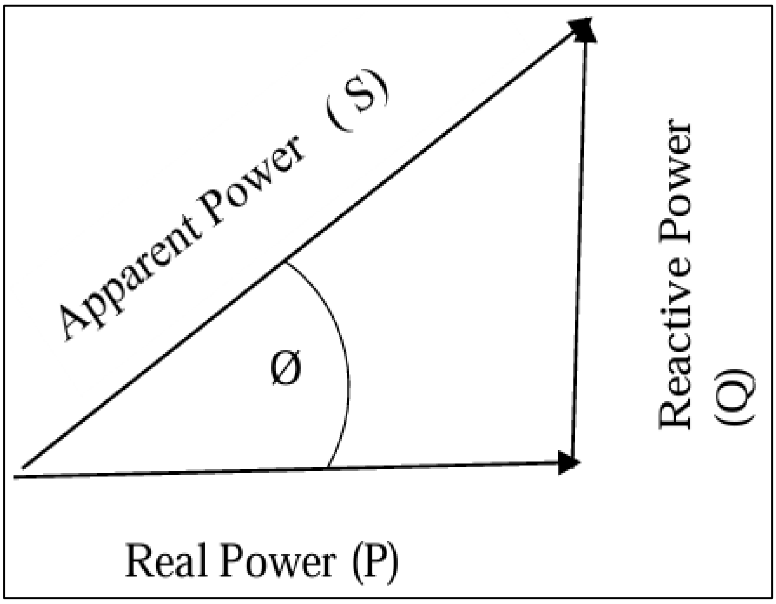


Fig 7 Graphical Power Factor Presentation

Power Factor = $\cos\Phi$ = P/S = P/VI

$I = P/V \cos\Phi$ ................................................................................................ ……………………………………Equ (I)

Equation (1) shows that the current is affected by the power factor. Hence, for a given power P by the load, the current I, taken by the load varies inversely as the load power factor cosΦ. Thus, a given load takes more current at a low power factor than it does at a high-power factor.

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A low power factor has caused a greater loss of Electricity in the electrical distribution system. This low power factor results in the equipment being overloaded, overheated and hence experiencing a shorter life time.

Four Customers were taken as a study sample and the following were identified.

Table 8 Customers with their Load Power Factor

| **Customer Name** | **PF** | **k V** | **I0,496** | **I0,98** | **W** | **kVA 0,496** | **kVA 0,98** | **Redu ction of kVA ie Dema nd** | **Annu al kVA Redu ction** |
|---|---|---|---|---|---|---|---|---|---|
| ECLAIRAGE PULIC RUGERAMIGOZI | 0,49 6043 | 0, 4 | 39,7 0967 | 20,0 9968 | 136 30,8 | 27,4 7909 | 13,9 0898 | 13,57 011 | 162,8 414 |
| MUNYINYA | 0,75 1458 | 0, 4 | 27,0 576 | 20,7 4761 | 140 70,2 | 18,7 2386 | 14,3 5735 | 4,366 512 | 52,39 815 |
| Quartier Commercial | 0,54 7851 | 0, 4 | 22,8 7867 | 12,7 899 | 867 3,6 | 15,8 3204 | 8,85 0612 | 6,981 428 | 83,77 713 |
| KABGAYI DIOCESE - ECONOMAT | 0,52 5617 | 0, 4 | 5,71 6376 | 3,06 5943 | 207 9,2 | 3,95 5732 | 2,12 1633 | 1,834 099 | 22,00 919 |
| TOTAL kVA Reductions | **321,0258454** | | | | | | | | |

As shown in the table above, improving power factor leads first in the reduction of Electricity demand.

Considering 13630,8 W load and 400 V system, the load current and copper losses are: $I_{0,496} = 13630.8/\sqrt{3}*400*0.496 = 39.70967$ A

$I_{0,98} = 13630.8/\sqrt{3}*400*0.98 = 20.09968$ A

Assuming that the copper losses are 3% of the load which is 0.03*13630.8 = 408.924W ( the Copper Losses at 0.496 Power Factor)

Therefore, the copper losses at 0,98 Power Factor

$I^2R_{0,98} = 408.924* (20.09968/39.70967)^2 = 104.7679222133$ W since the Copper losses is proportional to the Current.

The reduction in Copper Losses is = (408.924 – 104.7679) = 304.1561 W which is 74% decrease.

Likewise, the improvement of power factor reduces the demand as follows: kVA recorded at existing Power Factor i.e 0.496

$kVA_{0.496} = 13630.8/0.496 = 27.48145$ kVA $kVA_{0.98} = 13630.8/0.98 = 13.90898$ kVA

Therefore, the reduction in Demand = (27.48145-13.90898) = 13.57247 kVA

➢ *Disadvantages of Low Power Factor*

The undesirable effect of operating a low load at a low power factor is due to the large current required for a low power factor. The important dis advantages of low power factor are:

- Higher current is required by the equipment, due to which the economic cost of the equipment is increased.
- At low power factor, the current is high which gives rise to high copper losses in the system and therefore the efficiency of the system is reduced.
- Higher current produced a large voltage drop in the apparatus. This results in the poor voltage regulation.

Since both the capital and running cost are increased, the operation of the system at low power factor (whether it is lagging or leading) is uneconomical from the supplier’s point of view.

➢ *Electrical Energy Audit of Public Building Electricity Supply*

The Electrical Energy Audit was carried out on a PUBLIC Building in the center of the town and its Energy end use is 100% electric and all electricity in the building is supplied by the local supply network via a step-down Transformer.

Electricity is supplied from the local Network first to the automatic backup generator switch and then to the building itself through a main distribution switch located in the basement level. Each floor of the building is equipped with two electricity distribution panels which are supplied from the main distribution panel located in the basement.

➤ *Tariff and Charges*

The electricity service supplied to the building is billed in the following categories : Value Added Tax, Regulator fee as well as the consumption in kWhs. The Builging pays for electricity under a flat tariff structure, which includes a charge only for the consumption component energy supplied to the building.

Table 9 Summarizes the Charges and Tariffs of Electricity Supplied

| | |
|---|---|
| Regulator Fee | 0.3% (Applied to Energy) |
| Energy | RWF 222/Month |
| VAT | 18% (Applied to Energy) |

Table 10 Utility Billing History

| Months | Energy kWhs | Total Cost |
|---|---|---|
| Jan/19 | 54597,00 | 14336462,00 |
| Feb/19 | 42727,00 | 11219092,00 |
| Mar/19 | 38202,00 | 10030709,00 |
| Apr/19 | 46412,00 | 12186868,51 |
| May/19 | 42165,00 | 11407685,56 |
| Jun/19 | 39859,00 | 10468009,73 |
| Jul/19 | 42384,00 | 11131140,38 |
| Aug/19 | 42457,00 | 11150312,08 |
| Sep/19 | 49454,00 | 12987906,20 |
| Oct/19 | 39921,00 | 10484292,55 |
| Nov/19 | 36252,00 | 9520717,75 |
| Dec/19 | 45724,00 | 12008311,22 |

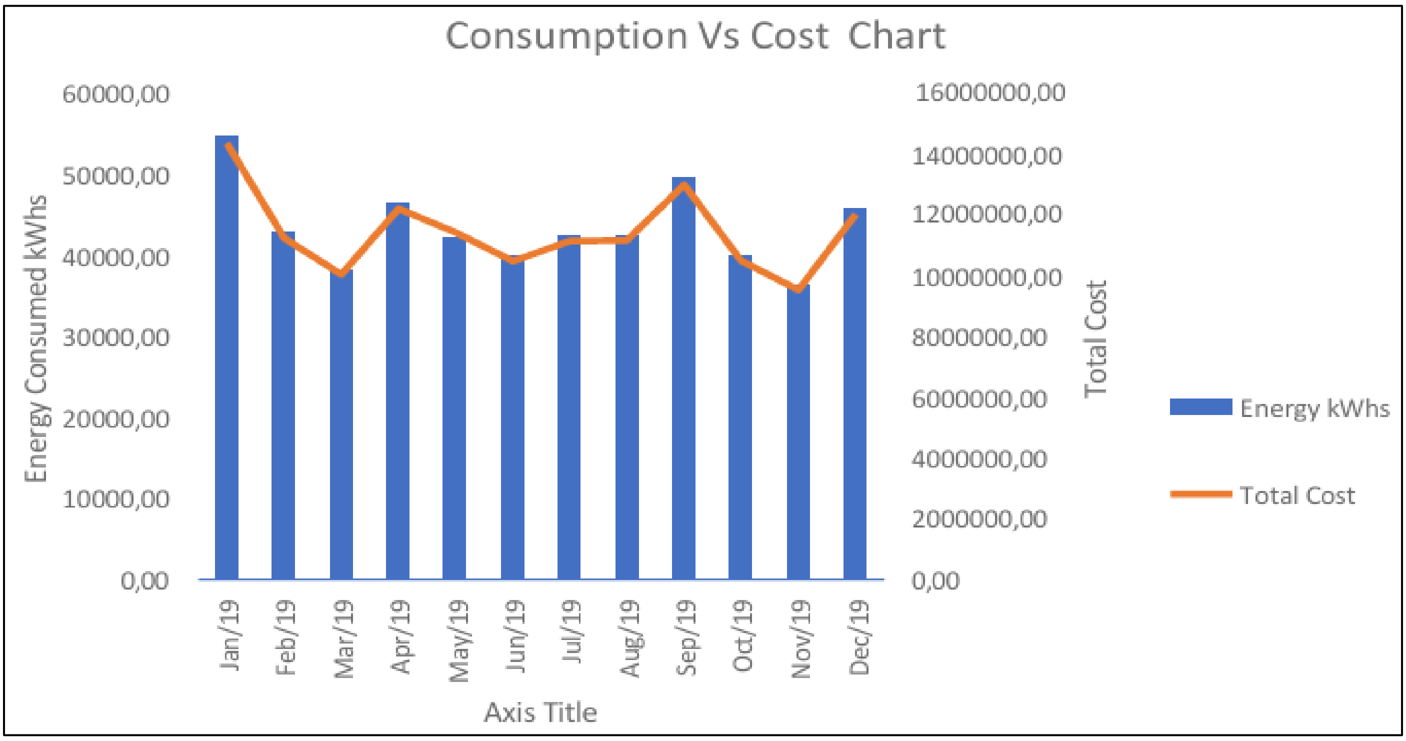


Fig 8 The Building Electricity Billing History

➤ *Instantaneous Primary Power Measurements*

Electrical measurements for the primary electric service to the Building were taken at a point of supply to the whole The following voltage and current measurements were observed.

Table 11 Electrical Power Supply to the Public Building

| Phase A | | | Phase B | | | Phase C | | |
|---|---|---|---|---|---|---|---|---|
| **Volts** | **Amps** | **kVA** | **Volts** | **Amps** | **kVA** | **Volts** | **Amps** | **kVA** |
| 239 | 148,2 | 35,4198 | 239,7 | 165,8 | 39,74226 | 239,6 | 201,6 | 48,30336 |
| Total kVA | 123,4654 | | | | | | | |

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As shown above, the building is facing the Phase current Imbalance of 17% which is out of acceptable limits as it is beyond 10%.

➢ *Elevator Instantaneous Power Measurements*

Since the specifications of the elevators were not available, instantaneous electrical measurements for the elevators were taken at the main control panel located on the 6th level to determine the electric power demand. The following voltage and current measurements were observed.

Table 12 Electrical Power Supply to the Elevators

| Phase A | | | Phase B | | | Phase C | | |
|---|---|---|---|---|---|---|---|---|
| **Volts** | **Amps** | **kVA** | **Volts** | **Amps** | **kVA** | **Volts** | **Amps** | **kVA** |
| 160 | 19 | 3 | 194 | 20 | 4 | 193 | 19 | 4 |
| Total apparent power: | | 11 kVA | | | | | | |

Electricity is supplied to the two elevators in the building from the same conductors, and the measurements shown above are the average readings for each as they operated.

➢ *End-Use Load Apportioning*

The Audit carried out used the above suggested three steps to apportion the total building load into its major end-use loads. The chart in below shows a sample of load apportioning of a building.

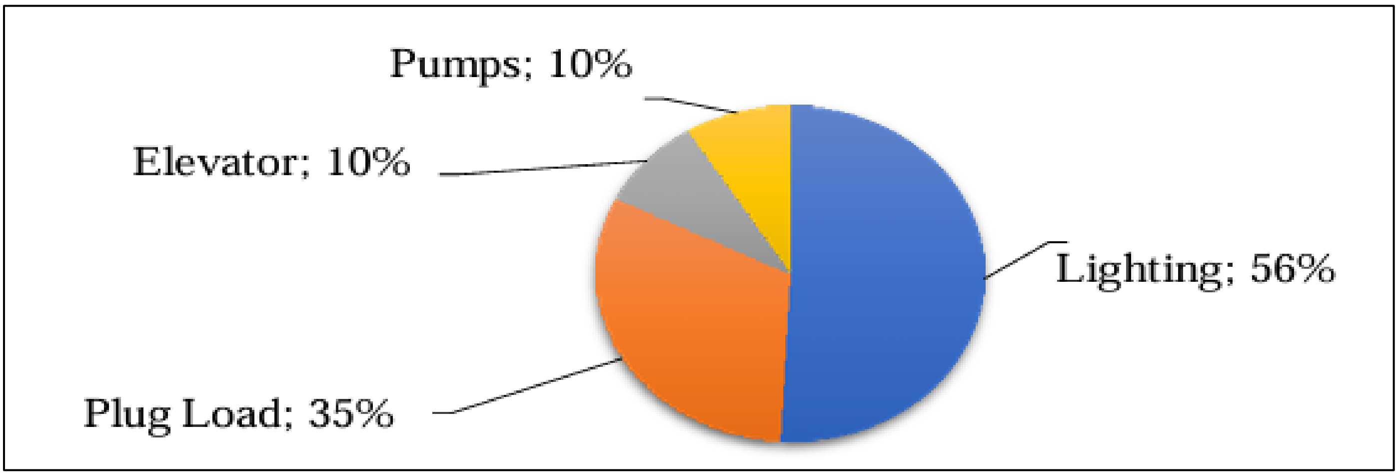


Fig 9 Public Building End-Use Load Apportioning

Energy end use for the building is categorized as shown in the table below, including the estimated peak load for each.

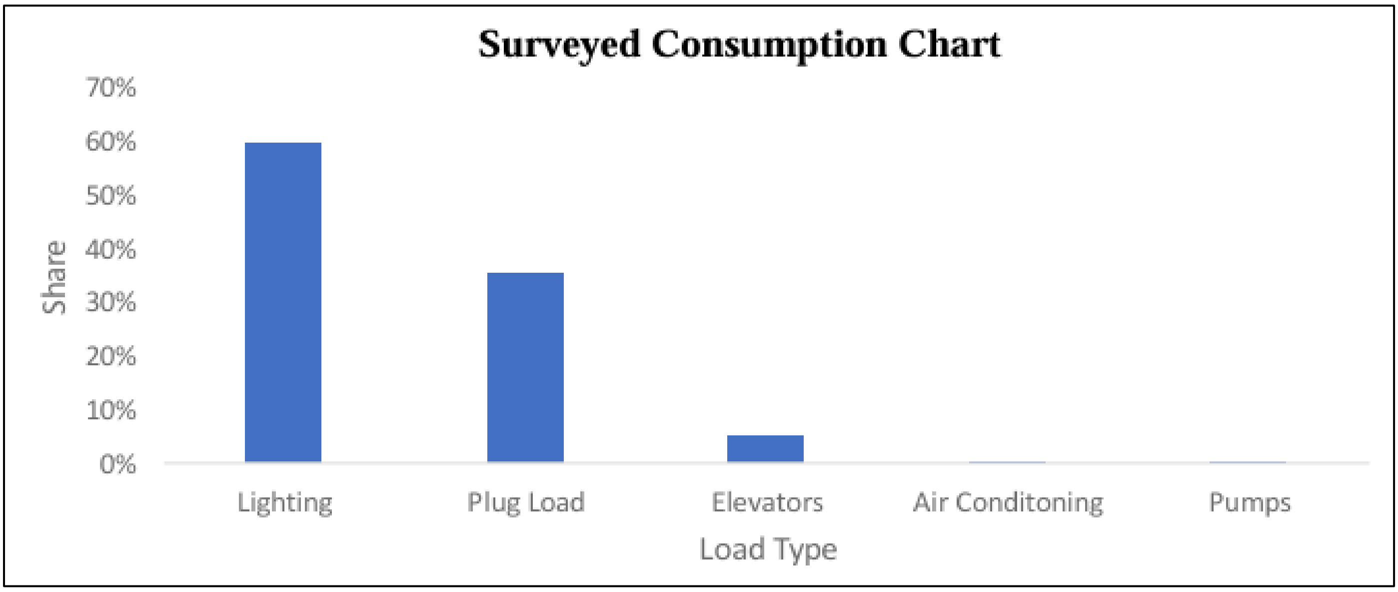


Fig 10 The Building Electricity End Use

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The energy end use for lighting, pumps and plug loads were estimated based on name plate data collected during the on-site data collection survey. A detailed survey of the fourth floor of the building was conducted to estimate the power density for lighting and plug loads. The recorded lighting and plug loads were categorized according to spaces with occupancy schedules noted. Power densities were then calculated on a meter/kW basis for the fourth floor and then applied to the remaining portions of the building with similar spaces. For spaces in the building, such as the basement floor, that do not have characteristics similar to the fourth floor, unique power density figures were derived. Once the loads were extrapolated to all spaces in the building, operating schedules were applied to loads to determine energy use.

- *Calculated Energy Use vs Billed Energy Use*

The energy use for the building was calculated for each end use category as described above. A comparison of the billed vs calculated energy use is shown below.

Table 13 Calculated Energy Use vs Billed Energy Use

| Load | Energy Use (kWh) | | | | Max (kW) Demand |
|---|---|---|---|---|---|
| | **From Electrical Measurements** | **From Name Plate Data** | **% Total** | **Total Energy (kWh)** | |
| Lighting | | 290.543 | 60% | 290.543 | 153 |
| Plug Load | | 172.759 | 35% | 172.759 | 69 |
| Elevators | 46257.12 | | 5% | 24024 | 21 |
| Air Conditioning | | 2,49 | 0,0005% | 2,49 | 4,8 |
| Pumps | | 338.208 | 0,07% | 339 | 3 |
| Totals | | 487.667 | 100% | 509900.2739 | 250,8 |
| **Total Surveyed** | | | | 509900.2739 | 250,8 |
| **Utility Bill** | | | | **520.154,00** | |
| **Difference** | | | | **2%** | |

- *Operating Schedules*

Operating schedules for space classifications in the building were determined through interviews with facility personnel. The following operating schedules were used for calculating end use in the building.

Table 14 Operating Schedules

| Area Classification | Description | Hours/Day | Hours/Week |
|---|---|---|---|
| Circulation General | Hallways | 15 | 105 |
| Circulation Stairs | Stairways | 15 | 105 |
| Meeting Room High Frequency | Meeting Room | 2 | 9 |
| Meeting Room Medium Frequency | Meeting Room | 0 | 2 |
| Meeting Room Low Frequency | Meeting Room | 1 | 3 |
| Utility High Frequency | Utility High | 2 | 10 |
| Utility Medium Frequency | Utility Low | 1 | 3 |
| Utility Low Frequency | Utility Medium | 1 | 5 |
| Office, General | General Offices | 10 | 45 |
| Office, Executive | Executive Offices | 10 | 45 |
| Lavatory | Toilets, Showers | 10 | 45 |

The operating schedules shown above are used as a baseline, with adjustments made to each area according to interviews with facility personnel for holidays, extended hours, etc.

- *Space Utilization and Occupancy Schedule General Operating Hours*

The building is substantially occupied from 8:00 a.m. to 5:00 p.m. five days per week (Monday through Friday). Interviews with the facility managers during on-site data collection revealed that there is limited after-hour use until about 10:00 p.m. on week nights and on weekends between 8:00 a.m. and 5:00 p.m. For the purpose of this audit, general office spaces were deemed to be normally occupied 10 hours per day.

- *Corridor Lighting*

Corridor lighting in the building typically operates from 7:00 a.m. to 10:00 p.m. hours 7 days per week. Office lighting is operated on demand through wall-mounted switches with no automation.

- *Occupancy and Use*

According to operation personnel, the building has at least 100 visitors per day. A large number of people were observed entering and exiting the building constantly during the site inspection. Much of the ground floor office space is dedicated to servicing investment inquiries and delivering counter services to visitors. The back and front doors are almost always open. The six upper floors of the building receive fewer visitors. Floor space in the first through fifth levels is mainly dedicated to general offices, with some space allocated to meeting rooms. Spaces in the sixth level of the building are dedicated to offices for facility maintenance personnel (20%), an employee canteen (20%) and storage (45%). The basement of the building is mostly used for storage, but has some areas for security personnel and electrical utilities.

➢ *Architectural Description*

The building is generally rectangular in shape with eight levels including the basement and ground floor. Interior office spaces are arranged around a large, enclosed atrium space from the ground to the sixth floor. The atrium is a pleasant architectural feature allowing a generous amount of natural light into the building. A glass elevator located on one side of the atrium serves all eight levels from basement to sixth floor.

➢ *Orientation*

The building is basically rectangular in shape with orientation of the narrower faces perpendicular to a direction approximately 20° off north to the east. The main front and rear entrances are located to the northeast and southeast faces of the building respectively.

➢ *Walls*

The core structure of the Building is constructed with reinforced concrete columns and floor plates. Exterior walls of the building are of two types: The first type of wall is concrete with the cladding being plasterboard with a cement finish. About 50% of the exterior face of the building is constructed of concrete wall. The second type of wall is a glass cladding system fastened to metal framing with no other layering. The glass cladding is single-glazed and layered with a reflective tint. Interiors of the building besides glazing are layered with a type of plasterboard and exterior finishing.

It is assumed that both the concrete wall system and glass cladding type wall have low thermal performance (i.e Lower U-factor).

➢ *Roof*

Most of the building's roofing system covers the fifth and sixth floors. About 15% of the roof covers the atrium and the remaining covers various other interior spaces such as offices, the cafeteria and storage areas.

The atrium roof is arched and constructed of single pane glass that has either been painted or had a green opaque film applied to it.

➢ *Lighting*

The majority of lighting fixtures in the building are 2 ft X 2 ft, 3 X 17 watt recessed parabolic fluorescent fixtures equipped with reflectors. Light fixtures are equipped with two ballasts with an assumed power consumption of 59% of the total fixture lamp power. Office spaces, meeting rooms and corridors generally have a lighting power density of 27 watts per square meter or 2.3 square meters per fixture.

Other than fluorescent lighting, which covers most interior spaces, there are various other light sources inside and outside the building. The atrium has light fixtures mounted at the ground floor, and exit signs equipped with incandescent bulbs are located throughout the building near each stairwell and point of egress.

The side windows in the roof over the glass atrium and windows in the central part of the building's northeast face let a considerable amount of natural light into the interior office and corridor spaces. However, since most of the atrium roof, although made of glass, is painted an opaque color that blocks almost all light, the potential for daylighting through the central space is significantly reduced.

During the site visit, it was observed that less than 50% of the light fixtures are working at all. About 25% of the working fixtures are not firing with lamps emitting only a slight orange glow at the tips.

During the audit, lighting levels were measured on the fifth floor. The table below shows the light level readings.

Table 15 Light levels in Fifth Floor

| Floor | Location | Light Level Reading |
|---|---|---|
| 5 | Window | 300 lux |
| 5 | Middle Office, Under Fixture | 250 lux |
| 5 | By Wall Far Side From Window | 30 lux |
| 5 | In corridor adjacent to atrium | 664 lux |
| 5 | In hallway between office and stairwell | 260 lux |

- *Heating, Ventilation and Air Conditioning (HVAC)*

The building is not equipped with any mechanical ventilation systems and has almost no air conditioning except for a few computer servers' rooms. All outside air ventilation in the building is natural, with air flowing through operable windows on each floor and doorways to the outside located at on the ground, fourth and sixth floors. The primary mode of air flow in the building during the site visit seemed to be horizontally through the operable windows. There did not seem to be a strong stack effect through the building's central atrium.

Most office spaces are open plan with transparent glass wall partitions separating adjacent office areas from each other and corridors. During the site visit, almost all doorways, interior and exterior, were left open, presumably to facilitate natural ventilation. The building was visited at 10:00 a.m. and 1:30 p.m., and most interior spaces seemed comfortable except those that had poor ventilation such as separate, enclosed offices and interior stairwells.

Designed with a large, interior atrium, the building is nearly ideal to leverage passive ventilation to facilitate the conditioning of interior spaces. Unfortunately, the atrium roof is completely sealed, eliminating the possibility of using a thermal stack affect to facilitate ventilation through the building. Existing passive ventilation is mainly across the building from operable windows and doors on one side of the building through to operable windows and doors on the other side of the building.

- *Air Conditioning*

As mentioned above, the building is generally not mechanically air conditioned. Only a single split system type direct expansion air conditioning system of 4.8 kW of cooling capacity was observed.

- *Space Temperatures*

Space temperatures were taken within the office spaces and the corridor adjacent near the atrium at all levels. In general, the office spaces were about 26°C, which is approximately 1°C more than the outside air temperature. Interestingly, the spaces at the atrium in the ground floor was about 26°C and increased by 4°C on the fifth floor in the corridor adjacent to the atrium. The thermocline in the building indicates good potential for passive ventilation using the atrium space.

- *Domestic Water and Sewage Systems*

- *Domestic Water Supply*

Presently, no domestic water end uses in the building utilize hot water. All energy related to domestic water use is due to a small pump that is used to fill a water tank at the top of the building. The exact power rating of the pump could not be determined, but considering the pipe size, building height and flow rate for such a system, the pump motor is estimated to be 0.27 kW.

The facility manager said that the pump operates when needed, which was estimated to be about 3 hours per day.

- *Sewage Circulation Pump*

Sewage from the building is piped to a pit located outside near the south-most corner of the building. According to the facility manager, the sewage pit is part of some sort of aerobic treatment system with a pump that circulates the sewage. The pump is estimated to run about 4 hours each day.

The power rating for the sewage pump could not be determined due to the confined space it is mounted within. However, the power rating of the pump motor power has been estimated at 3 kW given the application and motor size.

- *Plug Loads*

Plug load (portable electrical equipment) in the building consists almost exclusively of computers and printers. There are various other appliances and devices in the building, like the security scanners at main entrances, which add no more than an estimated 5,000 kWh to the building's annual energy consumption.

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# CHAPTER FIVE
# ANALYSIS AND IDENTIFICATION OF ENERGY CONSERVATION MEASURES (ECMS)

At about 64 kWh/ $m^2$/year, the building has extremely low energy intensity when compared to buildings in the US with energy intensity ranges of 200 kWh/$m^2$/year to 300 kWh/$m^2$/year. The low energy intensity is attributable to the fact that almost all of the building has no mechanical ventilation, spaces are not mechanically air conditioned and less than 50% of the light fixtures are functioning. The primary energy efficiency opportunity for the building is retrofitting of fluorescent light fixtures.

The effectiveness of the audit was related to the understanding in depth of the nature and operations of the audited building. Knowing the acceptable level of comfort and tolerance for lighting, temperature and humidity level are essential to come up with effective and acceptable ECMs.

➢ *The ECMs can be classified into the following categories:*

Table 16 Energy Conservation Measures Categories

| **Categories** | **Description** |
|---|---|
| No/low cost measures | Involves practically no/low cost investment and without any disruption to building operations, normally involving general housekeeping measures |
| Medium cost measures | Involves medium cost investments with some minor disruption to building operation |
| High cost measures | Involves relatively high capital cost investments with much disruption to building operation |

- Typical sample of one of E.C.Ms activities that can be started with are listed below:

➢ *E.C.Ms for Main Incoming*

- Ensure appropriate electricity tariff
- Power factor improvement
- Maximum demand control

➢ *E.C.Ms for Air Conditioning System*

- Equipment tuning
- Manual/automatic equipment control
- Equipment replacement
- Equipment maintenance
- Use of heat exchangers to pre-cool outside air used by Air handling Units (AHU) using spill air.
- Limit outside air intake to minimum requirements or use air quality sensors (e.g CO2 sensors) to control outdoor air intake according to occupancy level
- Use of ice storage for peak load reduction
- Improve piping insulation

➢ *ECMs for Lighting System*

- Manual/automatic control equipment (eg Dimmers, accupancy sensors, Photo/Daylight sensors cells, time clock, etc)
- Equipment maintenance (periodical cleaning, ballast replacement with more efficient alternatives)
- Delamping in over-lit areas
- Use of daylight in conjunction with lighting control
- Equipment replacement (e.g. Efficient luminaires, low loss ballast, tri-phosphor lamps, etc)

➢ *ECMs for Other Electrical Equipment*

- On - off system
- Maintain ventilation at optimum requirements
- High efficiency motors
- Use of variable speed drive to reduce fan and pump loads
- Use of equipment control for equipment start and stop

➢ *Lighting Retrofits*

- *General Office Fluorescent Fixture Retrofits*

The existing 2' x 2' fluorescent fixtures are equipped with 3 x 17 watt T8 lamps and magnetic ballasts with a total rating of about 62 watts including ballast losses. The standard retrofit for this fixture would involve replacing it with a T8 or T5 fixture equipped with electronic ballasts. The modelling for the existing light fixtures show that light levels from the 3-lamp T8 fixture would deliver light levels of about 1200 lux. The standard level of light needed for normal office tasks is about 500 lux.

During the audit, it was observed that many fixtures had missing lamps. Operations personnel said that ballasts and lamps frequently failed. However, considering the excessive light levels that would be produced from a normally functioning fixture, it would be logical to assume that operations personnel are purposely not re-lamping fixtures to reduce light levels. The exact specifications for the existing ballasts could not be located, but it is likely they were selected to drive the fixtures at their rated lumen levels.

The building has a significant amount of glazing and a central atrium that allows significant natural light in the building. Considering the excessive amounts of light that would be produced by the existing fixtures and the available daylight, the best retrofit would generally be T8, 2- lamp fixtures driven by electronic ballasts. This fixture would reduce wattage from 66 watts to 43 watts. Further energy consumption savings could be achieved by equipping perimeter areas in the building that are adjacent to windows and the atrium with dimmable ballasts using photosensor-based daylight harvesting capabilities.

Unfortunately, considering a lighting retrofit at this point would have a poor payback, because many existing fixtures have one or two lamps burned out. To make economic sense, the retrofit scenario would to calculate a baseline that assumes all existing fixtures are currently working to be economically viable. Therefore, any lighting retrofit should be implemented with the expectation that little or no savings will actually be seen at the building's meter.

➢ *Daylighting*

The building receives a considerable amount of daylight both from outside windows and interior corridors adjacent to the atrium. If the atrium glass were replaced with a transparent or translucent material, there would be even greater opportunity for leveraging daylight to light interior spaces. A technology that should be considered to leverage the available daylight are fluorescent light fixtures equipped with dimmable ballasts which attenuate lamp light output according to a light level reading from an integrated photocell.

➢ *Passive Ventilation Air Conditioning Options*

If the air conditioning retrofit is implemented as planned for all office spaces, this would add an estimated 87 kW of peak electrical load or 7.385,50 kWh of additional energy use and RWF 1.639.580,06 to the electricity bill each year.

Analyzing the number of cooling degree days for Kigali in a year according to the internal heat gains and thermal properties of the building, the air conditioning may run as many as 893 hours per year. Normally, once air conditioning is installed, the tolerance of indoor occupants to thermal discomfort decreases, which tends to increase the number of hours air conditioning would run in comparison to what would be considered uncomfortable in a building that did not have air conditioning at all.

As mentioned above, the building has an ideal architectural design for passive ventilation. Passive ventilation would be greatly enhanced by putting relief air vents near the top of the atrium roof. This simple measure would encourage natural ventilation by leveraging the stack effect in the building where air warmed from internal heat sources (people, computers) would be conveyed from the office spaces into the atrium space and up through the relief vents. Enhancing natural ventilation would greatly reduce or eliminate the periods in the year when mechanical air conditioning would be needed.

To investigate the possible effect of passive ventilation on the projected operating hours of the air conditioning equipment that will be installed in the building, a simple analysis based on cooling degree days was performed. The passive ventilation scenario was modeled by raising the estimated balance point temperature (outside air temperature at which air conditioning is turned on) by two degrees compared to the case without passive ventilation. Two degrees was selected because it has been shown that increasing passive ventilation can reduce the air temperature perceived by occupants in a building by two to five degrees.

It should be noted that, although passive ventilation represents an excellent opportunity, it is a solution that should be carefully modelled to select the appropriate modifications to the building. Achieving an optimum natural airflow rate through the building may require installing additional venting through the external class cladding system and internal partition walls that currently separate the offices from the atrium space.

➢ *Operational Hours*

During the preliminary data, the operational hrs. of the whole building as well as the specific area were recorded as follows. The operational hrs. were divided into before and after retrofitting.

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Table 17 The Building Operating Hrs Operational Hours Per the Specific Areas

| **Average Hours / Year** | **3744** |
|---|---|
| Hours Work Day | 12 |
| After Hours Weekday | 5 |
| Days Work Week | 5 |
| Holidays Per Year | 10 |
| Work Days Per Year | 251 |
| Hours Weekend | 6 |
| Work Start | 7 |
| Work End | 16 |
| After Hours End | 22 |
| Hallway Start | 7 |
| Hallway End | 22 |
| Utility Low Hours / Day | 0,5 |
| Utility Medium Hours / Day | 1 |
| Utility High Hours / Day | 2 |

| **Description** | **Hours/ Day** | **Hours/ Week** | **Hours / Year** |
|---|---|---|---|
| After_Hours | 6 | 42 | 312 |
| Circulation_General | 15 | 105 | 780 |
| Circulation_Pre_Retrofit | 2 | 14 | 728 |
| Circulation_Stairs | 15 | 105 | 780 |
| Daily_Normal | 9 | 63 | 468 |
| Day_Light_Harvest_Ciculation | 4 | 28 | 1456 |
| Day_Light_Harvest_Office | 4 | 20 | 1040 |
| Daylighting_Hours | 5 | | |
| Full | 168 | 1176 | 8736 |
| Holiday | 1 | 3 | 180 |
| Meeting_Room_High_Frequency | 2 | 9 | 468 |
| Meeting_Room_Low_Frequency | 0 | 2 | 16 |
| Meeting_Room_Medium_Frequency | 1 | 3 | 31 |
| None | 0 | 0 | 0 |
| Utility High | 2 | 10 | 104 |
| Utility Low | 1 | 3 | 26 |
| Utility Medium | 1 | 5 | 52 |
| Weekday_Full | 24 | 120 | 1128 |
| Weekday_Normal | 9 | 45 | 348 |

Table 18 Operating Hrs for Specific Areas

| **Weekday_Plus_After_Hours** | **15** | **75** | **3900** |
|---|---|---|---|
| Weekend_Full | 24 | 48 | 2496 |
| Weekend_Normal | 9 | 18 | 468 |
| Weekend_Plus_After_Hours | 15 | 30 | 1560 |
| **Months** | **Days** | **Weeks** | |
| Jan | 31 | 4,428571429 | |
| Feb | 28 | 4 | |
| Mar | 31 | 4,428571429 | |
| Apr | 30 | 4,285714286 | |
| May | 31 | 4,428571429 | |
| Jun | 30 | 4,285714286 | |
| Jul | 31 | 4,428571429 | |
| Aug | 31 | 4,428571429 | |
| Sep | 30 | 4,285714286 | |
| Oct | 31 | 4,428571429 | |
| Nov | 30 | 4,285714286 | |
| Dec | 31 | 4,428571429 | |

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- *Building Area Estimate:*

  The whole Building Floor area: 486m$^2$

Table 19 Estimated Surface Areas

| Floor Number | Area |
|---|---|
| B | 700 |
| G | 1179 |
| 1 | 1179 |
| **2** | 1227 |
| 3 | 1227 |
| 4 | 1227 |
| 5 | 1227 |
| 6 | 763 |

The ratio of the area of the 4$^{th}$ floor to the whole building area : (Area of the 4$^{th}$ floor- area of atrium)/ Total are of the building. Since the area of the atrium is 100m$^{2}$', the real area of the 4$^{th}$ floor is 1127m$^2$

The building has got its existing working hrs that were realised that once modified, the energy Consumption would reduce.

- *Annex A illustrates the working hrs before and after retrofitting. Example from the table in Annex A:*

- The atrium was found not to be utilised all the time whether in weekday or weekends. It is recommended to utilise it in all the time during weekdays plus after hrs ie 75 hrs/ week as well as weekends plus its after hrs ie 30 hrs/week.
- The executive office used for the meeting was is being used utilized al the time ( ie 45 hrs/ week during the weekdays as well as 18 hrs/week during weekends). It is recommended not utilize this as a meeting room as the first floor is mainly dedicated to the general offices with some space allocated to meeting rooms.
- The circulation within the Atrium is made all the time (ie 75 hrs/weekduring weekdays as well as 30 hrs/week during weekends) and this has been recommended to be reduced to 45 hrs/week in weekdays as well as 18 hrs/week in weekends.

All the above recommendations will affect the electricity Consumption.

- *Lighting Survey Data*

- *Fixture Surveys:*

  4th Floor Offices Fixture Densities as described in the followingng table 20 below:

Table 20 Floor Offices Fixture Densities on 4th Floor

| Area | Square meters/ Fixture | Fixture type |
|---|---|---|
| All | 0 | |
| Atrium | 0 | |
| Circulation | 2,3 | Fluorescent, (3) 24", STD lamp |
| Lavatory | 10 | Compact Fluorescent, (1)26W spiral lamp 4-pin, high CRI, electronic ballasted |
| Lifts | 2,3 | Compact Fluorescent, (1)26W spiral lamp 4-pin, high CRI, electronic ballasted |
| Office | 2,3 | Fluorescent, (3) 24", STD lamp |
| Stairs | 16,67 | Compact Fluorescent, (1)26W spiral lamp 4-pin, high CRI, electronic ballasted |
| Storage | 12,5 | Compact Fluorescent, (1)26W spiral lamp 4-pin, high CRI, electronic ballasted |

Below show the details concerning number of fixtures withinn every areas on each Floor. The table clearly show that the 290.543kWs can be saved anually by retrofitting the existing lights to the efficient ones that can reduce the electricity Consumption by 50% . The 4$^{th}$ floor is divided into the followingng areas that were audited: Atrium, Mai stairs, stairs at the coner, general Offices, Office for the Meeting, general circulation, atrium circulationn, mainn Lift and lavatories in South Western corner. Each area containsns certainn number of light fixtures that leads to its own energy consumption which all adds up to 114.537 kWrs which can be retrofitted to 57.268,5 kWhrs basing on the number of operational hours.

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Table 21 Number of Fixtures in Specified Areas

| Area Description | Schedule ID | Fixture ID | Fixture Description | Total Energy 100% Operational | Total Energy 50% Operational |
|---|---|---|---|---|---|
| Atrium_Atri um | None | | | - | - |
| Stairs_Main | Weekday_Pl us_After_Ho urs | ***CF26/1- L-SCRW*** | Compact Fluorescent, (1)26W spiral lamp 4-pin, high CRI, electronic ballasted | 427 | 214 |
| Stairs_Corne r | Weekday_Pl us_After_Ho urs | ***CF26/1- L-SCRW*** | Compact Fluorescent, (1)26W spiral lamp 4-pin, high CRI, electronic ballasted | 214 | 107 |
| Office_Gene ral | Weekday_N ormal | ***F23SS*** | Fluorescent, (3) 24", STD lamp | 30.822 | 15.411 |
| Office_Wind ow_Perimete r | Weekday_N ormal | ***F23SS*** | Fluorescent, (3) 24", STD lamp | 22.138 | 11.069 |
| Office_Exec utive/ Meeting | Weekday_N ormal | ***F23SS*** | Fluorescent, (3) 24", STD lamp | 3.425 | 1.712 |
| Circulation_ General | Weekday_Pl us_After_Ho urs | ***F23SS*** | Fluorescent, (3) 24", STD lamp | 33.394 | 16.697 |
| Circulation_ Atrium | Weekday_Pl us_After_Ho urs | ***F23SS*** | Fluorescent, (3) 24", STD lamp | 23.060 | 11.530 |
| Lifts_Main | Weekday_Pl us_After_Ho urs | ***CF26/1- L-SCRW*** | Compact Fluorescent, (1)26W spiral lamp 4-pin, high CRI, electronic ballasted | 774 | 387 |
| Lavatory_S W_Corners | Weekday_Pl us_After_Ho urs | ***CF26/1- L-SCRW*** | Compact Fluorescent, (1)26W spiral lamp 4-pin, high CRI, electronic ballasted | 285 | 142 |
| Total Consumption | | | | 114.537 | 57.269 |

- *4th Floor Area Consumptions*

Annex B Shows the electricity consumption by light fixtures in the whole building and this has been found that most of the lights are found in the 4th floor and are fluorescent where by the General Office s having many of them (ie 151)

- *Air Conditioning*

- Existing Uits: The building is generally not mechanically air conditioned. Only a single split system type direct expansion air conditioning system of 4.8 kW of cooling capacity was observed.

Table 22 Exisiting Air Conditioning**.**

| Equipment Name | Quantity | Power Estimate for Motors | | Annual Hours of Operation (hours) | Energy Consumption (kWh) |
|---|---|---|---|---|---|
| | | Nameplate kW demand | Average Load Factor (%) | | |
| LGS2465 | 2 | 4,8 | 1,00 | 520 | 2.496 |

- *Climate Data & Operating Hours for Air Conditioners*

From world Bank data, it was shown that the average temperatures per month from 1901 to 2016 varies as shown in the graph below:

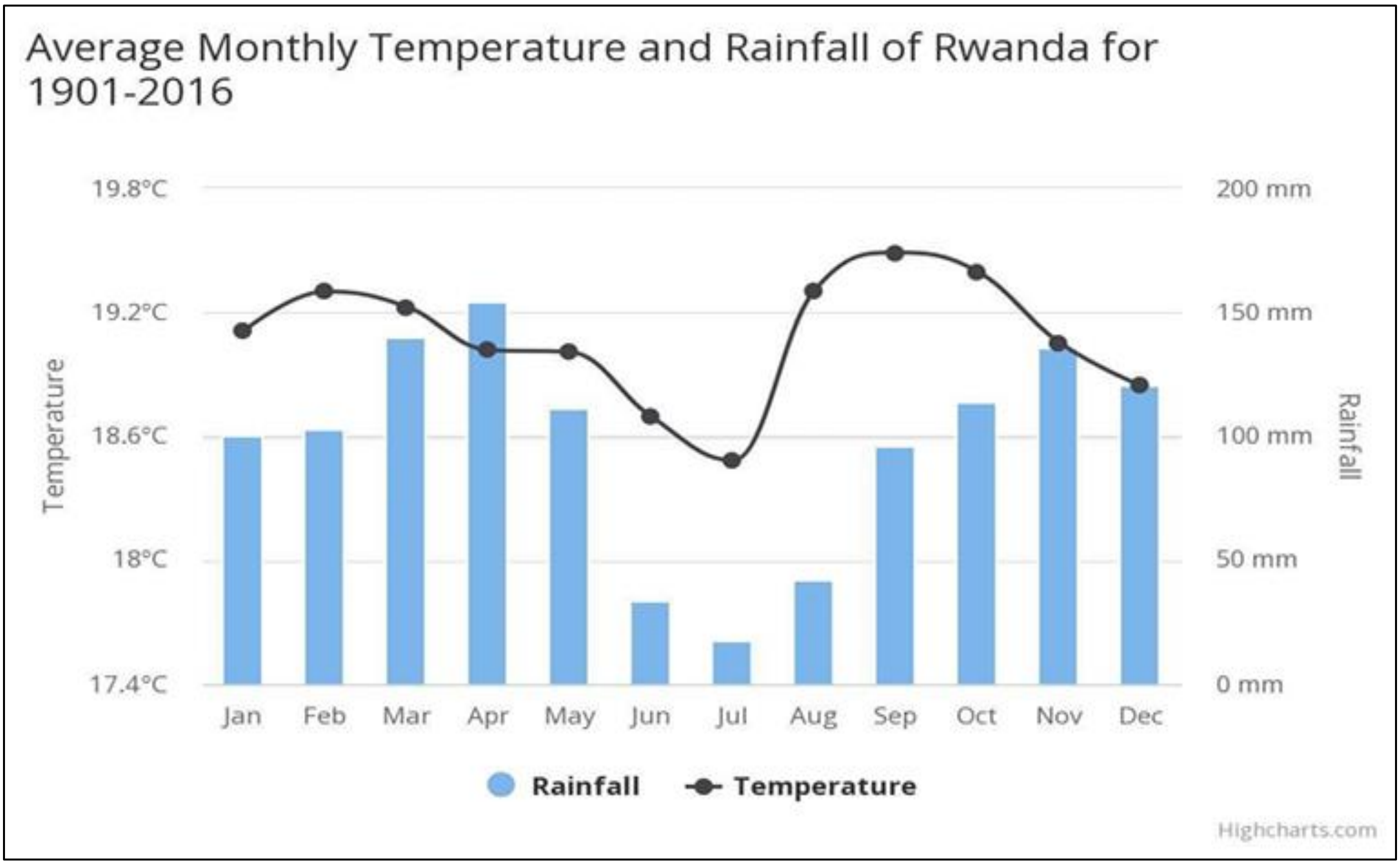


Fig 11 Average Monthly Temperature of Rwanda up to 2016.
Source: https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-historical

Basing on the above temperature data, the table below shows that there is no need of cooling during passive ventilation. As shown, the number of cooling degree days becomes less during passive than non-passive ventilation.

- *Cooling Temperature: 26,3°C Heating Temperature: 14,7°C*

Table 23 Climate Data & AC Hours

| Month | Average Temperature (◦C) | Humidity | Balance Point | Avg CDD | Max CDD | Max Cooling Hours | Cooling Hours | Balance Point Passive | Avg CDD | Max CDD | Max Cooling Hours | Cooling Hours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 19,11 | 70,4 | 18 | 34,41 | 257,3 | 279 | 37 | 20 | -27,59 | 195,3 | 279 | 0 |
| 2 | 19,3 | 66,5 | 18 | 36,4 | 232,4 | 252 | 39 | 20 | -19,6 | 176,4 | 252 | 0 |
| 3 | 19,23 | 76,1 | 18 | 38,13 | 257,3 | 279 | 41 | 20 | -23,87 | 195,3 | 279 | 0 |
| 4 | 19,02 | 78,4 | 18 | 30,6 | 249 | 270 | 33 | 20 | -29,4 | 189 | 270 | 0 |
| 5 | 19,01 | 62,8 | 18 | 31,31 | 257,3 | 279 | 34 | 20 | -30,69 | 195,3 | 279 | 0 |
| 6 | 18,7 | 49,9 | 18 | 21 | 249 | 270 | 23 | 20 | -39 | 189 | 270 | 0 |
| 7 | 18,48 | 45,1 | 18 | 14,88 | 257,3 | 279 | 16 | 20 | -47,12 | 195,3 | 279 | 0 |
| 8 | 19,31 | 46,4 | 18 | 40,61 | 257,3 | 279 | 44 | 20 | -21,39 | 195,3 | 279 | 0 |
| 9 | 19,48 | 56 | 18 | 44,4 | 249 | 270 | 48 | 20 | -15,6 | 189 | 270 | 0 |
| 10 | 19,4 | 74,9 | 18 | 43,4 | 257,3 | 279 | 47 | 20 | -18,6 | 195,3 | 279 | 0 |
| 11 | 19,04 | 81,4 | 18 | 31,2 | 249 | 270 | 34 | 20 | -28,8 | 189 | 270 | 0 |
| 12 | 18,85 | 78,1 | 18 | 26,35 | 257,3 | 279 | 29 | 20 | -35,65 | 195,3 | 279 | 0 |

It was found that since the building has enough natural ventilation, there is no need of additional of non-Passive ventilation. This will as well reduce the power consumption hence reduction of electricity bill as shown in the table below:

Cooling Density: 10,6 Meter / kW Cooling COP new AC System 5 kW Cooling / kW Power Balance Point with Air Conditioning 18$^0$C Balance Point without Air Conditioning: 15°C.

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Table 24 AC Retrofit Scenario

| | | | | Coolin g Hours | 1 | | |
|---|---|---|---|---|---|---|---|
| | | | | Cooling energy | | | |
| **Mont h** | **Average Temparature** | **Averag e Coolin g Degree Days** | **Total Air Condition ed Area** | **Coolin g Load (kW)** | **Electric al Load (kW)** | **No Passive Ventilation (kWh) (With Acs)** | **With Passive Ventilati on (With Natural Resources)** |
| 1 | 19,11 | 34,41 | 4593 | 434 | 87 | 647 | - |
| 2 | 19,3 | 36,4 | 4593 | 434 | 87 | 685 | - |
| 3 | 19,23 | 38,13 | 4593 | 434 | 87 | 717 | - |
| 4 | 19,02 | 30,6 | 4593 | 434 | 87 | 576 | - |
| 5 | 19,01 | 31,31 | 4593 | 434 | 87 | 589 | - |
| 6 | 18,7 | 21 | 4593 | 434 | 87 | 395 | - |
| 7 | 18,48 | 14,88 | 4593 | 434 | 87 | 280 | - |
| 8 | 19,31 | 40,61 | 4593 | 434 | 87 | 764 | - |
| 9 | 19,48 | 44,4 | 4593 | 434 | 87 | 835 | - |
| 10 | 19,4 | 43,4 | 4593 | 434 | 87 | 816 | - |
| 11 | 19,04 | 31,2 | 4593 | 434 | 87 | 587 | - |
| 12 | 18,85 | 26,35 | 4593 | 434 | 87 | 496 | - |

- *Motor Survey*

During the audit, it was found that the building have got some motors that are used I the following : Pumping Domestic water into the building, sewage circulation for aerobic treatment system as well as two elevators.

- *Domestic Water Pump:*

All energy related to domestic water use is due to a small pump that is used to fill a water tank at the top of the building. The exact power rating of the pump could not be determined, but considering the pipe size, building height and flow rate for such a system, the pump motor is estimated to be 0.27 kW. The facility manager said that the pump operates when needed, which was estimated to be about 3 hours per day.

- *The Following Parameters were Assumed:*

Assumed Building «height: 30 meters Assumed Flow Rate 1,5 M^3 / Hour Shaft Efficiency 0,6 Pump Power= (1 m3/h) (1000 kg/m3) (9.81 m/s2) (10 m) / (3.6 106) / Pump Effiency = 0,271699994kW.

- *Sewage Circulation Pump:*

All sewage from the building is piped to a sump located outside the building. According to the facility manager, the sewage sump is part of some sort of aerobic treatment system with a pump that circulates the sewage. The power rating for the sewage pump could not be determined due to the confined space it is mounted within. However, the power rating of the pump motor power has been estimated at 3 kW given the application and motor size. The pump is estimated to run about 4 hours each day.

- *Elevators:*

The Building has got two elevators whose power was determined by taking power measurements at their electricity supply as follows and they are estimated to run about 16 hrs. each day.

Table 25 Elevators Electrical Supply Measurements Electrical Measurements

| **Power Measurements** | **Phase A** | **Phase B** | **Phase C** |
|---|---|---|---|
| Voltage | 160 | 194 | 193 |
| Amperage | 19,3 | 20,1 | 18,7 |
| kVA | 3,088 | 3,8994 | 3,6091 |
| Total Power (kW) | 10,5965 | | |

- *Plug Loads in the 4th Floor Offices*

Table 26 Plug-in Loads

| **Equipment** | **Qty** | **Watts** | **Assume d Diversity Factors** | **Actual load** | **%ge** |
|---|---|---|---|---|---|
| **Desktop Computers** | 10 | 200 | 0,5 | 1000 | 36% |
| Laptop Computers | 10 | 40 | 0,5 | 200 | 7% |
| Monitors | 20 | 50 | 0,5 | 500 | 18% |
| Laser Printers | 10 | 1100 | 0,1 | 1100 | 39% |

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| | | | | | |
|---|---|---|---|---|---|
| Total | | | | 2800 | |
| Floor Area | **191,63** | | | | |
| **Plug-in Load Power Intensity ($M^2$/W)** | 0,0684375 (ie Floor Area/Total Load | | | | |
| **Area Class** | **Fraction** | | **Power Density** | | |
| All | 0,000 | | 0,0000 | | |
| Atrium | 0,000 | | 0,0000 | | |
| Circulation | 0,100 | | 0,6844 | | |
| Lavatory | 0,100 | | 0,6844 | | |
| Lifts | 0,000 | | 0,0000 | | |
| Office | 1,000 | | 0,0684 | | |
| Stairs | 0,000 | | 0,0000 | | |
| Storage | 0,000 | | 0,0000 | | |

➢ *Measurements Taken as the Supply to the Offices*

Table 27 Electrical Measurements Taken as the Supply to the Offices

| **Phase A** | | **Phase B** | | **Phase C** | | **Power** |
|---|---|---|---|---|---|---|
| Volts | Amps | Volts | Amps | Volts | Amps | |
| 160 | 19,3 | 194 | 20,1 | 193 | 18,7 | 10.597 |

Table 28 Building Area Operational Hrs

| **Area Description** | **Schedule ID** | **Area ($M^2$)** | **Diversity** | **Hours / Day** | **Hours / Weekday** | **Hours/ Weekend** | **Power Density (watt/m^)** | **Load (w)** | **Hours / Week** | **Total Energy 100% Operational (kWhs)** |
|---|---|---|---|---|---|---|---|---|---|---|
| Storage_General | _Weekday_Plus_After_Hours | 333 | 0 | 0 | 0 | 0 | 0 | 0 | 78,0 | 0 |
| Stairs_Main | _Weekday_Plus_After_Hours | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 78,0 | 0 |
| Stairs_Corner | _Weekday_Normal | 50 | 0,1 | 0,9 | 4,5 | 1,8 | 0 | 0 | 46,8 | 0 |
| Office_General | _Weekday_Normal | 329 | 0 | 0 | 0 | 0 | 0,068438 | 4808 | 46,8 | 12232 |
| Office_Window_Perimeter | _Weekday_Normal | 297 | 0 | 0 | 0 | 0 | 0,068438 | 4338 | 46,8 | 11035 |
| Circulation_General | _Weekday_Plus_After_Hours | 234 | 0 | 0 | 0 | 0 | 0,684375 | 342 | 78,0 | 1450 |
| Circulation_Atrium | _Weekday_Plus_After_Hours | 156 | 0 | 0 | 0 | 0 | 0,684375 | 228 | 78,0 | 968 |
| Lifts_Main | _Weekday_Plus_After_Hours | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 78,0 | 0 |
| Lavatory_SW_Corners | _Weekday_Plus_After_Hours | 20 | 0 | 0 | 0 | 0 | 0,684375 | 29 | 78,0 | 124 |
| Atrium_Atrium | _None | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0,0 | 0 |
| Stairs_Main | _Weekday_Plus_After_Hours | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 78,0 | 0 |
| Storage_Strong_Room | _Utility Low | 125 | 1 | 0,5 | 2,5 | 5 | 0 | 0 | 3,0 | 0 |
| Stairs_Corner | _Weekday_Plus_After_Hours | 50 | 1 | 15 | 75 | 30 | 0 | 0 | 78,0 | 0 |
| Office_General | _Weekday_Normal | 345 | 0,1 | 0,9 | 4,5 | 1,8 | 0,068438 | 5038 | 46,8 | 12817 |
| Office_Window_Perimeter | _Weekday_Normal | 359 | 1 | 9 | 45 | 18 | 0,068438 | 5251 | 46,8 | 13358 |
| Office_Executive / Meeting | _Weekday_Normal | 37 | 0,05 | 0,45 | 2,25 | 0,9 | 0,068438 | 542 | 46,8 | 1380 |
| Office_Executive / Meeting | _Weekday_Normal | 30 | 0,6 | 5,4 | 27 | 10,8 | 0,068438 | 443 | 46,8 | 1127 |
| Storage_General | _Utility Low | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2,8 | 0 |
| Circulation_General | _Weekday_Plus_After_Hours | 47 | 0 | 0 | 0 | 0 | 0,684375 | 69 | 78,0 | 291 |
| Circulation_Atrium | _Weekday_Plus_After_Hours | 156 | 0 | 0 | 0 | 0 | 0,684375 | 228 | 78,0 | 968 |
| Lifts_Main | _Weekday_Plus_After_Hours | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 78,0 | 0 |
| Utility_Electrical | _Utility Low | 25 | 1 | 0,5 | 2,5 | 60 | 0 | 0 | 8,5 | 0 |
| Lavatory_SW_Corners | _Weekday_Plus_After_Hours | 20 | 1 | 15 | 75 | 30 | 0,684375 | 29 | 78,0 | 124 |
| Atrium_Atrium | _None | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0,0 | 0 |
| Stairs_Main | _Weekday_Plus_After_Hours | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 78,0 | 0 |
| Stairs_Corner | _Weekday_Plus_After_Hours | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 78,0 | 0 |
| Office_General | _Weekday_Normal | 493 | 0 | 0 | 0 | 0 | 0,068438 | 7209 | 46,8 | 18339 |
| Office_Window_Perimeter | _Weekday_Normal | 297 | 0 | 0 | 0 | 0 | 0,068438 | 4338 | 46,8 | 11035 |
| Office_Executive / Meeting | _Weekday_Normal | 38 | 0 | 0 | 0 | 0 | 0,068438 | 560 | 46,8 | 1424 |

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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Office_Executive / Meeting | _Weekday_Normal | 48 | 0 | 0 | 0 | 0 | 0,068438 | 703 | 46,8 | 1787 |
| Storage_General | _Utility Low | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2,8 | 0 |
| Stairs_Main | _Weekday_Plus_After_Hours | 25 | 1 | 15 | 75 | 30 | 0 | 0 | 78,0 | 0 |
| Circulation_General | _Weekday_Plus_After_Hours | 7 | 1 | 15 | 75 | 30 | 0,684375 | 11 | 78,0 | 46 |
| Circulation_Atrium | _Weekday_Plus_After_Hours | 156 | 0,1 | 1,5 | 7,5 | 3 | 0,684375 | 228 | 78,0 | 968 |
| Lifts_Main | _Weekday_Plus_After_Hours | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 78,0 | 0 |
| Lavatory_SW_Corners | _Weekday_Plus_After_Hours | 20 | 0 | 0 | 0 | 0 | 0,684375 | 29 | 78,0 | 124 |
| Atrium_Atrium | _None | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0,0 | 0 |
| Stairs_Main | _Weekday_Plus_After_Hours | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 78,0 | 0 |
| Stairs_Corner | _Weekday_Plus_After_Hours | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 78,0 | 0 |
| Office_General | _Weekday_Normal | 433 | 0 | 0 | 0 | 0 | 0,068438 | 6324 | 46,8 | 16087 |
| Office_Window_Perimeter | _Weekday_Normal | 309 | 0 | 0 | 0 | 0 | 0,068438 | 4521 | 46,8 | 11500 |
| Circulation_General | _Weekday_Plus_After_Hours | 48 | 0 | 0 | 0 | 0 | 0,684375 | 70 | 78,0 | 296 |
| Office_General | _Weekday_Plus_After_Hours | 63 | 1 | 15 | 75 | 30 | 0,068438 | 913 | 78,0 | 3872 |
| Circulation_Atrium | _Weekday_Plus_After_Hours | 156 | 1 | 15 | 75 | 30 | 0,684375 | 228 | 78,0 | 968 |
| Lifts_Main | _Weekday_Plus_After_Hours | 13 | 0,1 | 1,5 | 7,5 | 3 | 0 | 0 | 78,0 | 0 |
| Lavatory_SW_Corners | _Weekday_Plus_After_Hours | 20 | 0 | 0 | 0 | 0 | 0,684375 | 29 | 78,0 | 124 |
| Circulation_General | _Weekday_Plus_After_Hours | 18 | 0 | 0 | 0 | 0 | 0,684375 | 26 | 78,0 | 108 |
| Atrium_Atrium | _None | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0,0 | 0 |
| Stairs_Main | _Weekday_Plus_After_Hours | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 78,0 | 0 |
| Stairs_Corner | _Weekday_Plus_After_Hours | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 78,0 | 0 |
| Office_General | _Weekday_Normal | 348 | 0 | 0 | 0 | 0 | 0,068438 | 5086 | 46,8 | 12938 |
| Office_Window_Perimeter | _Weekday_Normal | 250 | 0 | 0 | 0 | 0 | 0,068438 | 3653 | 46,8 | 9293 |
| Office_Executive / Meeting | _Weekday_Normal | 39 | 1 | 9 | 45 | 18 | 0,068438 | 565 | 46,8 | 1438 |
| Lifts_Main | _Weekday_Plus_After_Hours | 13 | 1 | 15 | 75 | 30 | 0 | 0 | 78,0 | 0 |
| Circulation_General | _Weekday_Plus_After_Hours | 226 | 0,1 | 1,5 | 7,5 | 3 | 0,684375 | 331 | 78,0 | 1402 |
| Circulation_Atrium | _Weekday_Plus_After_Hours | 156 | 0 | 0 | 0 | 0 | 0,684375 | 228 | 78,0 | 968 |
| Lifts_Main | _Weekday_Plus_After_Hours | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 78,0 | 0 |
| Lavatory_SW_Corners | _Weekday_Plus_After_Hours | 20 | 0 | 0 | 0 | 0 | 0,684375 | 29 | 78,0 | 124 |
| Atrium_Atrium | _None | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0,0 | 0 |
| Stairs_Main | _Weekday_Plus_After_Hours | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 78,0 | 0 |
| Stairs_Corner | _Weekday_Plus_After_Hours | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 78,0 | 0 |
| Office_General | _Weekday_Normal | 425 | 0 | 0 | 0 | 0 | 0,068438 | 6213 | 46,8 | 15806 |
| Office_Window_Perimeter | _Weekday_Normal | 359 | 1 | 9 | 45 | 18 | 0,068438 | 5251 | 46,8 | 13358 |
| Office_Executive / Meeting | _Weekday_Normal | 43 | 0,1 | 0,9 | 4,5 | 1,8 | 0,068438 | 628 | 46,8 | 1597 |
| Lavatory_SW_Corners | _Weekday_Plus_After_Hours | 100 | 0 | 0 | 0 | 0 | 0,684375 | 146 | 78,0 | 620 |
| **TOTAL** | | **7741** | | | | | | | | **180095** |

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# CHAPTER SIX
# CONCLUSION AND RECOMMENDATIONS

- Losses in electrical power systems have become a serious problem to utilities worldwide. Amidst the escalating global crisis for energy, the attention of utilities has shifted towards reduction of losses. The economic, financial and social consequences of power system losses are being gradually understood. As such, utilities and countries as a whole are devising various measures to arrest losses in electrical power systems. However, an initial and essential step towards reduction of losses is accurately estimating losses.
- Losses in electricity distribution represent dominant part in the overall power system losses. From the survey taken in two Municipalities with butch of MV/LV Distribution Tranformers, it was found that the LV Distributionn losses are around 10%.
- Since the overall losses were estimated to be 15% considering the estimated Peak loss, this keens that all other loses including Transmission and generation constitute about 5%
- In any efforts to arrest losses, it is of paramount importance that the losses are estimated accurately. It is a pre-requisite before developing strategies to counter losses. It is required to segregate distribution losses to identify the losses at different levels.
- As discussed above, although there are opportunities for energy efficiency measures, these measures will have a low impact on reducing the current utility bill. However, if the energy efficiency opportunities for the building are considered in the right context, there is a case for implementation.
- From the temperature data given, it has bee realised that most of the buildings can use Passive ventilation to make the comfortability of the occupants and this not only reduce the Greenhouse gas emissions but also saves on the electricity bill hence advantageous to the Building owners.
- Most of the electricity Consumers have got low power factor which contributes to the distribution Losses.
- The Single-phase extended Distribution Lines were constructed hence contributing to the serious load Imbalances in the network.
- In order to identify the real losses in the network, there is a need to segregate them in different Levels i.e. transmission and Distribution.
- It is recommended to install SMART meters at all Distribution nodes as to identify the energy distributed from those nodes.
- Its is recommended to carry out Phase Balancing on distribution transformers.
- It is recommended to apply the incentives to the customers in order to rectify their Poor Power Factor.

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## REFERENCES

[1]. Article *in* Engineer - Journal of the Institution of Engineers, Sri Lanka · July 2019. https://www.researchgate.net/publication/334431852
[2]. Electrical Energy Audit guidelines by SURUHANJAYA TENAGA (ENERGY COMMISSION) No. 12, Jalan Tun Hussein, Precinct 2, 62100 Putrajaya, Malaysia. ISBN 978-967-13778-6-4 ST Publication No. : ST(P) 16/09/2016
[3]. World Bank Climate change knowledge Portal https://climateknowledgeportal.worldbank.org/country/rwanda/climate-data-historical
[4]. International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 Vol. 2 Issue 8, August – 2013.

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# ANNEX A: WORKING HRS OF DIFFERENT AREAS

| | | Pre-Retrofit | | | | Post-Retrofit - Daytiming & Occupancy Sensors | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Weekday | | Weekend | | Weekday | | Weekend | | Lighting | | Plug Load |
| Area Descriptor | Area (m²) | Schedule | Hrs | Schedule | Hours | Schedule | Hours | Schedule | Hours | Meters / Fixture | Total Fixtures | Watts/ Meter |
| General | 333 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Full | 120 | Building_Weekday_Full | 120 | 13 | 27 | 0 |
| Main | 50 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | 17 | 3 | 0 |
| Corner | 50 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | 16,7 | 3 | 0 |
| General | 329 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | 2,3 | 143 | 0,0684375 |
| Window_Perimeter | 297 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | 2,3 | 129 | 0,0684375 |
| General | 234 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | 2,3 | 102 | 0,684375 |
| Atrium | 156 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | 2,3 | 68 | 0,684375 |
| Main | 13 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | 2,3 | 5 | 0 |
| SW_Corners | 20 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekday_Plus_After_Hours | 75 | 10,0 | 2 | 0,684375 |
| Atrium | 100 | Building_None | 0 | Building_None | 0 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 0 | 0 | 0 |
| Main | 50 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 17 | 3 | 0 |
| Strong_Room | 125 | Building_Utility Low | 2,5 | Building_Utility Low | 5 | Building_Utility Low | 2,5 | Building_Utility Low | 5 | 13 | 10 | 0 |
| Corner | 50 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 17 | 3 | 0 |
| General | 345 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | 2 | 150 | 0,0684375 |
| Window_Perimeter | 359 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | 2 | 156 | 0,0684375 |
| Executive/ Meeting | 37 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | | | | | 2 | 16 | 0,0684375 |

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| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Executive/ Meeting | 30 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | | | | | 2 | 13 | 0,0684375 |
| General | 2 | Building_Utility Low | 2,5 | Building_Utility Low | 2,5 | Building_Utility High | 10 | | | 13 | 0 | 0 |
| General | 46,9375 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 2 | 20 | 0,684375 |
| Atrium | 156 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | 2 | 68 | 0,684375 |
| Main | 13 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 2 | 5 | 0 |
| Electrical | 25 | Building_Utility Low | 2,5 | S | 60 | Building_Utility Medium | 5 | Building_Utility Medium | 10 | 13 | 2 | 0 |
| SW_Corners | 20 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 10 | 2 | 0,684375 |
| Atrium | 100 | Building_None | 0 | Building_None | 0 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 0 | 0 | 0 |
| Main | 50 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 17 | 3 | 0 |
| Corner | 50 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 17 | 3 | 0 |
| General | 493 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 2 | 215 | 0,0684375 |
| Window_Perimeter | 297 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | 2 | 129 | 0,0684375 |
| Executive/ Meeting | 38 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | | | | | 2 | 17 | 0,0684375 |
| Executive/ Meeting | 48 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | | | | | 2 | 21 | 0,0684375 |
| General | 2 | Building_Utility Low | 2,5 | Building_Utility Low | 2,5 | Building_Utility High | 10 | | | 13 | 0 | 0 |
| Main | 25 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Full | 120 | Building_Weekend_Full | 48 | 17 | 2 | 0 |
| General | 7,4375 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 2 | 3 | 0,684375 |
| Atrium | 156 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 2 | 68 | 0,684375 |
| Main | 13 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 2 | 5 | 0 |
| SW_Corners | 20 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 10 | 2 | 0,684375 |

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| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Atrium | 100 | Building_None | 0 | Building_None | 0 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 0 | 0 | 0 |
| Main | 50 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 17 | 3 | 0 |
| Corner | 50 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 17 | 3 | 0 |
| General | 433 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 2 | 188 | 0,0684375 |
| Window_Perimeter | 309 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | 2 | 135 | 0,0684375 |
| General | 47,75 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 2 | 21 | 0,684375 |
| General | 63 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | 2 | 27 | 0,0684375 |
| Atrium | 156 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | 2 | 68 | 0,684375 |
| Main | 13 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 2 | 5 | 0 |
| SW_Corners | 20 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 10 | 2 | 0,684375 |
| General | 18 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | 2 | 8 | 0,684375 |
| Atrium | 100 | Building_None | 0 | Building_None | 0 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 0 | 0 | 0 |
| Main | 50 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 17 | 3 | 0 |
| Corner | 25 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 17 | 2 | 0 |
| General | 348 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | 2 | 151 | 0,0684375 |
| Window_Perimeter | 250 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | 2 | 109 | 0,0684375 |
| Executive/ Meeting | 39 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | | | | | 2 | 17 | 0,0684375 |
| Main | 13 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | 2 | 5 | 0 |
| General | 226 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 2 | 98 | 0,684375 |
| Atrium | 156 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | 2 | 68 | 0,684375 |

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| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Main | 13 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 2 | 5 | 0 |
| SW_Corners | 20 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 10 | 2 | 0,684375 |
| Atrium | 100 | Building_None | 0 | Building_None | 0 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 0 | 0 | 0 |
| Main | 50 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 17 | 3 | 0 |
| Corner | 25 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 17 | 2 | 0 |
| General | 425 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | 2 | 185 | 0,0684375 |
| Window_Perimeter | 359 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | 2 | 156 | 0,0684375 |
| Executive/Meeting | 43 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | | | | | 2 | 19 | 0,0684375 |
| SW_Corners | 100 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | 10 | 10 | 0,684375 |
| General | 2 | Building_Utility Low | 2,5 | Building_Utility Low | 2,5 | Building_Utility High | 10 | | | 13 | 0 | 0 |
| General | 33 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 2 | 15 | 0,684375 |
| Atrium | 156 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | 2 | 68 | 0,684375 |
| Main | 13 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 2 | 5 | 0 |
| SW_Corners | 20 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 10 | 2 | 0,684375 |
| Atrium | 50 | Building_None | 0 | Building_None | 0 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 0 | 0 | 0 |
| General | 214 | Building_Utility Low | 12,5 | Building_Utility Low | 5 | Building_Utility Low | 12,5 | Building_Utility Low | 5 | 13 | 17 | 0 |
| Main | 50 | Building_Weekday_Plus_After_Hours | 375 | Building_Weekend_Plus_After_Hours | 60 | Building_Utility Low | 12,5 | Building_Utility Low | 5 | 17 | 3 | 0 |
| General | 50 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | 2 | 22 | 0,0684375 |
| Atrium | 100 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | Building_Weekday_Normal | 45 | Building_Weekend_Normal | 18 | 0 | 0 | 0 |
| General | 210 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 2 | 92 | 0,684375 |
| Atrium | 156 | Building_None | 0 | Building_None | 0 | Building_Utility Low | 2,5 | Building_Utility Low | 2,5 | 2 | 68 | 0,684375 |
| | | Building_Weekd | | Building_Weeke | | Building_Weekda | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| Main | 13 | ay_Plus_After_Hours | 75 | nd_Plus_After_Hours | 30 | y_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 2 | 5 | 0 |
| SW_Corners | 20 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | Building_Weekday_Plus_After_Hours | 75 | Building_Weekend_Plus_After_Hours | 30 | 10 | 2 | 0,684375 |

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## ANNEX B: LIGHT FIXTURES

| *Floor* | | *Area* | *De-Rating* | *Hours /* | *Hours* | *Hours /Weekend* | *# Fixtures* | *Lamps* | *Power /* | *Ballast* | *(W)* | *Total Power (w)* | *Hours /* | *Total Energy* | *Total Energy* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *Factor* | *Day* | */ Weekday* | | | */ Fixture (#)* | *Lamp( W)* | *Power (W)* | | | *Week* | *100% Operational* | *50% Operational* |
| B | Storage | 332,5 | 1 | 15 | 75 | 30 | 13 | 1 | 1 | 25 | 26 | 325 | 105 | 1.779 | 890 |
| G | Stairs | 50 | 1 | 15 | 75 | 30 | 17 | 1 | 1 | 25 | 26 | 433 | 105 | 2.373 | 1.186 |
| G | Stairs | 50 | 1 | 9 | 45 | 18 | 17 | 1 | 1 | 25 | 26 | 433 | 63 | 1.424 | 712 |
| G | Office | 329,0625 | 1 | 9 | 45 | 18 | 2 | 3 | 3 | 53 | 62 | 143 | 63 | 468 | 234 |
| G | Office | 296,875 | 1 | 9 | 45 | 18 | 2 | 3 | 3 | 53 | 62 | 143 | 63 | 468 | 234 |
| G | Circulation | 234 | 1 | 15 | 75 | 30 | 2 | 3 | 3 | 53 | 62 | 143 | 105 | 781 | 390 |
| G | Circulation | 156,25 | 1 | 15 | 75 | 30 | 2 | 3 | 3 | 53 | 62 | 143 | 105 | 781 | 390 |
| G | Lifts | 12,5 | 1 | 15 | 75 | 30 | 2 | 1 | 1 | 25 | 26 | 60 | 105 | 327 | 164 |
| G | Lavatory | 20 | 1 | 15 | 75 | 30 | 2 | 1 | 1 | 25 | 26 | 52 | 105 | 285 | 142 |
| 1 | Atrium | 100 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | - |
| 1 | Stairs | 50 | 1 | 15 | 75 | 30 | 3 | 1 | 1 | 25 | 26 | 78 | 105 | 427 | 214 |
| B | Storage | 125 | 1 | 0,5 | 2,5 | 5 | 10 | 1 | 1 | 25 | 26 | 260 | 7,5 | 102 | 51 |
| 1 | Stairs | 50 | 1 | 15 | 75 | 30 | 3 | 1 | 1 | 25 | 26 | 78 | 105 | 427 | 214 |
| 1 | Office | 344,8125 | 1 | 9 | 45 | 18 | 150 | 3 | 3 | 53 | 62 | 9.295 | 63 | 30.534 | 15.267 |
| 1 | Office | 359,375 | 1 | 9 | 45 | 18 | 156 | 3 | 3 | 53 | 62 | 9.688 | 63 | 31.823 | 15.912 |
| 1 | Office | 37,125 | 1 | 9 | 45 | 18 | 16 | 3 | 3 | 53 | 62 | 1.001 | 63 | 3.287 | 1.644 |
| G | Office | 30,3125 | 1 | 9 | 45 | 18 | 13 | 3 | 3 | 53 | 62 | 817 | 63 | 2.684 | 1.342 |
| 1 | Storage | 2 | 1 | 0,5 | 2,5 | 2,5 | 0 | 1 | 1 | 25 | 26 | 4 | 5 | 1 | 1 |
| 1 | Circulation | 46,9375 | 1 | 15 | 75 | 30 | 20 | 3 | 3 | 53 | 62 | 1.265 | 105 | 6.927 | 3.464 |
| 1 | Circulation | 156,25 | 1 | 15 | 75 | 30 | 68 | 3 | 3 | 53 | 62 | 4.212 | 105 | 23.060 | 11.530 |
| 1 | Lifts | 12,5 | 1 | 15 | 75 | 30 | 5 | 1 | 1 | 25 | 26 | 141 | 105 | 774 | 387 |
| B | Utility | 25 | 1 | 0,5 | 2,5 | 60 | 2 | 1 | 1 | 25 | 26 | 52 | 62,5 | 169 | 85 |
| 1 | Lavatory | 20 | 1 | 15 | 75 | 30 | 2 | 1 | 1 | 25 | 26 | 52 | 105 | 285 | 142 |
| 2 | Atrium | 100 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | - |
| 2 | Stairs | 50 | 1 | 15 | 75 | 30 | 3 | 1 | 1 | 25 | 26 | 78 | 105 | 427 | 214 |
| 2 | Stairs | 50 | 1 | 15 | 75 | 30 | 3 | 1 | 1 | 25 | 26 | 78 | 105 | 427 | 214 |
| 2 | Office | 493,375 | 1 | 9 | 45 | 18 | 215 | 3 | 3 | 53 | 62 | 13.300 | 63 | 43.689 | 21.845 |
| 2 | Office | 296,875 | 1 | 9 | 45 | 18 | 129 | 3 | 3 | 53 | 62 | 8.003 | 63 | 26.289 | 13.144 |
| 2 | Office | 38,3125 | 1 | 9 | 45 | 18 | 17 | 3 | 3 | 53 | 62 | 1.033 | 63 | 3.393 | 1.696 |
| 3 | Office | 48,0875 | 1 | 9 | 45 | 18 | 21 | 3 | 3 | 53 | 62 | 1.296 | 63 | 4.258 | 2.129 |
| 2 | Storage | 2 | 1 | 0,5 | 2,5 | 2,5 | 0 | 1 | 1 | 25 | 26 | 4 | 5 | 1 | 1 |
| B | Stairs | 25 | 1 | 15 | 75 | 30 | 2 | 1 | 1 | 25 | 26 | 39 | 105 | 214 | 107 |
| 2 | Circulation | 7,4375 | 1 | 15 | 75 | 30 | 3 | 3 | 3 | 53 | 62 | 200 | 105 | 1.098 | 549 |
| 2 | Circulation | 156,25 | 1 | 15 | 75 | 30 | 68 | 3 | 3 | 53 | 62 | 4.212 | 105 | 23.060 | 11.530 |
| 2 | Lifts | 12,5 | 1 | 15 | 75 | 30 | 5 | 1 | 1 | 25 | 26 | 141 | 105 | 774 | 387 |
| 2 | Lavatory | 20 | 1 | 15 | 75 | 30 | 2 | 1 | 1 | 25 | 26 | 52 | 105 | 285 | 142 |
| 3 | Atrium | 100 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | - |
| 3 | Stairs | 50 | 1 | 15 | 75 | 30 | 3 | 1 | 1 | 25 | 26 | 78 | 105 | 427 | 214 |
| 3 | Stairs | 50 | 1 | 15 | 75 | 30 | 3 | 1 | 1 | 25 | 26 | 78 | 105 | 427 | 214 |

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| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | Office | 432,7875 | 1 | 9 | 45 | 18 | 188 | 3 | 3 | 53 | 62 | 11.666 | 63 | 38.324 | 19.162 |
| 3 | Office | 309,375 | 1 | 9 | 45 | 18 | 135 | 3 | 3 | 53 | 62 | 8.340 | 63 | 27.396 | 13.698 |
| 3 | Circulation | 47,75 | 1 | 15 | 75 | 30 | 21 | 3 | 3 | 53 | 62 | 1.287 | 105 | 7.047 | 3.524 |
| B | Office | 62,5 | 1 | 15 | 75 | 30 | 27 | 3 | 3 | 53 | 62 | 1.685 | 105 | 9.224 | 4.612 |
| 3 | Circulation | 156,25 | 1 | 15 | 75 | 30 | 68 | 3 | 3 | 53 | 62 | 4.212 | 105 | 23.060 | 11.530 |
| 3 | Lifts | 12,5 | 1 | 15 | 75 | 30 | 5 | 1 | 1 | 25 | 26 | 141 | 105 | 774 | 387 |
| 3 | Lavatory | 20 | 1 | 15 | 75 | 30 | 2 | 1 | 1 | 25 | 26 | 52 | 105 | 285 | 142 |
| B | Circulation | 17,5 | 1 | 15 | 75 | 30 | 8 | 3 | 3 | 53 | 62 | 472 | 105 | 2.583 | 1.291 |
| 4 | Atrium | 100 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | - |
| 4 | Stairs | 50 | 1 | 15 | 75 | 30 | 3 | 1 | 1 | 25 | 26 | 78 | 105 | 427 | 214 |
| 4 | Stairs | 25 | 1 | 15 | 75 | 30 | 2 | 1 | 1 | 25 | 26 | 39 | 105 | 214 | 107 |
| 4 | Office | 348,060938 | 1 | 9 | 45 | 18 | 151 | 3 | 3 | 53 | 62 | 9.383 | 63 | 30.822 | 15.411 |
| 4 | Office | 250 | 1 | 9 | 45 | 18 | 109 | 3 | 3 | 53 | 62 | 6.739 | 63 | 22.138 | 11.069 |
| 4 | Office | 38,6734375 | 1 | 9 | 45 | 18 | 17 | 3 | 3 | 53 | 62 | 1.043 | 63 | 3.425 | 1.712 |
| B | Lifts | 12,5 | 1 | 15 | 75 | 30 | 5 | 1 | 1 | 25 | 26 | 141 | 105 | 774 | 387 |
| 4 | Circulation | 226,265625 | 1 | 15 | 75 | 30 | 98 | 3 | 3 | 53 | 62 | 6.099 | 105 | 33.394 | 16.697 |
| 4 | Circulation | 156,25 | 1 | 15 | 75 | 30 | 68 | 3 | 3 | 53 | 62 | 4.212 | 105 | 23.060 | 11.530 |
| 4 | Lifts | 12,5 | 1 | 15 | 75 | 30 | 5 | 1 | 1 | 25 | 26 | 141 | 105 | 774 | 387 |
| 4 | Lavatory | 20 | 1 | 15 | 75 | 30 | 2 | 1 | 1 | 25 | 26 | 52 | 105 | 285 | 142 |
| 5 | Atrium | 100 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | - |
| 5 | Stairs | 50 | 1 | 15 | 75 | 30 | 3 | 1 | 1 | 25 | 26 | 78 | 105 | 427 | 214 |
| 5 | Stairs | 25 | 1 | 15 | 75 | 30 | 2 | 1 | 1 | 25 | 26 | 39 | 105 | 214 | 107 |
| 5 | Office | 425,214281 | 1 | 9 | 45 | 18 | 185 | 3 | 3 | 53 | 62 | 11.462 | 63 | 37.654 | 18.827 |
| 5 | Office | 359,375 | 1 | 9 | 45 | 18 | 156 | 3 | 3 | 53 | 62 | 9.688 | 63 | 31.823 | 15.912 |
| 5 | Office | 42,9509375 | 1 | 9 | 45 | 18 | 19 | 3 | 3 | 53 | 62 | 1.158 | 63 | 3.803 | 1.902 |
| B | Lavatory | 100 | 1 | 15 | 75 | 30 | 10 | 1 | 1 | 25 | 26 | 260 | 105 | 1.424 | 712 |
| 5 | Storage | 2 | 1 | 0,5 | 2,5 | 2,5 | 0 | 1 | 1 | 25 | 26 | 4 | 5 | 1 | 1 |
| 5 | Circulation | 33,4597813 | 1 | 15 | 75 | 30 | 15 | 3 | 3 | 53 | 62 | 902 | 105 | 4.938 | 2.469 |
| 5 | Circulation | 156,25 | 1 | 15 | 75 | 30 | 68 | 3 | 3 | 53 | 62 | 4.212 | 105 | 23.060 | 11.530 |
| 5 | Lifts | 12,5 | 1 | 15 | 75 | 30 | 5 | 1 | 1 | 25 | 26 | 141 | 105 | 774 | 387 |
| 5 | Lavatory | 20 | 1 | 15 | 75 | 30 | 2 | 1 | 1 | 25 | 26 | 52 | 105 | 285 | 142 |
| 6 | Atrium | 50 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | - |
| 6 | Storage | 214,0625 | 1 | 0,5 | 12,5 | 5 | 17 | 1 | 1 | 25 | 26 | 445 | 17,5 | 406 | 203 |
| 6 | Stairs | 50 | 1 | 15 | 375 | 60 | 3 | 1 | 1 | 25 | 26 | 78 | 435 | 1.769 | 885 |
| 6 | Office | 50 | 1 | 9 | 45 | 18 | 22 | 3 | 3 | 53 | 62 | 1.348 | 63 | 4.428 | 2.214 |
| 6 | Circulation | 210,46875 | 1 | 15 | 75 | 30 | 92 | 3 | 3 | 53 | 62 | 5.674 | 105 | 31.062 | 15.531 |
| 6 | Circulation | 156,25 | 1 | 0 | 0 | 0 | 68 | 3 | 3 | 53 | 62 | 4.212 | 0 | - | - |
| 6 | Lifts | 12,5 | 1 | 15 | 75 | 30 | 5 | 1 | 1 | 25 | 26 | 141 | 105 | 774 | 387 |

## ANNEX C: TRANSFORMER LOAD IMBALANCES

| Collection Point Name | Frozen Date | Data Item Name | I max | %ge Imbalace |
|---|---|---|---|---|
| ACOTE M T N NGENDA201609005301 | 2020-05-05 | (Curve) Phase-A Current(A) | 16,3 | 41,7% |
| | | (Curve) Phase-B Current(A) | 15,2 | |
| | | (Curve) Phase-C Current(A) | 28,2 | |
| | 2020-05-06 | (Curve) Phase-A Current(A) | 16,1 | 48,9% |
| | | (Curve) Phase-B Current(A) | 12,2 | |
| | | (Curve) Phase-C Current(A) | 27,9 | |
| | 2020-05-07 | (Curve) Phase-A Current(A) | 17,7 | 38,5% |
| | | (Curve) Phase-B Current(A) | 15,3 | |
| | | (Curve) Phase-C Current(A) | 28,3 | |
| | 2020-05-08 | (Curve) Phase-A Current(A) | 22,1 | 28,1% |
| | | (Curve) Phase-B Current(A) | 19,1 | |
| | | (Curve) Phase-C Current(A) | 30,7 | |
| | 2020-05-10 | (Curve) Phase-A Current(A) | 40,7 | 26,4% |
| | | (Curve) Phase-B Current(A) | 26,7 | |
| | | (Curve) Phase-C Current(A) | 29,2 | |
| | 2020-05-11 | (Curve) Phase-A Current(A) | 18,2 | 43,6% |
| | | (Curve) Phase-B Current(A) | 13,5 | |
| | | (Curve) Phase-C Current(A) | 29,1 | |
| AKILLAH MAYANGE201609005695 | 2020-05-05 | (Curve) Phase-A Current(A) | 21,16 | 40,4% |
| | | (Curve) Phase-B Current(A) | 33,8 | |
| | | (Curve) Phase-C Current(A) | 48,32 | |
| | 2020-05-06 | (Curve) Phase-A Current(A) | 18,48 | 56,2% |
| | | (Curve) Phase-B Current(A) | 29,04 | |
| | | (Curve) Phase-C Current(A) | 51,64 | |
| | 2020-05-07 | (Curve) Phase-A Current(A) | 22,32 | 55,9% |
| | | (Curve) Phase-B Current(A) | 33,72 | |
| | | (Curve) Phase-C Current(A) | 60,64 | |
| | 2020-05-08 | (Curve) Phase-A Current(A) | 21,52 | 43,3% |
| | | (Curve) Phase-B Current(A) | 33 | |
| | | (Curve) Phase-C Current(A) | 49,84 | |
| | 2020-05-09 | (Curve) Phase-A Current(A) | 28,16 | 22,5% |
| | | (Curve) Phase-B Current(A) | 29,8 | |
| | | (Curve) Phase-C Current(A) | 40 | |
| | 2020-05-10 | (Curve) Phase-A Current(A) | 15,76 | 57,8% |
| | | (Curve) Phase-B Current(A) | 49,04 | |
| | | (Curve) Phase-C Current(A) | 47,32 | |
| | 2020-05-11 | (Curve) Phase-A Current(A) | 20,04 | 63,1% |
| | | (Curve) Phase-B Current(A) | 80,44 | |
| | | (Curve) Phase-C Current(A) | 47,48 | |
| ARRETE CENTRE201609005303 | 2020-05-05 | (Curve) Phase-A Current(A) | 53,9 | 10,6% |
| | | (Curve) Phase-B Current(A) | 56,1 | |
| | | (Curve) Phase-C Current(A) | 64,2 | |
| | 2020-05-06 | (Curve) Phase-A Current(A) | 48,8 | 19,0% |
| | | (Curve) Phase-B Current(A) | 48 | |
| | | (Curve) Phase-C Current(A) | 63,6 | |
| | 2020-05-07 | (Curve) Phase-A Current(A) | 37,7 | 28,2% |
| | | (Curve) Phase-B Current(A) | 56,6 | |
| | | (Curve) Phase-C Current(A) | 63,3 | |
| | 2020-05-08 | (Curve) Phase-A Current(A) | 59,9 | 17,4% |
| | | (Curve) Phase-B Current(A) | 83,8 | |
| | | (Curve) Phase-C Current(A) | 73,9 | |
| | 2020-05-09 | (Curve) Phase-A Current(A) | 42,5 | 14,2% |
| | | (Curve) Phase-B Current(A) | 49,8 | |
| | | (Curve) Phase-C Current(A) | 56,3 | |

| | | | | |
|---|---|---|---|---|
| | 2020-05-10 | (Curve) Phase-A Current(A) | 84,7 | 18,5% |
| | | (Curve) Phase-B Current(A) | 62,9 | |
| | | (Curve) Phase-C Current(A) | 83,8 | |
| | 2020-05-11 | (Curve) Phase-A Current(A) | 54,4 | 10,3% |
| | | (Curve) Phase-B Current(A) | 48,1 | |
| | | (Curve) Phase-C Current(A) | 58,4 | |
| BATIMA CENTRE201609003726 | 2020-05-05 | (Curve) Phase-A Current(A) | 119,1 | 7,8% |
| | | (Curve) Phase-B Current(A) | 131 | |
| | | (Curve) Phase-C Current(A) | 137,5 | |
| | 2020-05-06 | (Curve) Phase-A Current(A) | 208,1 | 0,8% |
| | | (Curve) Phase-B Current(A) | 206 | |
| | | (Curve) Phase-C Current(A) | 205 | |
| BENIMPUHWE201609000689 | 2020-05-05 | (Curve) Phase-A Current(A) | 18,226 | 22,2% |
| | | (Curve) Phase-B Current(A) | 26,582 | |
| | | (Curve) Phase-C Current(A) | 25,466 | |
| | 2020-05-06 | (Curve) Phase-A Current(A) | 17,954 | 21,4% |
| | | (Curve) Phase-B Current(A) | 26,463 | |
| | | (Curve) Phase-C Current(A) | 24,067 | |
| | 2020-05-07 | (Curve) Phase-A Current(A) | 18,932 | 19,0% |
| | | (Curve) Phase-B Current(A) | 26,599 | |
| | | (Curve) Phase-C Current(A) | 24,566 | |
| | 2020-05-08 | (Curve) Phase-A Current(A) | 19,194 | 17,8% |
| | | (Curve) Phase-B Current(A) | 26,472 | |
| | | (Curve) Phase-C Current(A) | 24,369 | |
| | 2020-05-09 | (Curve) Phase-A Current(A) | 19,754 | 14,6% |
| | | (Curve) Phase-B Current(A) | 24,736 | |
| | | (Curve) Phase-C Current(A) | 24,864 | |
| | 2020-05-10 | (Curve) Phase-A Current(A) | 15,872 | 134,9% |
| | | (Curve) Phase-B Current(A) | 130,141 | |
| | | (Curve) Phase-C Current(A) | 20,182 | |
| | 2020-05-11 | (Curve) Phase-A Current(A) | 18,143 | 27,1% |
| | | (Curve) Phase-B Current(A) | 30,523 | |
| | | (Curve) Phase-C Current(A) | 25,979 | |
| BIDUDU201609000845 | 2020-05-05 | (Curve) Phase-A Current(A) | 14,892 | 0,7% |
| | | (Curve) Phase-B Current(A) | 15,087 | |
| | | (Curve) Phase-C Current(A) | 14,952 | |
| | 2020-05-06 | (Curve) Phase-A Current(A) | 14,595 | 2,0% |
| | | (Curve) Phase-B Current(A) | 15,101 | |
| | | (Curve) Phase-C Current(A) | 14,963 | |
| | 2020-05-07 | (Curve) Phase-A Current(A) | 15,497 | 2,9% |
| | | (Curve) Phase-B Current(A) | 15,01 | |
| | | (Curve) Phase-C Current(A) | 15,856 | |
| | 2020-05-08 | (Curve) Phase-A Current(A) | 15,22 | 1,6% |
| | | (Curve) Phase-B Current(A) | 15,682 | |
| | | (Curve) Phase-C Current(A) | 15,508 | |
| | 2020-05-09 | (Curve) Phase-A Current(A) | 21,461 | 1,2% |
| | | (Curve) Phase-B Current(A) | 21,211 | |
| | | (Curve) Phase-C Current(A) | 21,717 | |
| | 2020-05-11 | (Curve) Phase-A Current(A) | 34,452 | 77,1% |
| | | (Curve) Phase-B Current(A) | 14,809 | |
| | | (Curve) Phase-C Current(A) | 70,939 | |
| BUGANDE201609000682 | 2020-05-05 | (Curve) Phase-A Current(A) | 49,848 | 2,1% |
| | | (Curve) Phase-B Current(A) | 49,112 | |
| | | (Curve) Phase-C Current(A) | 47,956 | |
| | 2020-05-06 | (Curve) Phase-A Current(A) | 115,759 | 8,2% |
| | | (Curve) Phase-B Current(A) | 130,13 | |

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| | | | | |
|---|---|---|---|---|
| | | (Curve) Phase-C Current(A) | 114,976 | |
| | 2020-05-07 | (Curve) Phase-A Current(A) | 94,236 | 49,3% |
| | | (Curve) Phase-B Current(A) | 38,593 | |
| | | (Curve) Phase-C Current(A) | 95,606 | |
| | 2020-05-08 | (Curve) Phase-A Current(A) | 50,639 | 3,0% |
| | | (Curve) Phase-B Current(A) | 48,902 | |
| | | (Curve) Phase-C Current(A) | 47,982 | |
| | 2020-05-09 | (Curve) Phase-A Current(A) | 30,767 | 8,4% |
| | | (Curve) Phase-B Current(A) | 33,8 | |
| | | (Curve) Phase-C Current(A) | 29,003 | |
| | 2020-05-10 | (Curve) Phase-A Current(A) | 96,147 | 18,3% |
| | | (Curve) Phase-B Current(A) | 71,446 | |
| | | (Curve) Phase-C Current(A) | 94,764 | |
| | 2020-05-11 | (Curve) Phase-A Current(A) | 29,371 | 5,5% |
| | | (Curve) Phase-B Current(A) | 29,448 | |
| | | (Curve) Phase-C Current(A) | 31,907 | |