COLLEGE OF SCIENCE AND TECHNOLOGY

(SCHOOL OF ENGINEERING)

DEPARTMENT OF MECHANICAL AND ENERGY ENGINEERING

MASTER OF SCIENCE IN RENEWABLE ENERGY

Master's Thesis

TOPIC: OPTIMAL PRIORITIZATION OF ENERGY EFFICIENCY MEASURES IN BUILDINGS IN RWANDA

A thesis submitted in partial fulfillment of the requirements for the award of Master of Science in Renewable Energy.

Submitted by

MUKESHIMANA Olivier (Ref. No: 217022715)

Supervised by: Dr. Vénant KAYIBANDA

Project ID: UR/ MEE/MSC- REN /002/2019 ***AUGUST, 2019***

DECLARATION

I declare that this thesis is the result of my own work and has not been submitted for any other degree at the University of Rwanda or any other institutions.

Signature: .... Date...

Olivier MUKESHIMANA

This thesis has been submitted for examination with our approval as the University Supervisor:

Signature: .... Date...

Dr Vénant KAYIBANDA

University of Rwanda

ACKNOWLEDGEMENTS

I would like to extend many thanks to those who assisted me in this long journey of studying. Thanks go to my family, my lecturers especially Dr. Ernest Mazimpaka, Dr. Vénant Kayibanda and Dr. Anastase Rwigema for their guidance and comfort that was given to me while conducting Master's courses and thesis. I would like to acknowledge the University of Rwanda for the financial support during my Master's studies. I also acknowledge my classmate for their collaboration, ideas and support.

Contents

LIST OF ACRONYM

AC: Alternative Current

CO_2: Carbon dioxide

DC: Direct Current

DSM: Direct Side Management

EDPRS: Economic Development and Poverty Reduction Strategy

EES: Energy Efficiency Strategy

EPA: Environmental Protection Agency

ESCOs: Energy Serving Companies

ESSP: Energy Sector Strategic Plan

EU: European Union

EUCL: Energy Utility Corporate Limited

GDP: Gross Domestic Product

GHG: Greenhouse Gas

GW: Gigawatts

GWh: Gigawatts hour

GWth: Gigawatts-thermal

HVDC: High Voltage Direct Current

IEA: International Energy Agency

IEC: International Electrotechnical Commission

ISO: International Organization for Standardization

kV: kilo Volt

kW: kilo Watt

kWh: kilo Watt hour

LED: Lighting Emitting Diode

MEPS: Minimum Energy Performance Standards

MININFRA: Ministry of Infrastructure

MW: Megawatt

NST: National Strategy for Transformation

PV: Photo voltaic

RDB: Rwanda Development Board

RE: Renewable Energy

REG: Rwanda Energy Group

REG HQ: Rwanda energy Group Headquarters

REP: Rwanda Energy Policy

SDGs: Sustainable Development Goals

S&L: Standards &Labelling

RURA: Rwanda Utility Regulatory Authority

SEP: Superior Energy Performance

TWh: TeraWatts hour

USD: United State Dollars

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Economic growth and industrial growth of any country depend on its energy production. Higher the utilization of energy in a nation, greater is the progression and overall growth. In this perspective, country's utilization of energy is supposed as its social-economic growth.

Currently, the requirement of energy is rising day by day according to the advancements of technology and population growth. Electricity is a major source for achieving the goal of economic growth and fulfill power necessities of a nation. Electricity production has increased substantially as it has become a major requirement in a country's development, but the consumption and production of electricity should be balanced.

Residential buildings consumed more than three times the energy used by non-residential buildings end users. Currently, a significant amount of electricity is lost during transmission and distribution. Ensuring that losses are reduced to an acceptable level (some level of losses is unavoidable) can reduce the required generation level and support the financial performance of the sector. Inefficient consumption of electricity brings significant financial and environmental penalties. Behaviours, technologies and standards can be introduced to reduce the amount spent on electricity by consumers, reduce the current pronounced peak demand and increase the power quality of the distribution system. It is becoming increasingly clear that energy efficiency can bring many significant economic and environmental benefits. Yet it is also clear that huge energy efficiency potential remains untapped. While energy efficiency is improving, its impact on global energy use is being overwhelmed by increasing economic activity across all sectors. Energy efficiency is the key to ensure sustainable, safe, reliable and affordable energy system supply in the future.

The methodology used to gather information in this study was interviewing the user of buildings, staff from Public Institution, Energy Development and Utility Bodies as well as site visit to the buildings for visual inspection on use of electricity during work hours and those two methods was done in combination with readings the books, standards, national policy, strategies and other publications related to generation, transmission, distribution of electrical energy, loss reduction and energy efficiency.

In this study, we proposed the policies and actions required to deliver available energy efficiency and monitoring the use of energy within the buildings. The role of Government in ensuring market readiness to deliver efficiency improvements, and in evolving measures, using monitoring and evaluation, to increase ambition as technology develops and costs fall. This study is done to provide a clear picture on implementation of energy efficiency technologies and measures in buildings within Rwanda; it targeted to provide the basic potential benefits, the opportunities to improve the efficiency of buildings in energy management and give a background on the key issues that need to be considered for developing appropriate policies and a legal framework for implementation.

The study proposed the methodology that can be used for determining the efficacy of buildings in terms of energy efficiency and some of useful mechanisms necessary to finance the energy efficiency actions. It concludes with a discussion on the route and procedures for development and implementation of on energy efficiency policy and strategies in buildings.

Based on findings, to maximize energy efficiency within a building, the implementation of energy efficiency in building should started from the design of the buildings by considering all parameters and standards related to the use efficiency products. Government to set up minimum energy standards performance and those standards to be used during installation within the buildings.

CHAPTER ONE: INTRODUCTION

1.1 Background

Globally the building sector is considered as the most use of electricity energy than other sector. With the increase of urbanization, the number and size of buildings will increase in urban areas, and that will increase demand for electricity and other different mode of energy frequently used in building industry. The increasing of demand in electricity, brought in the needs of new energy generation. Although renewable sources for electricity production like hydro, geothermal or wind produce electricity at lower cost, their capital expenditure is too large, they are very complex and the implementation takes long time. Short term solution to meet the required demand while waiting the implementation of those lower cost generation, diesel based generation is the solution but it will increase the electricity [3].

The investments in building energy efficiency sector can be compared with the cost of capital investments required to supply the energy to produce a same amount of peak capacity or annual energy production. Commonly, the efficiency capital costs are lower than comparable investments in increased energy supply and not require additional operating costs compared to substantial operating costs for supply-side options. In addition, investments in energy efficiency generally have much shorter lead times than investments in energy supply, there is a need of particularly important consideration in places where the energy services demand is rapidly growing [1].

One reliable quality in the building industry is that it is subject to a high degree of regulation. Building codes and regulations often influence the choice of material to use and standards that have a significant impact on energy efficiency [3].

In Rwanda, access to sustainable energy, safe, reliable and cost effective energy is necessary to achieving the growth target as required in the Economic Development and Poverty Reduction Strategy (EDPRS II) and the National Strategy for Transformation (NST). Energy is a critical productive sector that plays an important role in catalyzing broader economic growth and contributes significantly the achievement of the country’s social economic transformation aspirations.

To achieve the desired development impact of 7-year Rwanda Government Program, EDPRS-II as well as Rwanda Vision 2020, the Government of Rwanda adopted and implements sound, comprehensive national energy policy, strategies and plans capable of taking into account dynamic factors such as, population and economic growth, natural resource constraints and dispersed settlement [4].

Energy sustainability is the cornerstone to the economic and population growth. The energy efficiency improvement is one of the most cost-effective measure to concurrently improve the security of energy supply, reduce energy-related emissions, assure affordable energy prices and increase economic competitiveness [5].

Energy efficiency means using less energy to provide the same product or service. It is achieved through improving operations and processes, investing in efficient technologies and changing consumer behaviors [1].

Efficiency use of energy, can be interpreted as the reduction of energy quantity use for a given service or level of activity, or in short doing more with less input. Energy efficiency and renewable energy are normally the twin pillars for sustainable energy policy.

In industry, electricity is the lifeblood of manufacturing sector as the electricity is the one used to transform raw materials into end products. Furthermore, electrical energy is also one of the most convenient form of energy and safe for use in the buildings. But with climate change and diminishing economies taking centre stage worldwide in latest years, it is very important that energy is used efficiently both to cut usage costs and protect the environment [1].

In many countries, energy efficiency plays a key role in national energy security because it can be used to reduce the level of energy to import from neighbouring countries and may reduce the rate at which domestic energy resources are depleted. Efficient use of electricity reduces the national electrical load and hence delay the capital reserved for generation and transmission projects. International experience has shown that energy efficiency brings significant economic and environmental benefits [3].

Energy efficiency is at the forefront topic of different present debates about building technology. The increasing population globally, decreasing fossil-based energy resources, increasing of emissions of harmful gases are the main motivators of energy efficiency in building sector. Although the energy consumption in buildings depends on different factors like social differences, cultural habits, climate, geographical location, the new figures show that around 40% of the annual energy consumed around the world is used in the buildings today. Based on all these reports, over the last century, the countries has increased effort into the development of energy efficient design [1].

The economic argument for energy efficiency is clear, and it is internationally recognized as the most cost-effective means of balancing supply and demand. Initial investments are paid back through reduced expenditure on energy. The World Bank estimates that harnessing more efficient allocation of resources across the global economy can boost economic output by 18 USD trillion by 2035 [1].

1.2 Problem statement

Rwanda has achieved remarkable development successes over the last two decades, with high levels of economic growth and significant poverty reduction. The target is to become a knowledge-based, service-oriented, lower middle-income economy by 2020 and upper middle-income by 2035. Achieving this target will significantly increase energy demand and increase the requirement for energy efficiency.

Currently, a significant amount of electricity is lost during transmission and distribution. This electricity represents unnecessary generation, with REG, the country's utility, paying the production costs but receiving no revenue. Ensuring that losses are reduced to an acceptable level (some level of losses is unavoidable) will reduce the required generation level and support the financial performance of the sector. The target of Rwanda is to have 100% of households with access to electricity with 52% on grid and 48% off grid in 2024 and electricity generation capacity of 418 MW with loss reduction to 15% as well as safe, reliable and effective energy [5].

Consumption of electricity represents clear opportunities for energy efficiency. Across the residential, public and commercial & industrial sectors, inefficient technologies and behaviours result in higher demand at the national level and higher electricity bills for citizens and businesses than are necessary. Reducing unnecessary consumption will benefit the environment, the sector and citizens and businesses.

The Rwanda Energy Policy (REP), Energy Efficiency Strategy (EES) and Energy Sector Strategic Plan (ESSP) note the importance of energy efficiency and the REP directly links energy efficiency to reducing peak demand and delivering economic benefits. However, both the REP and ESSP are focused on end-users. There is now the need to develop and expand on these approaches to prioritise energy efficiency across the electricity value chain [6]

This project work is focused on the optimum use of energy efficiency in residential and institutional building in Rwanda for reducing the losses (technical and non-technical losses) and promoting the energy management within the country in economic benefits.

1.3 Objectives

The main objective of this study is to analyze the use of energy in Rwanda and how improvement can be done in management of energy in order to reduce energy losses and maximize the efficiency use of energy in Rwanda, especially in domestic and institutional buildings. To achieve this main objective, the following specific objectives need to be addressed:

a. Promote the efficiency use of electrical energy in domestic and institutional buildings and introduce the concept and benefits of energy efficiency in buildings
b. Reduce high demand due to energy losses in Distribution of Electrical Energy within the Country
c. Contribute to the implementation of Rwanda Energy Policy, Energy Efficiency Strategy and Energy Sector Strategic Plan of Rwanda
d. Assess Energy Resource Efficiency, Transmission and Distribution Efficiency and End-User Efficiency.
e. Analyze measures and opportunities for reduction of energy use in buildings without surrendering comfort level.
f. Address the legal framework and policy tools that can successful promote energy efficiency in building.

1.4 Scope and limitations

The study is focused on general consideration of energy efficiency in buildings but it will consider also the promotion of reducing energy losses during generation, transmission and distribution; with aims to promote the culture of energy efficiency within Rwanda by providing clear understanding of the potential benefits, opportunities for improving the energy generation, transmission and distribution by reducing all losses. The study will help policymakers and regulators understand the potential benefits and opportunities for improving the efficiency in buildings sector. With this study, brief description on the key issues to be addressed while developing appropriate policies and legal framework for implementation of energy efficiency measures will be provided. It will briefly discuss the practices and procedures to be used for determining the efficiency of buildings in terms of energy consumption and the mechanisms that can be used to finance energy efficiency projects. It concludes with a discussion on the process of developing and implementing policy on energy efficiency in buildings and gives a summary on policy tools that can be used to facilitate implementation of energy efficiency in buildings.

The study will describe the different scenario of energy used across the world in general and in Rwanda particularly, energy status, energy efficiency and monitoring process which includes but not limited to setting up standards, policies, strategies and regulations on energy efficiency, energy consumption in Rwanda and in building sector particularly. The study will be also on challenges and mitigation for reducing energy losses, key indicators for energy efficiency within the sector, challenges and energy efficiency measures to be undertaken for domestic and institutional buildings in Rwanda.

For the development of this study, more information on generation, transmission and distribution of electrical energy in Rwanda and access to electricity as well as use of that energy in domestic and public buildings were gathered from interview of the end users, staff from utility and public institutions. In additional to interview, the site visit to the buildings for visual inspection on use of electricity during work hours were used and also some information was collected from the readings of books, standards, national policy, strategies and other publications related to generation, transmission, distribution of electrical energy, loss reduction and energy efficiency. The study was done on sample buildings located in City of Kigali, Nyarugenge and Kicukiro Districts. The building structure, surrounding environment and occupancy are taken into consideration during the choice of the buildings.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

The basic requirement for the national economy transformation as defined in NST 1is the development of energy sector. Availability of adequate infrastructure in energy sector are the key essential tools for industries and businesses development especially for energy intensive industries such as mining, steel industry, milk processing, coffee and tea factories, high quality service delivery from social institutions such as schools, health facilities and public institutions. With focus on a green and low carbon development in regard to electricity generation and biomass use, the country is committed to achieve a sustainable and durable development [4].

The sustainability of energy is the foundation of the competitiveness of production and manufacture industries in global economy. Beside many other considerations such as markets access and availability of labor, the effective utilization of affordable and secure energy is the best options for the companies and societies to be competitive and have sustainable leadership. The sustainability of energy is much more important than the process of being environmentally responsible and earning the right to operate as a business. The energy efficiency improvement is one of the most cost-effective means to improve the security of energy supply, reduce emissions and assure affordable energy prices, and that will impact the improvement of economic competitiveness [6]. This research presents a review of studies that have been carried out on energy sector in general and energy efficiency in building sector to stabilize the energy consumption around the world in general and Rwanda in particularly.

2.2 Energy profile in the world

The energy sector comprises all energy extraction, conversion, storage, transmission and distribution processes with the exception of those that use final energy in the end-use sectors (industry, transport, building, agriculture, forestry).

Energy is and will continue to be a primary engine for economic development. It is central to achieving the goals of sustainable development. Socio-economic development requires energy for improved living standards, enhanced productivity, effective transportation of goods to the point of need, and as inputs to a wide range of economic production activities. A variety of technologies and natural resources, such as petroleum-based fuels, hydro, solar, methane gas, peat, geothermal, biomass, waste, and wind; contribute to the generation of electricity [1].

Energy security is a socio-economic and political factor that contributes to sustainable development in any nation. Access to reliable, affordable, sustainable, and modern energy to all people is one of the sustainable development goals (SDGs). Energy resources can be non-renewable or renewable; however, currently, the world is dominated by the usage of non-renewable energy such as fossil fuels. These are unsatisfactory because of their depletion and environmental concerns. For instance, currently, more than a half of the air pollution is contributed by energy globally. The use of non-renewable energy is considered the principal provider to climate change, which is about 60% of the total greenhouse gas emissions; therefore, decrease of carbon concentration is a key goal in long-term climate objectives. Thus, the use of renewable energy is considered as alternative to the realization of sustainable development now and in the future [7].

Worldwide, the total primary energy demand rose about 2.0% in 2017 and is expected to rise around 30% in 2035 by increasing prosperity in terms of wealth generation and drivers for socio-economic development in developed and developing countries, partially offset by a fast improvement in energy efficacy. More than 21% of the population globally lacks access to contemporary electricity by which 3,000 million people rely on traditional fuels such as firewood, coal, animal slurry, and charcoal for heating and cooking [1].

In the buildings sector with 31% of total final consumption, the largest energy consuming end-use sector today consumption increases by an average of 0.9% per year. The industry sector accounted for around 29% of total final energy consumed in 2017, sees growth of 1.3% per year, the fastest among the end-use sectors [8]. By 2017, the energy consumption by category was distributed as shown in figure 1.

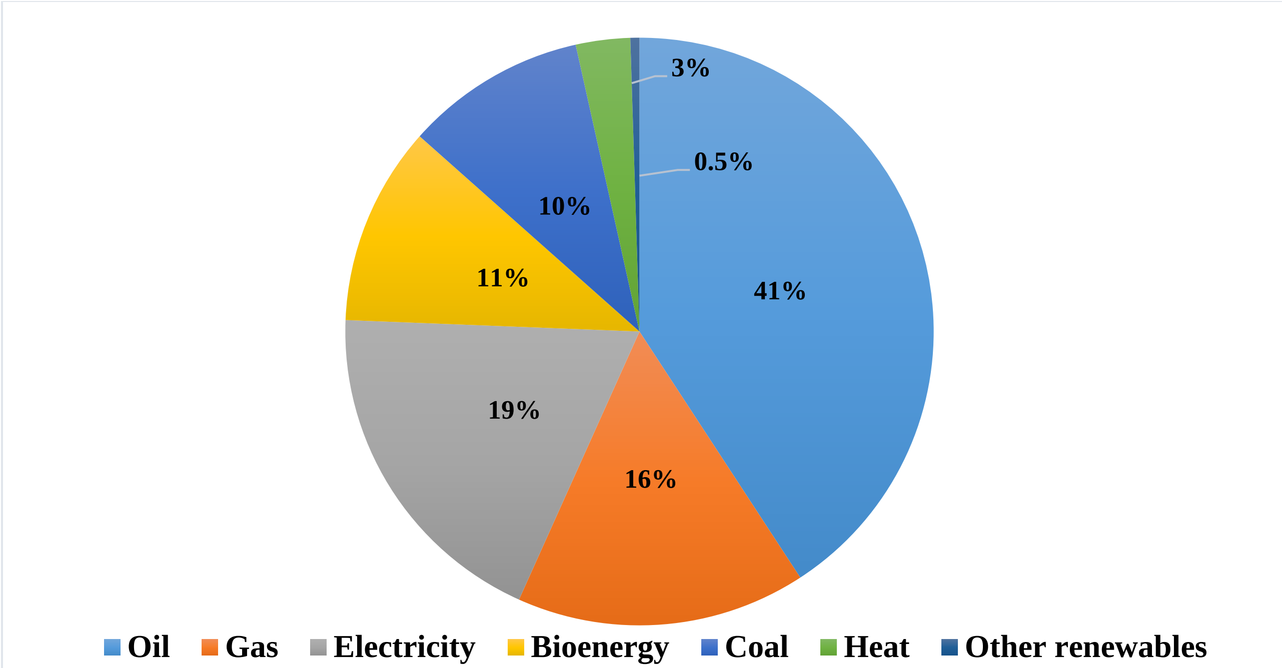

Figure 1:World energy consumption by category[8]

From 1974 to 2016, gross electricity production in the world increased from 6 298 TWh to 25 082 TWh, with annual average growth rate of 3.3%. The figure 2 indicates gross electricity production as by 2016 in the world [8].

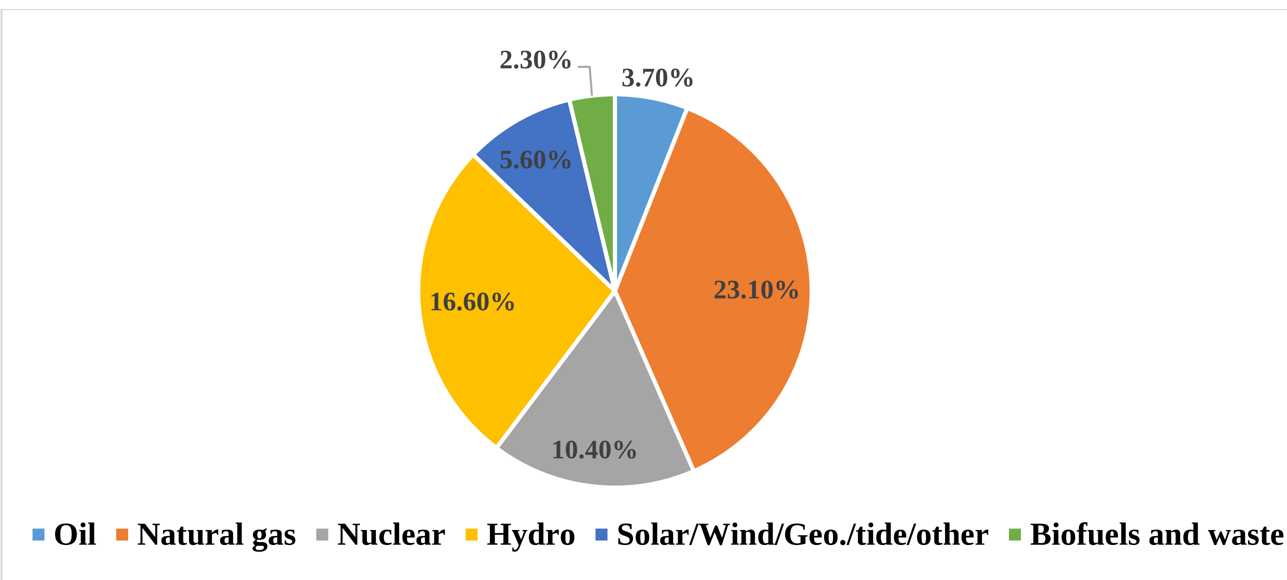

Figure 2: World gross electricity production(2016)) [8]

Hydropower is the leading renewable source for electricity generation globally, supplying 71% of all renewable electricity at the end of 2015. The global hydropower capacity increased by more than 30% between 2007 and 2015 the increasing of capacity in 2017 were an estimated 19 GW, bringing total capacity to approximately 1,114 GW. While significant, this is the smallest annual increment seen over the last five years. Among the priorities of the hydropower industry in 2017 were continued advances towards more sustainable development of hydropower resources, increased climate change resilience, and ongoing modernisation efforts and digitalisation of existing and new facilities [9].

Oil remained the world's leading fuel, accounting for 32.9% of global energy consumption. Crude oil prices recorded the largest percentage decline since 1986 (73%). Roughly 63% of oil consumption is from the transport sector [8].

Natural gas is the second largest energy source in power generation, representing 22% of generated power globally and the only fossil fuel whose share of primary energy consumption is projected to grow.

Global wind power generation reached 432 GW in 2015, around 7% of total global power generation capacity (420 GW onshore, 12 GW offshore) with a record of 63 GW added in 2015.

Coal production decreased with 0.6% in 2014 and with a further 2.8% in 2015, the first decline in global coal production growth since the 1990s. Coal still provides around 40% of the world's electricity. However, climate change mitigation demands, transition to cleaner energy forms and increased competition from other resources are presenting challenges for the sector. Asia presents the biggest market for coal and currently accounts for 66% of global coal consumption [9].

An estimated 0.7 gigawatts (GW) of new geothermal power capacity came online in 2017, bringing the global total to around 12.8 GW. Geothermal direct use (direct thermal extraction for heating and cooling) increased by an estimated 1.4 gigawatts-thermal (GWth) of capacity to an estimated global total of 25 GWth. Space heating continued to be one of the largest and fastest growing sectors, with several new projects feeding into district heat systems in Europe and China, in particular. The geothermal industry remained constrained by various sector-specific challenges, such as long project lead-times and high resource risk, but technology innovation to address such challenges continued during 2017 [8]. The industry is focused on advancing technologies to reduce development risk and to cost-effectively tap geothermal resources in more locations, as well as to reduce the potential environmental consequences [8].

New solar PV installations surpassed net additions of fossil fuels and nuclear power combined. Solar PV was the top source of new power generating capacity in 2017, due largely to strong growth in China, with more solar PV installed globally than the net additions of fossil fuels and nuclear power combined. Global capacity increased nearly one-third, approximately 402 GW. Although solar PV capacity is concentrated in a short list of countries, by years end every continent had installed at least 1 GW of capacity, and at least 29 countries had 1 GW or more [8].

Energy use in Africa as a whole has raised by just under 60% and surpasses that of the European Union towards the end of the outlook period, although it remains the lowest consumer of energy on a per-capita basis [8].

The energy sector faces multiple threats from climate change, in particular from extreme weather events and increasing stress on water resources. Greater resilience to climate change impacts will be essential to the technical viability of the energy sector and its ability to cost-effectively meet the rising energy demands driven by global economic and population growth. Energy sector stakeholders, including governments, regulators, utilities/energy companies and financial institutions (banks, insurers, investors), will need to define climate change resilience and adaptation challenges and identify actions needed to address these challenges [3].

Improving energy efficiency in power transmission and distribution could help reduce GHG emissions. Losses as a fraction of energy generated vary widely between countries, with some developing countries having losses of over 20%. Increased use of improved transformers and distributed power generation would reduce losses, while new technologies such as dynamic loading, gas-insulated transmission lines and high voltage DC transmission (HVDC) could offer reductions [2].

2.2.1 Renewable Energy

Renewable energy is a general term used to describe energy derived from sources that can be infinitely replenished, such as energy from the sun, wind, and water.
These resources are contrasted with fossil fuels, which primarily consist of oil, coal, and natural gas and are “non---renewable [4].

The electricity transition is well under way, due mostly to increases in installed capacity and in the cost competitiveness of solar PV and wind power. Renewable energy generating capacity saw its largest annual increase ever in 2017, raising total capacity by almost 9% over 2016. Overall, renewables accounted for an estimated 70% of net additions to global power capacity in 2017, due in large part to continued improvements in the cost-competitiveness of solar PV and wind power. Solar PV led the way, accounting for nearly 55% of newly installed renewable power capacity in 2017. Wind (29%) and hydropower (11%) accounted for most of the remaining capacity additions. Several countries are successfully integrating increasingly larger shares of variable renewable power into electricity systems [8].

While China, Europe and the United States accounted for nearly 75% of the global investment in renewable power and fuels, 2017 saw significant investment in developing country markets. When measured per unit of gross domestic product, the Marshall Islands, Rwanda, the Solomon Islands, Guinea-Bissau and many other developing countries are investing as much as or more in renewables than developed and emerging economies. These positive developments need to be scaled up for a global energy transition [2].

The Renewables 2018 Global Status Report reveals two realities: one in which a revolution in the power sector is driving rapid change towards a renewable energy future, and another in which the overall transition is not advancing with the speed needed. While momentum in the power sector is positive, it will not on its own deliver the emissions reductions demanded by the Paris climate agreement or the aspirations of Sustainable Development Goal 7 [10].

Renewable energy (RE) sources have significant potential for reducing GHG emissions, and are becoming more competitive. RE provides just over one fifth of the world’s electricity supply, and in 2012 accounted for just over half of the new electricity-generating capacity added globally [7]. The number of countries with renewable energy targets and support policies increased again in 2017, and several jurisdictions made their existing targets more ambitious. Strong growth continued in the renewable power sector, while other renewable sectors grew very slowly. Solar photovoltaic (PV) capacity installations were remarkable, nearly double those of wind power (in second place), adding more net capacity than coal, natural gas and nuclear power combined [11].

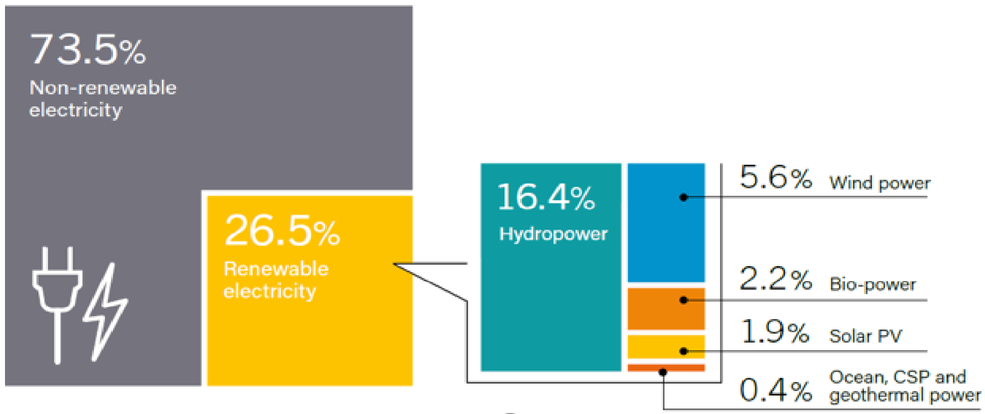

Figure 3:Estimated renewable energy share global electricity production (2017) [7]

The number of countries with renewable energy targets and support policies increased again in 2017, and several jurisdictions made their existing targets more ambitious. Strong growth continued in the renewable power sector, while other renewable sectors grew very slowly. Solar photovoltaic (PV) capacity installations were remarkable, nearly double those of wind power (in second place), adding more net capacity than coal, natural gas and nuclear power combined [7].

Renewable energy policies and targets remain focused on the power sector, with support for heating and cooling and transport still lagging. Renewable energy continues to attract the attention of policy makers worldwide. Renewable technologies for power generation, heating and cooling, and transport are considered key tools for advancing multiple policy objectives, including boosting national energy security and economic growth, creating jobs, developing new industries, reducing emissions and local pollution, and providing affordable and reliable energy for all citizens [7].

2.2.2 Energy efficiency

Renewable energy and energy efficiency are being advanced in some cases by climate change policies, including under commitments to achieve net-zero emissions or through specific mechanisms such as carbon taxes, the elimination of fossil fuel subsidies, and emissions trading schemes. Energy efficiency is a growing policy priority for many countries around the world. It is widely recognised as the most cost-effective and readily available means to address numerous energy-related issues, including energy security, the social and economic impacts of high energy prices, and concerns about climate change. At the same time, energy efficiency increases competitiveness and promotes consumer welfare. As an energy resource, energy efficiency has the unique potential to simultaneously contribute to long-term energy security, economic growth, and even improved health and well-being; in particular, it is a key means to reduce greenhouse gas emissions. By reducing or limiting energy demand, energy efficiency measures can increase resilience against a variety of risks, such as energy price rises and volatility, stress on energy infrastructure, and disruptions to energy supply systems [12].

Energy efficiency (EE) and renewable energy (RE) are the “twin pillars” of sustainable energy policy. Both resources must be developed aggressively if we are to stabilize and reduce carbon dioxide emissions in our lifetimes. Efficiency is essential to slowing the energy demand growth so that rising clean energy supplies can make deep cuts in fossil fuel use. If energy use grows too fast, renewable energy development will chase a receding target. Likewise, unless clean energy supplies come online rapidly, slowing demand growth will only begin to reduce total emissions; reducing the carbon content of energy sources is also needed. Any serious vision of a sustainable energy economy thus requires major commitments to both efficiency and renewables. Efficiency and renewables also provide complementary economic development benefits by generating investment and employment in different sectors, which expands the total economic stimulus effect. The majority of utility expenditures in most states is exported to national and global energy companies, so efficiency and renewable investment is in fact the best way to generate new economic activity within a state’s borders [12].

Energy efficiency can result in large and highly cost-effective energy savings and emissions reductions. However, energy efficiency often lacks the “sex appeal” that renewable energy enjoys among the general public and many policymakers. Renewable energy, on the other hand, often needs to address challenges regarding economics and near-term savings [12].

The improvement of energy efficiency is one of the most cost-effective ways to concurrently improve the security of supply, reduce energy-related emissions, assure affordable energy prices, and improve economic competitiveness [4].

Energy efficiency can be defined as using less energy for the same or even increased output is increasingly being recognized as one of the most important and cost effective solutions to reduce greenhouse gas (GHG) emissions. Along with the benefits to the environment, successful energy efficiency projects also typically improve a company's overall efficiency, including by increasing productivity and competiveness. Energy efficiency is called "the first fuel" as it is the best way of getting more out of existing resources, supporting economic growth, and reducing energy costs. Significant potential for improving energy efficiency exists worldwide, but attempts to improve it often fall short because of inadequate national policy frameworks or lack of enforcement of appropriate legislation [4].

Energy efficiency is the use of technology that requires energy to perform the same function. Energy efficiency is key to ensuring a safe, reliable, affordable and sustainable energy system for the future. Energy intensity is defined as the amount of energy consumed per activity or output for sub-sectors and end uses. Global energy intensity measured as the amount of primary energy demand needed to produce one unit of gross domestic product (GDP) fell by 1.8% in 2016 [10]. Since 2010, intensity has declined at an average rate of 2.1% per year, which is a significant increase from the average rate of 1.3% between 1970 and 2010. The improvement in intensity varies widely across countries and regions. This is avoiding huge amounts of energy use, generating financial savings for consumers and holding back the growth in greenhouse gas (GHG) emissions [11].

In emerging economies, energy efficiency gains have limited the increase in energy use associated with economic growth. The energy intensity is a measure of the energy required per unit of output or activity. At national level the ratio of the energy consumption to GDP is often used as a measure of energy intensity. Falling energy intensity is the main factor behind the flattening of global energy related GHG emissions since 2014 [12]. Lower energy intensity, driven largely by efficiency improvements, is combining with the ongoing shift to renewables and other low emission fuels to offset the impact of GDP growth on emissions.

In addition to the environmental benefits, energy efficiency is bolstering energy security. Efficiency improvements since 2000 avoided additional spending on energy imports in many countries. In Japan, for example, oil imports would have been 20% higher in 2016 and gas imports 23% higher had those efficiency gains not been achieved [9].

In Germany and the United Kingdom, Europe's largest gas markets, energy efficiency improvements resulted in gas savings equivalent to 30% of Europe's total imports from Russia [10].

Efficiency has also improved short-term energy security by reducing peak daily gas demand. Without energy efficiency improvements over the same period, the United Kingdom and France would have needed access to an additional 240 million cubic metres of daily gas supply during periods of peak demand, equivalent to more than five times the daily withdrawal capacity of the United Kingdom's largest gas storage site, in order to maintain current levels of short-term security [10].

Improved energy efficiency has reduced household expenditure on energy. Energy efficiency gains helped households across the world save 10 to 30% of their annual energy spending in 2016. For example, in Germany the amount that consumers spent on energy for their homes and cars in 2016 was nearly USD 580 per capita lower due to energy efficiency. Savings are also being made in large emerging economies, where demand for energy services is growing [13].

Industrial energy efficiency has improved, with use of energy management systems increasing. Energy use per unit of economic output in the industrial sector fell by nearly 20% between 2000 and 2016.
Energy intensity as an indicator of energy efficiency. Changes in global primary energy intensity are influenced by improvements in energy efficiency as well as changes in economic structure, such as the movement of economic activity away from energy intensive industry towards less intensive service sectors [12].

Energy efficiency implementation is increasingly being recognized by policymakers worldwide as one of the most effective means to mitigating rising energy prices, tackling potential environmental risks, and enhancing energy security, mainstreaming its financing in developing country markets continues to be a challenge. Experience shows that converting cost-effective energy savings potential, particularly the demand side improvement opportunities across sectors, into investments face many barriers and unforeseen transaction costs [12].

Energy efficiency provides numerous benefits to companies, including improvements in worker comfort, product quality, overall flexibility and productivity, as well as reductions in maintenance cost, risk, production time and waste.

Energy efficiency measures in buildings are approaches through which the energy consumption can be reduced while maintaining or improving the level of comfort [3]. They can typically be categorized into:

a) Reducing heating demand;
b) Reducing cooling demand;
c) Reducing the energy requirements for ventilation;
d) Reducing energy use for lighting;
e) Reducing energy used for heating water;
f) Reducing electricity consumption of office equipment and appliances;
g) Good housekeeping and people solutions.

2.2.3 Impact of energy efficiency on energy use

The extent to which energy efficiency contributes to changes in final energy use, taking into account a variety of other factors. In the residential sector, the efficiency effect varies depending on end use. For heating, cooling and lighting, it is the energy use per unit of floor area; for cooking and water heating, it is energy use per number of dwellings; and for appliances it is energy use per unit of stock. The efficiency effect constitutes the impact of energy efficiency on final energy use and provides a more accurate reflection of energy efficiency progress [9].

Energy efficiency reduces energy use worldwide Globally, energy efficiency improved 13% between 2000 and 2016. Without this improvement, global final energy uses in 2016 would have been 12% higher equivalent to adding the annual final energy use of the European Union to the global energy market. Energy savings from efficiency improvements in IEA member countries made up nearly half of the global total, equivalent to the current energy use of Germany, France and the United Kingdom combined, with the major emerging economies accounting for around 40% [14].

Energy efficiency has reduced the need for additional primary energy Greenhouse gas emissions savings from energy efficiency improvements; energy efficiency reduces the amount and cost of energy imports; energy efficiency has substantially reduced European gas imports; energy efficiency improves short-term energy security where energy efficiency improvements have also strengthened short-term supply security in Europe by reducing peak daily gas demand [12].

For maintaining the energy efficiency, the World Energy Council has recommended the Energy Efficiency Policy Recommendations which are:

1. Energy prices should reflect real costs and give more incentives to consumers.
2. Consumers should be better informed.
3. Innovative financing tools should be implemented to support consumers' investments.
4. The quality of energy-efficient equipment and services should be controlled.
5. Regulations should be enforced and regularly strengthened.
6.Behavior should be addressed as much as technologies, relying on information and communications technologies.
7. Monitoring achievements is necessary to evaluate the real impact of energy efficiency policies.
8. International and regional cooperation should be enhanced [9].

2.2.4 Development and implementation of Energy Efficiency Policy

The formulation of National Energy Efficiency Policy, National Energy Efficiency Strategy and National Energy Efficiency Action Plan should be developed by the relevant ministry in partnership with relevant stakeholders. Energy efficiency policy is moving from a naive "energy savings" perspective to one that increasingly seeks to uncover diverse consumer and societal outcomes for better understanding. The policy and strategy are owned by the ministry and guides the ministry on what it would like to achieve, how long it will take and what it should do to achieve it. The energy efficiency policy does not have to be exclusive to buildings and can cover energy efficiency in buildings, as well as supply and demand-side management if policies for these do not already exist. The drafting of a law to implement and enact the policy is the only guaranteed means to ensure its application [9].

An Energy Efficiency low will:

a) Establish an energy efficiency agency or bureau and define its functions and powers;
b) Establish or identify a body to facilitate and enforce efficient use of energy;
c) Establish penalties for failure to comply to the energy efficiency standards and set up a body or office with powers to adjudge compliance;
d) Establish an appellate tribunal and appeal framework to hear appeals of those who have been adjudged and penalized [12].

2.2.5 Energy efficiency investment, finance and markets

Millions of consumers and businesses across all sectors of the economy invest in measures that improve energy efficiency. In most cases, energy efficiency is just one of many characteristics of an investment, so the proportion of the investment dedicated to improving efficiency needs to be calculated with reference to the cost of a less efficient alternative. For example, if the price of a less efficient refrigerator is USD 400 and the price of a more efficient equivalent is USD 450, the incremental investment in energy efficiency would be measured as USD 50. It is the sum of these incremental investments that the IEA defines as energy efficiency investment. Broader systemic investment that also affects the energy efficiency of the economy, such as improvements to public transport, is not included in the data. Pure investment in energy efficiency services, for example through energy service companies (ESCOs), makes up a small proportion of the overall market and is a subset of the estimate of incremental investment [15].

In 2016, global investment in energy efficiency increased by 9% to USD 231 billion. This increase coincided with a slowdown in investment on the supply side of the energy system. Energy efficiency investment now represents 13.6% of the USD 1.7 trillion invested across the entire energy market [10].

Over the past three years, energy efficiency investment in the buildings sector increased steadily, growing by 8% in 2015 and 12% in 2016. Only a small share of the spending on new buildings is considered energy efficiency investment, as the majority is considered an autonomous improvement [8]

The largest investment increase was in the lighting sub-sector (light bulbs, luminaires and light fixtures), where incremental investment increased by one-third. The ongoing transition from incandescent and halogen lamps to efficient light bulbs and luminaires, mainly LEDs, has contributed to this growth in global investment. Incremental energy efficiency investment in buildings was USD 133 billion in 2016, one-third of the USD 406 billion in total energy efficiency spending on projects in the sector. Lighting had the highest incremental investment as a share of total energy efficiency spending, with just over 60% [12].

2.3 Energy Management

The aim of energy management is to lower energy costs and bring immediate benefits to an organization or enterprise. Energy management is the structured application of a range of management techniques that enables an organization to identify and implement measures for reducing energy consumption and costs. Energy management activities typically cover: Energy purchasing; metering and billing; performance measurement; energy policy development; energy surveying and auditing; awareness-raising, training and education; capital investment management.

Industrial energy efficiency has improved, with use of energy management systems increasing Energy use per unit of economic output in the industrial sector fell by nearly 20% between 2000 and 2016. The application of energy management systems, which provide a structure to monitor energy consumption and identify opportunities to improve efficiency, is growing, driven by policy and financial incentives. The implementation of energy management systems is a key element of industry energy efficiency policy in many countries. The ISO 50001 standard provides an internationally consistent benchmark for implementation and has aided policy makers by providing a means of verifying compliance. The number of ISO 50001 certifications is an indicator of attitudes towards energy management and the effectiveness of policies in driving uptake [10]. The total number of certificates, globally, grew from 459 in 2011 to 11 985 in 2015. Europe has the largest proportion of certificates of any region, with 85% of the total, see the figure 5. Early evidence suggests that companies that implement ISO 50001 or similar standards can achieve annual energy and financial savings of over 10% and other benefits including improved management of other production inputs [10].

The figure 4 shows the number of certified companies against ISO 50001 up to 2015: Energy Management System while the table 2 shows the number of certified industries based on sub sector [10].

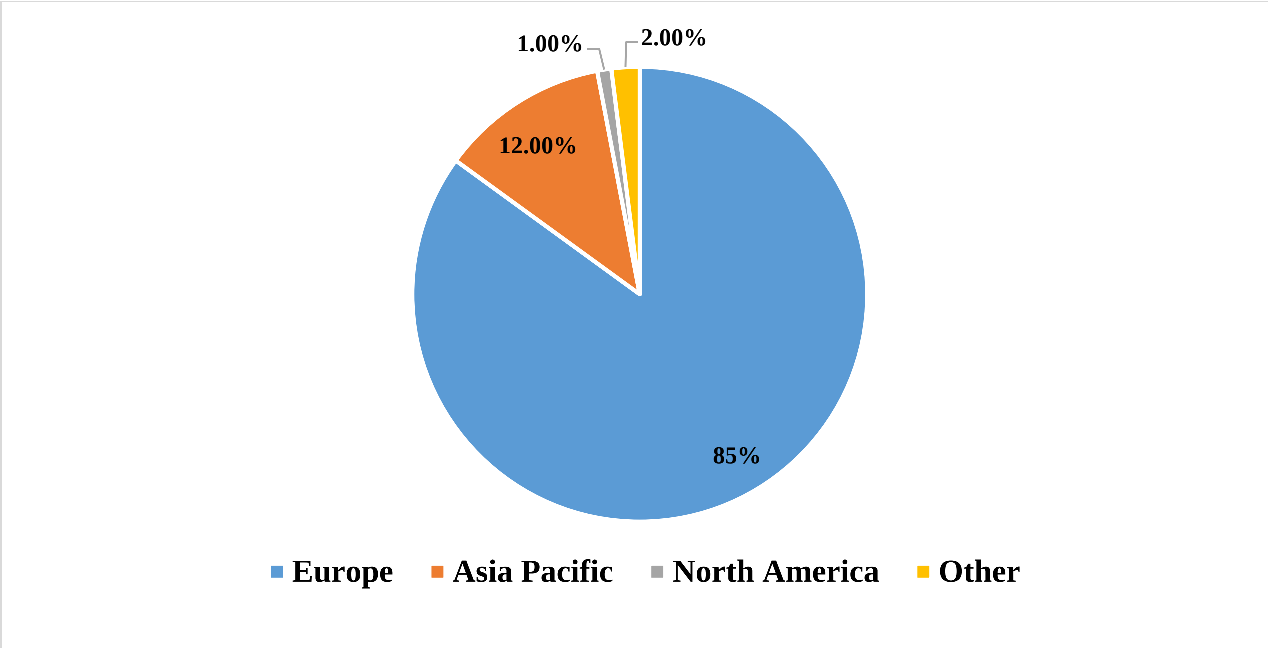

Figure 4:ISO 50001 certificates by region [10].

The verified quarterly energy and cost savings for ten companies across various sectors that participated in the US Superior Energy Performance (SEP) program, including the rate of energy performance improvement before implementation. The verified results confirm the greater than business as usual benefits that companies obtained by implementing ISO 50001. Energy savings in the four quarters before implementation averaged 3.2% of total energy use. This increased to an average of 7.5% in the first four quarters after implementation and 14.2% in quarters five to seven. Similarly, cost savings averaged 3.0% in the four quarters before implementation but increased to 6.3% in the first four quarters after implementation and 12.2% in quarters five to seven [10].

Implementing an energy management system provides several benefits beyond energy and cost savings. These include improvements in staff skills, safety and the management of other production inputs, as well as reduced maintenance costs. Assessing the non-energy benefits of energy efficiency projects greatly enhances the case for implementation.

2.3.1 Energy Demand Side Management

Demand Side Management refers to Actions taken on the customer's side of the meter to change the amount or timing of energy consumption. Electricity DSM strategies have the goal of maximizing end-use efficiency to avoid or postpone the construction of new generating plants [2].

Demand-side management typically used in the specific sense of actions to modify electricity loads to achieve higher system efficiency. Also used to refer to efforts to modify demands for any type of energy e.g. fuel oil, gas, coal so as to improve energy efficiency and reduce energy consumption for a given output [2].

2.3.2 Role and benefits of using energy Demande Side Management

Various reasons are put forward for promoting or undertaking DSM. Some of the following issues are addressed by DSM:

a) Cost reduction: Many DSM and energy efficiency efforts have been introduced in the context of integrated resource planning and aimed at reducing total costs of meeting energy demand;
b) Environmental and social improvement: Energy efficiency and DSM may be pursued to achieve environmental and/or social goals by reducing energy use, leading to reduced greenhouse gas emissions;
c) Reliability and network issues: Ameliorating and/or averting problems in the electricity network through reducing demand in ways which maintain system reliability in the immediate term and over the longer term defer the need for network augmentation;
d) Improved markets: Short-term responses to electricity market conditions ("demand response"), particularly by reducing load during periods of high market prices caused by reduced generation or network capacity [10].

The benefits of DSM to consumers, enterprises, utilities and society can be realized through:

a) Reductions in customer energy bills;
b) Reductions in the need for new power plant, transmission and distribution networks;
c) Stimulation of economic development;
d) Creation of long-term jobs due to new innovations and technologies;
e) Increases in the competitiveness of local enterprises;
f) Reduction in air pollution;
g) Reduced dependency on foreign energy sources;
h) Reductions in peak power prices for electricity.
a) Reliability and network motives [2].

2.3.3 Drives of Demand Side Management

For utility companies, the reduction or shift of a customer's energy demand could mean avoiding or delaying building additional generating capacity. In some situations, this would avoid or defer energy price increases that would otherwise be imposed on customers to help finance new investments in system capacity. For customers, DSM offers the opportunity to reduce their energy bill through efficiency and conservation measures. In the case of industrial customers, this would translate to lower production costs and a more competitive product. For domestic customers it means that they would save money that could be spent on other household commodities [2].

Utilities can therefore be one of the key driving forces behind DSM implementation but energy customers should also be motivated in using energy more efficiently, subsequently reducing their energy demand and thus their energy costs. Consumers may also be able to take advantage of any special incentives offered by utility companies, and may participate in programs offered by the utilities. Organizations with energy dependent activities such as industrial manufacturers and owners/operators of buildings are often strongly interested in DSM, primarily to reduce their own energy consumption and costs, and partly perhaps to assist their local utility to maintain a reliable energy supply. The latter is of course directly in the interests of the energy user [2].

Industrial plants are often able to reduce overall demand by adopting various kinds of energy efficiency measures. Depending on the processes used, many have the flexibility to reschedule their periods of highest demand to cut peak loads and to even out their demand over a longer or different time period, thus helping the utility itself to run at higher efficiency. The investment needed for these actions may be quite low if a simple retiming of operations proves possible. Other measures, such as replacing electric motors with high efficiency versions or installing variable speed drives, will require investments. A financial evaluation of any proposed measure is needed to see where and when the benefits of DSM can be accrued to the industrial enterprise [2].

Provided a reasonable return on investment can be assured, the enterprise management should take prompt action, in some cases with the technical advice of the utility company experts. For building owners or operators, there may be a variety of cost effective measures available. For example, light fixtures can be modified, and heating and cooling systems can be altered from constant-volume to variable-volume drive applications (or indeed replaced entirely by new equipment). Equipment changes and new controls and other instruments, e.g. meters or timers, should also be considered [2]. The driving forces of using DSM are cost reduction and environmental motives and reliability and network motives.

2.3.4 Demande Side Management measures

Most DSM measures are put in place by utilities or by the energy end-users themselves; typically, industrial enterprises. Utilities try to encourage energy users to alter their demand profile, and this is generally accomplished through positive tariff incentives allowing customers to schedule demand activities at a time that will reduce their energy costs. This in turn helps the utilities by moving the demand away from the peak period. In some cases, negative incentives (penalties) are charged for the continued operation of inefficient equipment with unnecessarily high loads: this is intended to encourage customers to upgrade equipment and thereby reduce electrical demand [16].

Industrial enterprises will normally consider a wide range of possible actions to reduce the consumption of all types of energy. A straightforward reduction in energy consumption will normally reduce costs, and a shift of demand to a different time might reduce costs if an appropriate tariff is available. The main measures of DSM activities may be classified in three categories:

a) Energy reduction programs: Reducing demand through more efficient processes, buildings or equipment; by using different program and technology like using energy efficiency equipment, putting in place mechanism of energy using within the building or country like promotion of energy efficiency lamps and application of energy labelling program that will help in reduction of energy demand.
b) Load management programs: Changing the load pattern and encouraging less demand at peak times and peak rates; put in place mechanisms that will encourage people to use more energy during low demand peak hours.
c) Load growth and conservation programs, put in place the programs that can limit the load growth like setting up the minimum energy performance standards that will promote the use of energy efficiency products.

2.4 Energy Performance and Labelling Standards

2.4.1 Overview and development of MEPS and Labelling Standards

Energy performance improvements in consumer products are an essential element in any government's portfolio of energy-efficiency and climate change mitigation programs. Governments need to develop balanced programs, both voluntary and regulatory, that remove cost-ineffective, energy-wasting products from the marketplace and stimulate the development of cost-effective, energy-efficient technology. Energy-efficiency labels and standards for appliances, equipment, and lighting products deserve to be among the first policy tools considered by a country's energy policy makers.

Worldwide, the use of energy in human activities related to buildings, including the use of appliances, equipment, and lighting, accounts for 34% of total energy consumption. Energy consumption also contributes about 25 to 30% of energy-related CO_2 emissions, accounting for 19 to 22% of all anthropogenic CO_2 emissions and 10 to 12% of our net contribution to climate change from all greenhouse gases [12].

Energy Efficiency Standards and Labels (S&L) are complementary policy tools that are instrumental in promoting a sustainable energy path, in all economies. They are meant to help the market recognize energy efficiency and act on it. Without the information provided by labels, consumers and other end users are often unable to make an informed decision about the true cost of a product, and manufacturers lack the incentive to improve the energy performance of it as there is no way for the market to recognize and value this aspect. Standards can be set to ensure that obsolete and inefficient technology does not continue to dominate the market, much more effectively than is possible by the actions of individual end users [17].

Minimum Energy Performance, Energy Efficiency Standards and Labels (EE S&L) are sets of procedures and regulations that, respectively, prescribe the minimum energy performance of manufactured products and the informative labels on these indicating products' energy performance and efficiency in a way that allows for comparison between similar products or endorses the products' use. MEPS, EE&L for appliances, equipment, and lighting offer a huge opportunity to improve energy efficiency and are especially effective as an energy policy [17].

Energy efficiency labels are informative labels that are affixed to manufactured products and describe a product's energy performance (usually in the form of energy use, efficiency, or energy cost) to provide consumers with the data necessary for making informed purchases [18]. Energy efficiency standards are procedures and regulations that prescribe the energy performance of manufactured products, sometimes prohibiting the sale of products that are less energy efficient than the minimum standard. There are three types of energy-efficiency standards which are prescriptive standards, minimum energy performance standards (MEPS), and class-average standards [19].

Standards shift the distribution of energy efficient models of products sold in the market upward by eliminating the least efficient models and establishing a baseline for programs that provide incentives for "beating the standard. Labels shift the distribution of energy efficient models upward by providing information that assists consumers in making rational decisions and stimulating manufacturers to design products that achieve higher ratings than the minimum standard [19].

The effect of well-designed energy efficiency labels and standards is to reduce unnecessary electricity and fuel consumption by household and office equipment. Well designed, mandatory energy efficiency standards remove inefficient products from the marketplace, increasing the overall economic welfare of most consumers without seriously limiting their choice of products. Energy labels empower consumers to make informed choices about the products they buy and to manage their energy bills. Labels and standards are appropriate for most cultures and marketplaces; therefore, the energy efficiency labels and standards deserve to be the cornerstone of any country's balanced portfolio of energy policies and programs [12]. The figure 5 shows the impact of energy efficiency labels and standards on marketplace.

The implementation of Energy Performance and Labelling Standards empower the following to the country:

a. Energy Performance and Labelling Standards reduce the required capital investment in energy supply infrastructure
b. Energy Performance and Labelling Standards improve national economic efficiency by reducing energy bills
c. Energy Performance and Labelling Standards improve consumer welfare
d. Energy Performance and Labelling Standards reinforce competitive markets
e. Labels and Standards meet climate change goals

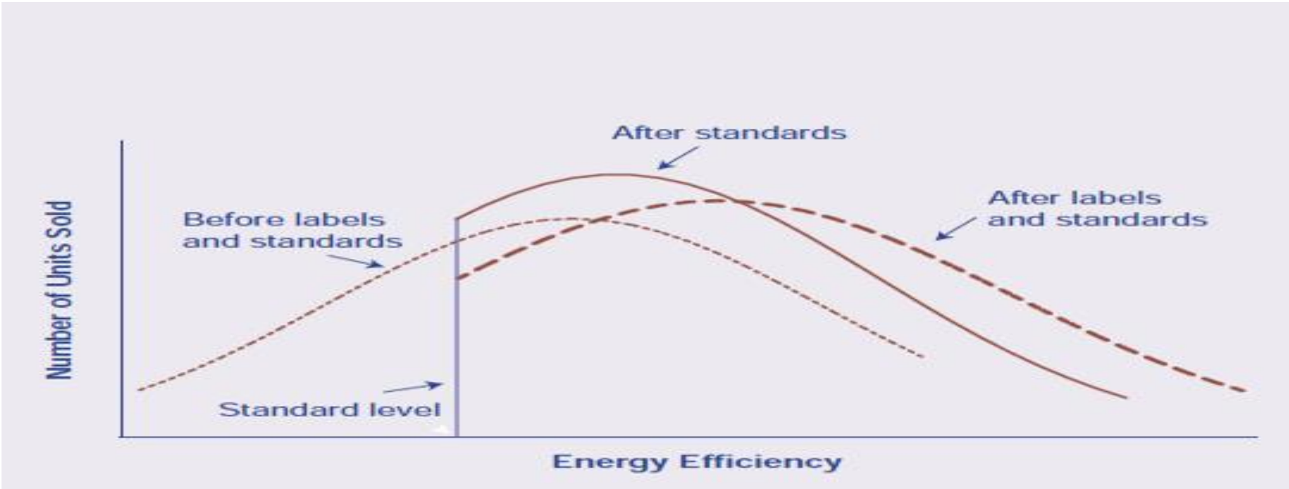

Figure 5:The impact of energy efficiency labels and standards on the distribution of products in the marketplace [19].

Labelling and minimum efficiency standards for appliances and equipment have confirmed to be one of the most favorable policy instruments. Labelling and minimum efficiency standards used for many years in different IEA Member countries, they brought tangible results. They are amongst the cheapest and least intrusive of policies. Energy efficiency standards and labelling programs, while they are designed to help rather than disturb competition, can be effective in promising the development, marketing and sale of energy efficient products. They can also re enforce other policies to encourage the use of energy efficient products and equipments [20].

Standards and labels are commonly designed to increase energy efficiency without degrading the other features of the products such quality, performance, safety as well as overall cost. Improvement of energy efficiency at the end consumer level is progressively very important as Climate Change commitments force the policy makers to find the areas where the reduction of greenhouse gas emissions can be achieved [8].

Labelling programs are intended to change the selection criteria of consumers by drawing their consideration to the energy consumption of household appliances. Energy labels provide information to consumers which empowers them to compare the energy efficiency of the different appliances on the market.

Performance Standards aim the improvement of the energy efficiency for new appliances either by imposing MEPS to eliminate the least efficient products from the market or by demanding sales of weighted average energy efficiency improvements.

Labelling and MEPS programme have the following advantages compared to other energy efficiency measures:

a) Produce very large energy savings and even though it requires time for S&L programmes to start yielding large energy savings, once they are implemented, they tend to be sustainable due to long term lifetime of the appliances.
b) Has the potential benefits of being cost effective way of reducing energy demand without impacting on or reducing economic growth.
c) Requires change in the behaviour of some manufacturer companies instead of the entire consuming public.
d) As stakeholders are required to comply with the laws and regulations, this program ensures that all actors involved in the scheme across the value chain are treated in the same way.
e) Assuming compliance, the energy savings are assured, simple to quantify and easily verified.
f) Contribute considerably towards alleviating the country's electricity deficit over the medium to long term.
g) Reduce capital investments in energy generation plants.
h) Improve national economic productivity through higher efficiency.

Setting up the Energy Performance and Labelling Standards within the country, the following shall be taken into account [13]:

a. **Engineering analysis:** Engineering analysis assesses the energy performance of products currently being purchased in the country and establishes the technical feasibility and cost of each technology option that might improve a product's energy efficiency as well as evaluating its impact on overall product performance.
b. **National impact analysis:** National impact analysis assesses the societal costs and benefits of any proposed standard; the impacts on gas and electric utilities that would result from reduced energy consumption; and the environmental effects in terms of changes in emissions of pollutants such as carbon dioxide, sulfur oxides, and nitrogen oxides that would occur in residential and commercial buildings and power plants as a result of reduced energy consumption.

c. **Consumer analysis:** Consumer analysis establishes the economic impacts on individual consumers of any standard being considered, including increased equipment prices and reduced operating expenses.

d. **Manufacturing analysis:** Manufacturing analysis predicts the impact of any standard being considered on international and domestic manufacturers and their suppliers and importers. It assesses the resulting profitability, growth, and competitiveness of the industry and predicts changes in employment.

Standards levels to comply with should be assessed based on national conditions and should incorporate factors such as the use environment, user habits, the technological and financial states of affected manufacturers, and the projected impact on the national level of economy. Standards for efficiency naturally eliminate the least efficient models on the market. Labelling complements MEPS by ensuring that ratings are visible and easy for consumers to understand.

Energy performance test procedures are the single most important factor of any successful S&L programme as they are the tools for measuring and comparing energy performance. Although there are many institutions which develop test procedures and standards many are focused at a country or a regional level due to the large market size and unique conditions. The two primary international standards bodies are the International Organization for Standardization (ISO) and the International Electro Technical Commission (IEC). Membership for both bodies is made up with national standards bodies and participants from these institutions participate in the development of the international standards, currently, 164 countries are members of ISO and 86 countries are members of IEC and one country can be member of both ISO and IEC. Many countries use IEC or ISO standards for energy performance directly in their implementation of labelling and standards programmes, others adopt national versions of the international standards, by which may or may not have some variations, other adopt them and also make use of other preferred national or international standard [13].

2.4.2 Illustration of samples of existing labelling

2.4.2.1 Energy Star

The Energy Star is a voluntary programme, developed by the United State Environmental Protection Agency (EPA), that helps consumers to reduce their energy costs and protect the environment. The

Energy Star certifies products (appliances, electronics, office equipment, building products, etc.), commercial buildings, industrial plants, as well as new and existing buildings. EPA ensures that each product / building / industrial plant granted with the Energy Star label is independently certified to deliver the quality, performance, and savings that the consumer expects [18].

2.4.2.2 EU Energy labelling Scheme

The EU Energy Labelling framework uses a classification (rating) system. A product is classified from A (best energy performance) to G (inefficient), figure 8 illustrated EU labelling scheme and figure 9 illustrated different other labelling scheme used in different countries, Rwanda is in process of setting up the energy labelling system and the labels will be published by end of December 2019 [18].

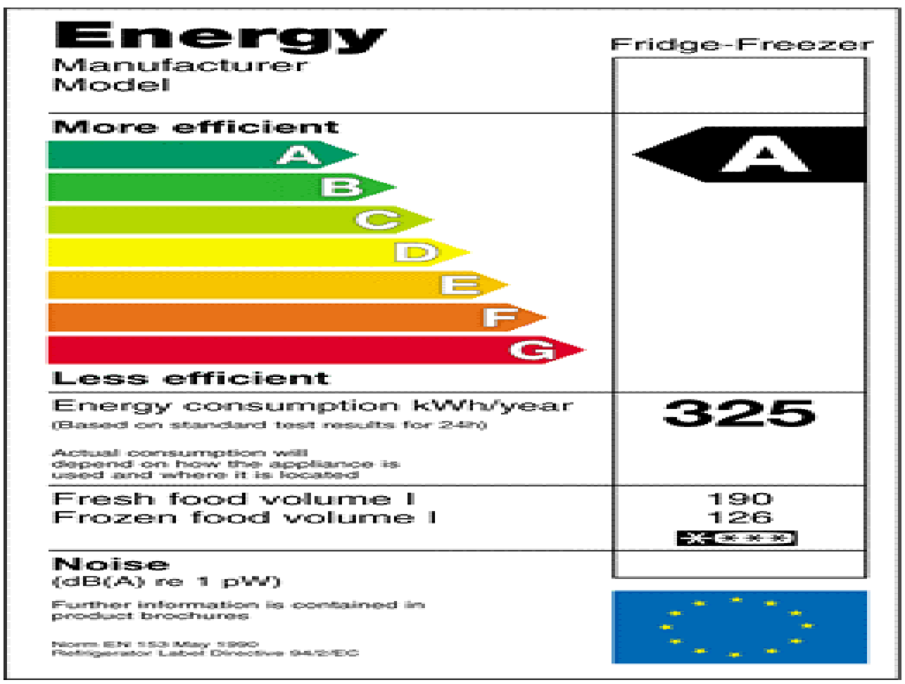

Figure 6:EU labelling [18]

Figure 7: Labelling symbols around the world [18]

2.5 Energy sector in Rwanda

2.5.1 Generation

Sufficient, reliable and affordable energy supply is critical to country's economic transformation. The government of Rwanda adopted and implements sound, comprehensive national energy policy and plans to include the energy sector strategy that takes into account dynamic factors such as, economic and population growth, natural resource limitations and dispersed settlement configurations. Currently, the biomass energy is the most important energy consumed in Rwanda at rate of 85% as shown in figure 8 [6]. About 92% of the biomass energy generated is consumed by households, with the remaining consumption shared between industry (4%), non-energy usage (2%) and commercial and the public sector (both 1%) as shown in figure 9. Based on energy consumption rate, households are considered as the largest category of energy consumer, at 82%, with transport at 8%, industries at 6% and others at 4% as shown in figure 10 [6].

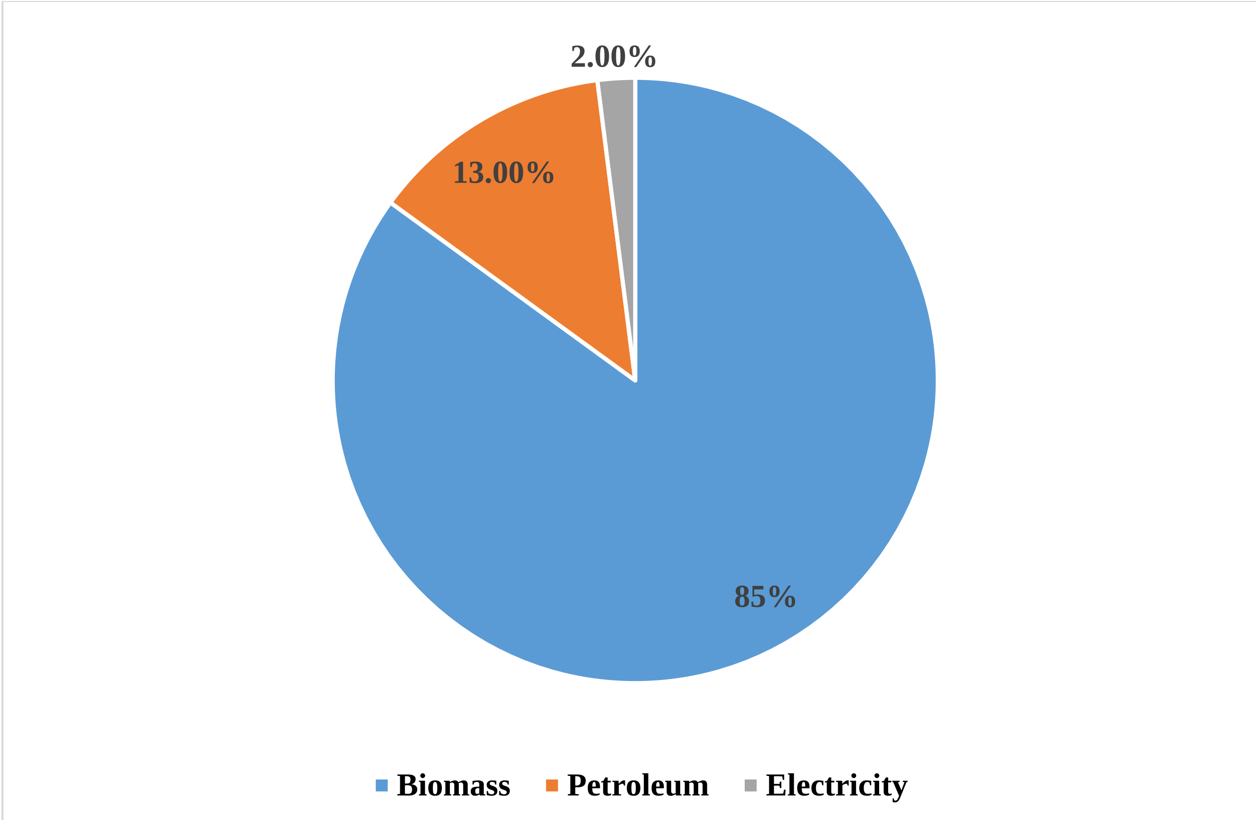

Figure 8:Energy consumption by energy sector [6].

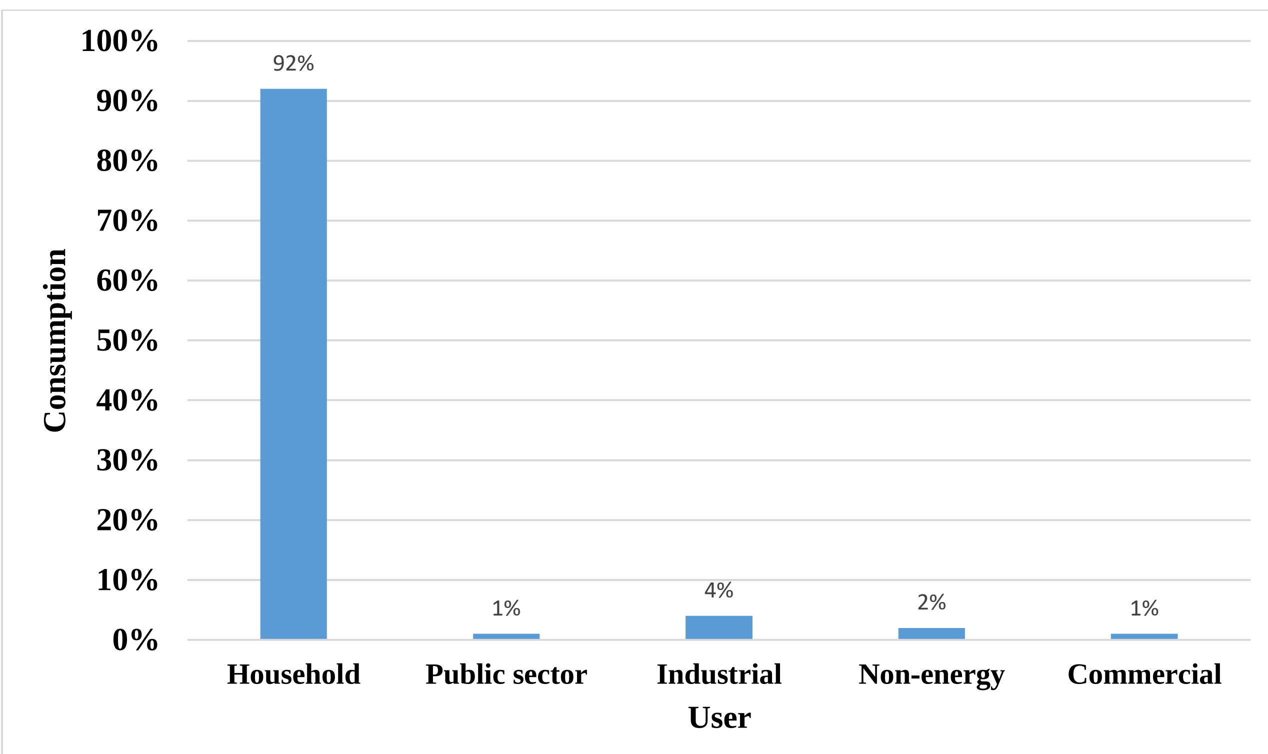

Figure 9: Biomass consumption by user category (2016) [6].

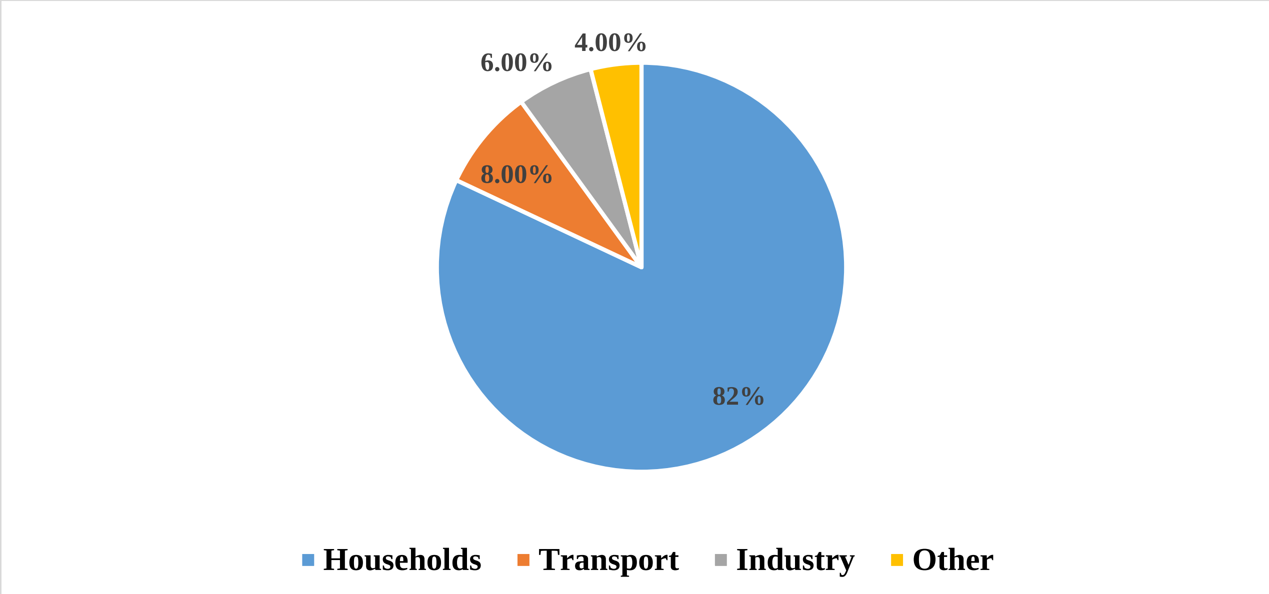

Figure 10: Energy consumption per user category [5]

While production of electricity in Rwanda has increased and stabilized since the severe power shortages happened in 2004, generation capacity is still low; currently the production is estimated at 221.1 MW of existing installed capacity with target of having installed capacity of 556MW in 2024. The figure 11 shows how the evolution of electricity production from 1994 to 2019 [21].

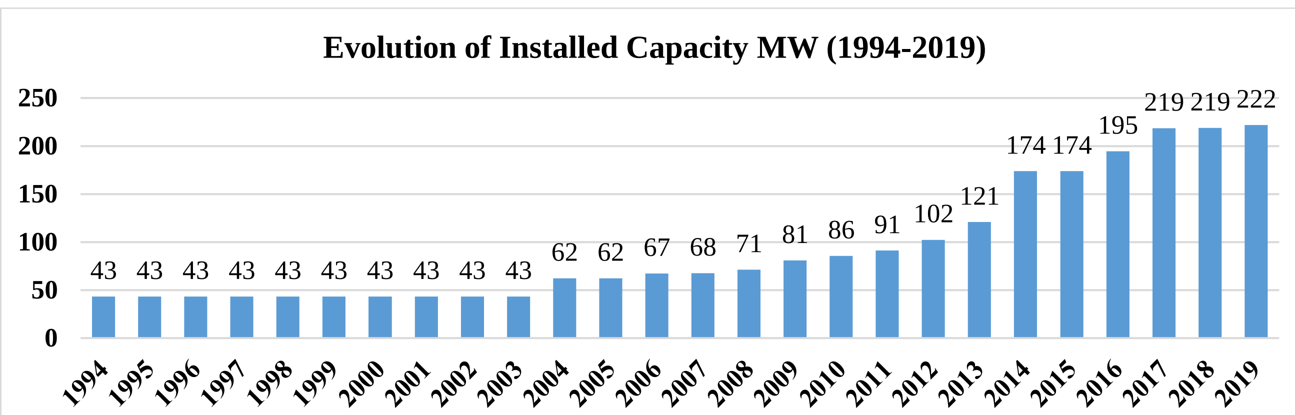

Figure 11:Evolution of installed electricity generation capacity [21]

In Rwanda, different sources of energy such as hydro, solar, peat, methane gas, heavy fuel and light fuel oil used to run thermal power plants and another portion is imported to generate electricity. The installed capacity of 100.6MW for Hydro; 12.4MW from Solar;58.8MW from Thermal;29.6MW from Methane; 15.0MW from Peat and 5.5 MW from import as shown in figure 12. In cumulative, the generated electricity from renewable resources is more greater than the generated electricity from non-renewables with share of 53% renewables sources [21].

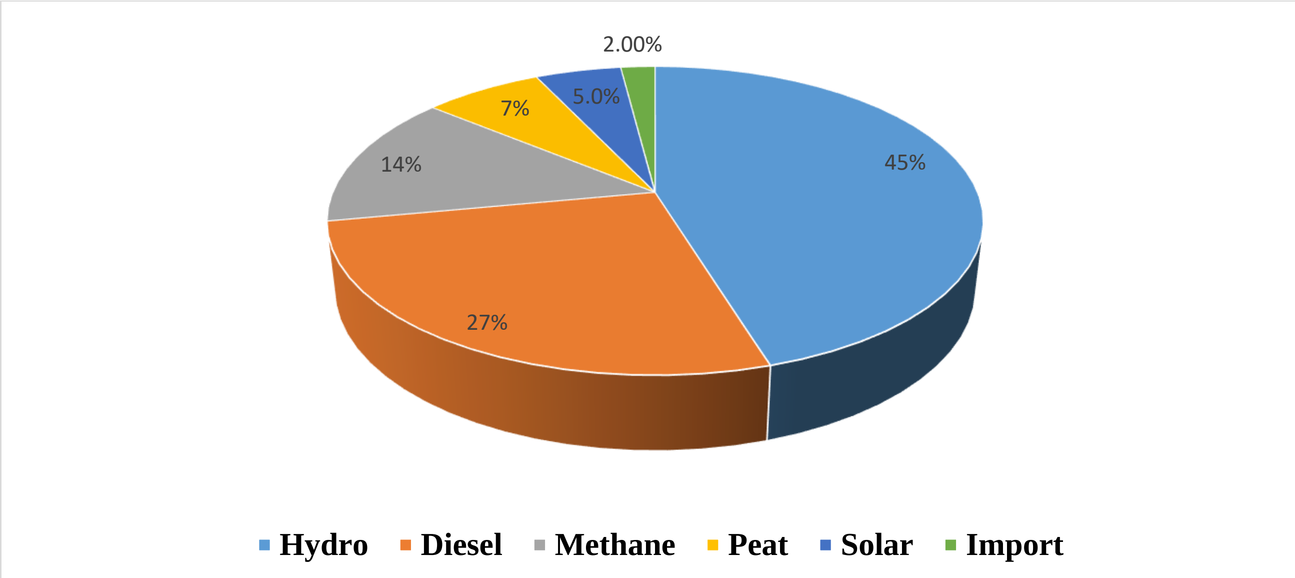

Figure 12:Power generation mix [21].

2.5.2 Access

As June 2019, the transmission lines including 220kV and 110kV has reached to 1,139.62km, representing 33% increase from 854.3km in 2016/17. Of the total transmission network laid, 425.1km are of 220Kv network while 714.5km are for 110 kV transmission infrastructure with access rate of 38% of households connected to the grid and 13% of households (see figure 13) for off grid and Country target is to have total access of 100 % (52% grid connected and 48% off grid) in 2024 [21].

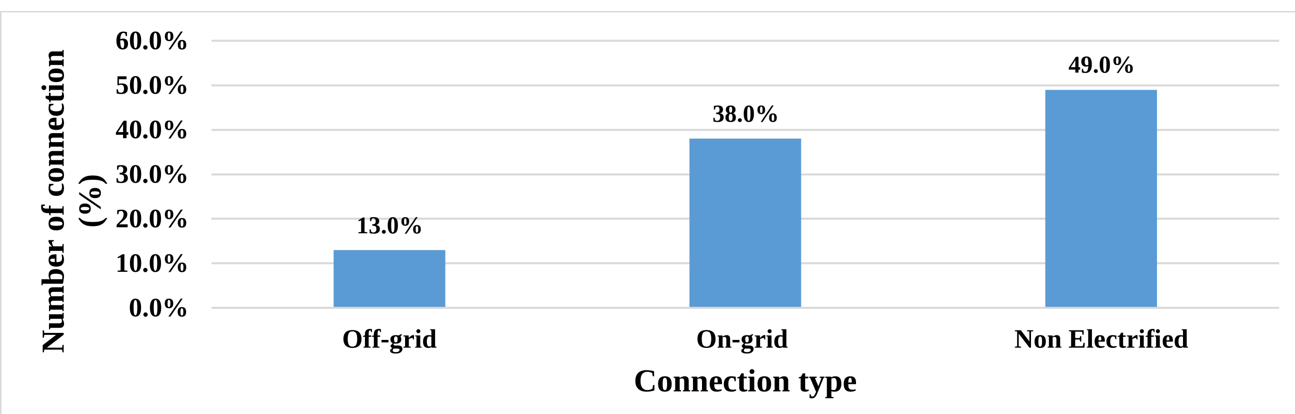

Figure 13: Access to electricity [21].

2.5.3 Power losses

All electricity systems incur losses. Losses refers to electricity transmitted and distributed by the transmission and distribution grids that is not paid for by end users. Total losses consist of two categories:

1. **Technical losses** caused mainly by electricity dissipation in system components such as conductors, transformers, transmission and distribution lines and measurement equipments. Every material has a resistance which opposes to flow of electric current, so energy is consumed in the form of heat. In other words, we can say that technical losses are occurred due to the internal resistance of conductors and other equipment.
2. **Non-technical losses (Commercial losses)** caused mainly by errors in record-keeping, theft, accounting and non-payment by end users. This loss normally happened due to metering errors, inaccurate meters, tempering of meters, improper meter reading, ignorance of meter readers, illegal power usage and poor administration. The main point for non-technical loss is that it affects the other quality of power. Meter tempering or bypass metering is very common in the distribution system that is the main part of the non-technical loss.

Power losses in Rwanda have been reducing, from 25% in 2003 to 19.82% in 2017/2018 as given in figure 18, REG still considers these losses high and has taken clear actions to reduce at least 1% loss per year, which will lead to the strategic target of 15% losses by 2024 [22].

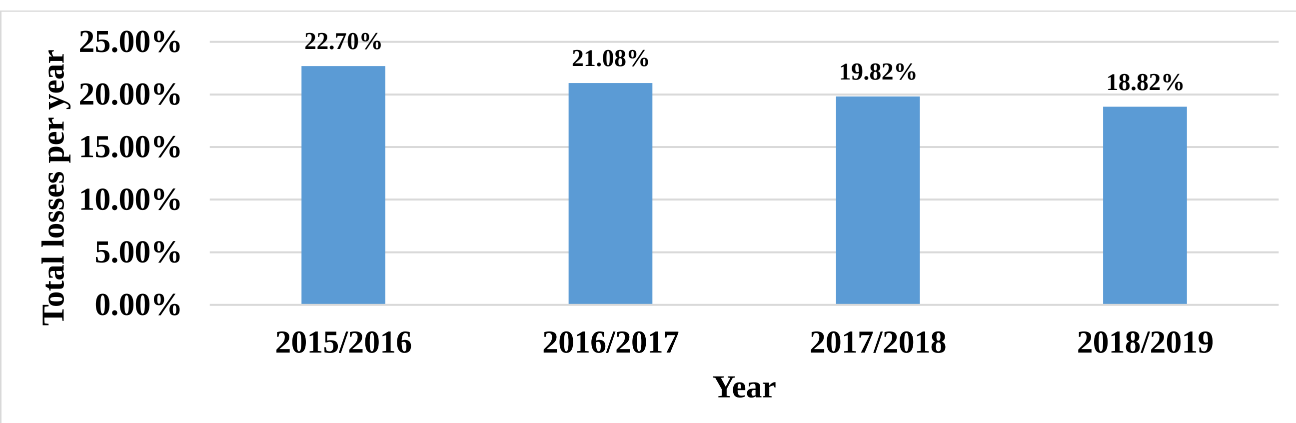

Figure 14:Reduction of power losses [22].

2.5.4 Regulatory framework and standards

To ensure reliability, sufficient, sustainability, efficiency and more affordability power supply. The following measures were taken:

a. Revised and upgraded the energy policy, regulatory, legal, institutional and financial frameworks to support the rapid growth of the electricity industry in the country;
b. Energy Policy, Rural Electrification Strategy, Energy Sector Strategic Plan, Energy Efficiency Strategy were developed and published, currently are under implementation.
c. Diversify power generation resources over time and increase the share of clean power in the total mix over time;
d. Ensure supply is closely aligned to projected demand, and better align plan for investment and mobilization of funding more closely to a power generation road map and master plan, put in place a least-cost power development plan, and action plan for electricity sub-sector;
e. Boost regional cooperation and trade in electricity energy, such as investment in development of transmission network with target of improving security of energy supply;
f. Rwanda Standards Board has adopted different IEC and ISO Standards related to energy efficiency, labelling and energy performance;
g. Restructure IPP processes and fast track project delivery by securing long-term funding for planned projects, through revising and expanding the existing Renewable Energy Feed-In Tariff regime, medium-term budget expenditure framework, develop the information management systems to update procedures, and building better capacity in procurement, planning and negotiating power transactions [21].

Other initiatives are currently under development and those include:

a. Energy law which combine renewable energy and energy efficiency
b. Minimum Energy Performance and Labelling Standards Strategy
c. Biomass Energy Strategy
d. Energy Efficiency and data management strategy
e. Setting testing facilities and development of standards for enforcement of energy efficiency requirements.

The Energy Sector Strategy Plan for 2018-2024 was developed with the following objectives:

a. Generation capacity increased to ensure that all demand is met and a 15% reserve margin is maintained.
b. Reliability of electricity supply improved: average number of power interruptions per year reduced to 14.2 and average number of hours without power to 91.7.
c. Household access to electricity increased to 100%.
d. Productive user access to electricity increased to 100%.
e. Existing, New major national and urban roads provided with street lighting.
f. Losses in the transmission, distribution networks and commercial reduced to 15%.
g. Reduce the number of HH using traditional cooking technologies to attain a sustainable balance between supply and biomass demand by promoting the best energy efficient technologies
h. Petroleum strategic reserves increased to cover three months' supply [6].

CHAPTER THREE: EFFICIENCY USE OF ENERGY IN BUILDING IN RWANDA

3.1 Introduction

The main energy-using systems related to buildings are building envelope elements, heating, air conditioning equipment, ventilation and energy-consuming appliances and devices including lighting equipment. Their efficiency can be improved by implementing different various measures including switching to energy efficient equipment. Another tool for improving energy efficiency is by applying load management technologies.

With consideration of the current rate of urbanization and consequently the increase in energy demand, energy efficiency has a momentous role to play in promoting the energy security measures within the country. The government should share the load and the cost of warranting the security of supply with the end consumers through energy efficiency considering the increasing cost of complexity of new energy sources and the escalating cost of energy.

Improvements of the technology in building design and appliances deliver new opportunities for energy savings. The cost of implementing energy savings and resistance to change and accommodate new technologies requires to set up policy and regulatory framework in order to achieve the changes. The limitation to the access on information related to energy consumption trends in buildings as well as opportunities and potential for energy savings is a major barrier [24].

The building stock includes, commercial, residential, public and institutional structures. Opportunities to decrease energy requirements over energy efficiency and passive renewable energy within the buildings include building materials, cooling, building design, heating, appliances and lighting.

Commercial buildings include a wide diversity of building types which include the hospitals, offices, schools, places of worship, police stations, libraries, warehouses, shopping malls, hotels, etc. These different commercial activities have unique energy needs and in deed the commercial buildings use more than half their energy for cooling, heating and lighting.

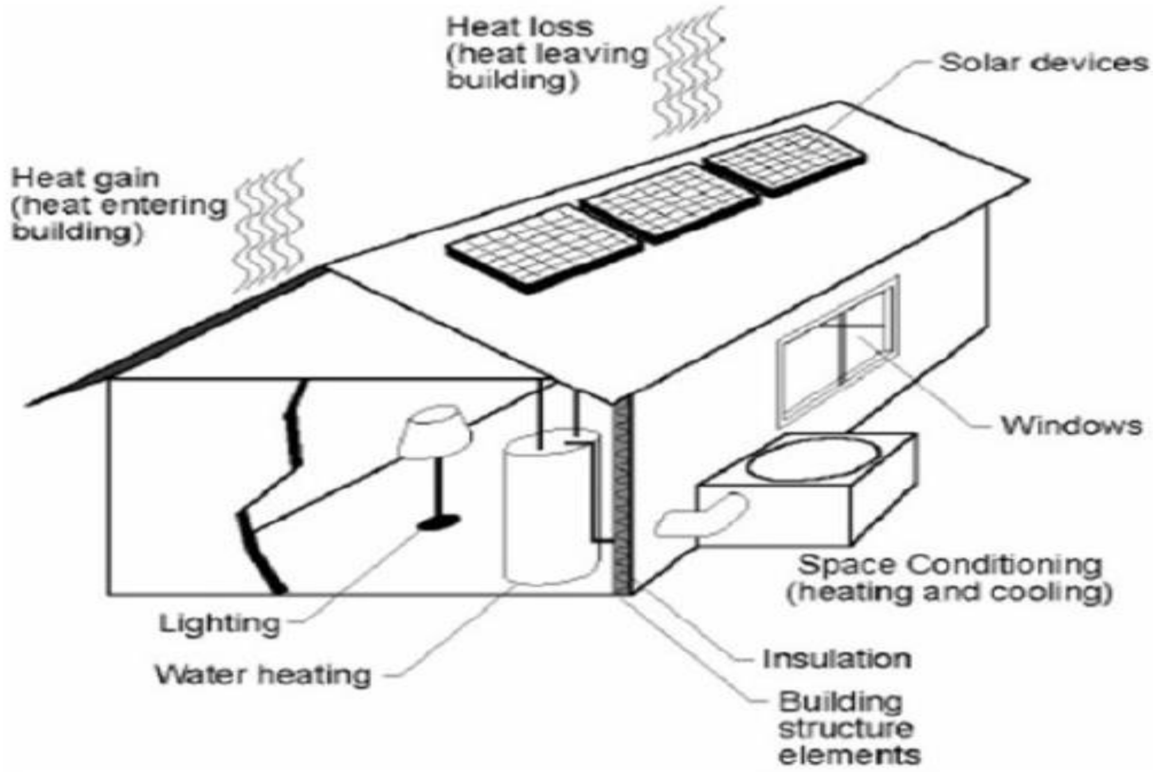

Figure 15: Types of energy use related to buildings [24].

Energy efficiency in buildings means utilizing the smallest amount of energy for cooling and heating equipment and lighting in order to maintain comfort conditions in a building. An important factor that affects the energy efficiency is the building structure and how energy is used. The structure includes all building elements between the exterior and the interior of the building like: windows, walls, doors, foundations and roof (see figure 17) [20].

Energy audits can be conducted as a useful way of determining how energy efficient in the building is and what improvements can be made to enhance efficiency. Tests should be undertaken to ensure that the heating, cooling, equipment and lighting all work together effectively and efficiently.

3.2 Building structure for energy efficiency use

Building structure refer to the thermal integrity of the building and contain the type and materials of construction of the shell, insulation as well as the types of doors and windows. The way all these materials are used affects the degree level at which heat loss or heat gain is gathered.

Insulation means made out of synthetic fibers decreases heating and cooling loads by fighting against the heat transfer through walls, floors and ceilings [24]. Storm doors and windows are fixed over existing windows and doors to generate an insulating air space that decreases heat loss through the glass. Infiltration and Indoor Air Quality Control where air infiltration is the uncontrolled leakage of air into or out of a building, through ceilings, walls, cracks, floors, and so on. It is due to the differences in temperature and pressure between the outside and inside of a building produced by natural convection, wind as well as other forces [24].

A passive solar design is done by assembling the primarily non-mechanically driven architectural components which translate solar energy into usable heat. In winter, heat obtained through windows and walls when the sun is shining is kept in masonry and/or water for being released during the night while in summer, roof overhangs and landscape structures limit heat gain, and vents disperse unsolicited heat. The best solar design is the one that maximizes heat gain in the winter and in the summer it minimizes heat gain and that results in minimizing the total cost of providing heating and cooling in building during its lifespan.

3.3 Electricity consumption in buildings

In Rwanda, buildings (nonresidential and residential) are the largest consumer of electricity in Rwanda. The 30.4% of electricity supplied by EUCL in the first quarter of the year 2019 were sold to nonresidential customers, 29.4% to industries, and 17.7% to residential customers and the remaining 22.5% were sold to water pumping station, water treatment plan, telecom towers, health facilities, broadcasters, and hotels [23].

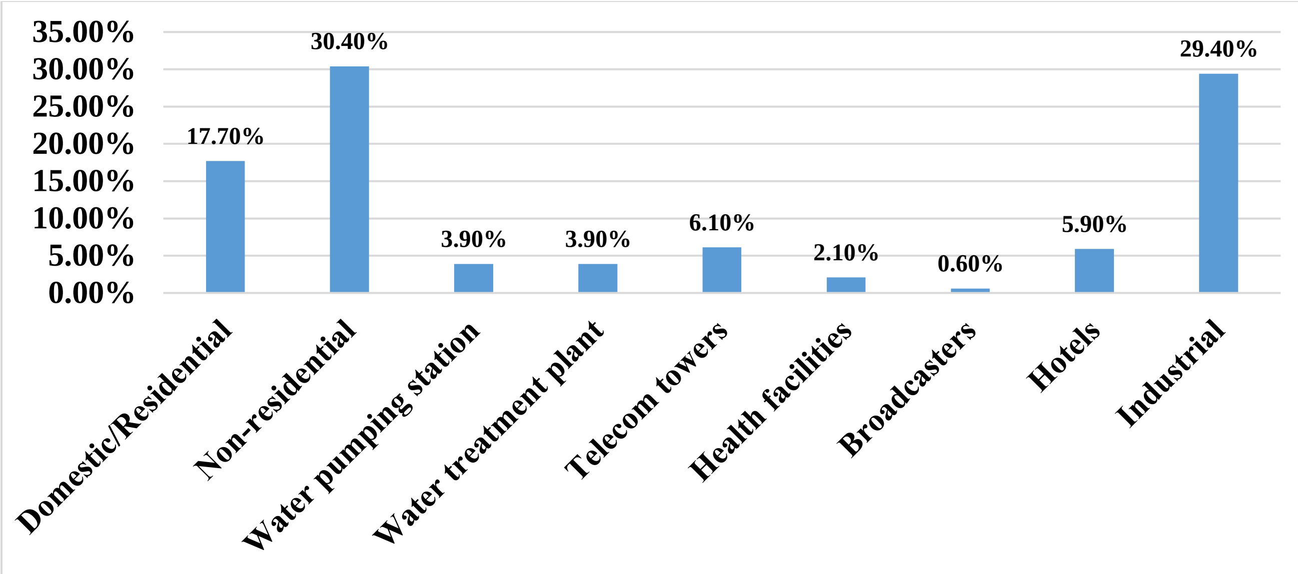

Figure 16: Electricity sold(kWh) per type of customers as of March 2019 [23].

The electricity consumed is billed based on tariff as published by RURA and that tariff has different categories as indicated in table 1 for Tariffs for non –industrial customer category but the tariff used to be reviewed every six months, the new tariff replaced the one of June 2018.

Table 1: Tariffs for non-residential customer category [23].

Category	**Consumption block per month(kWh)**	**Frw/kWh(VAT & Regulatory fee exclusive)**
Residential	]0 – 15]	89
	]15 – 50]	182
	>50	210
Non residential	]0 – 100]	204
	>100	222
Telecom towers	All	185
Water treatment plants & Water pumping stations	All	126
Hotels	All	126
Health facilitations	All	192
Broadcasters	All	184

Based on the RURA Statistics, the table 2 and table 3 shown the number of residential consumers per electricity consumption blocks and electricity consumption of residential consumers per block respectively where the biggest number is in the first block that consume electricity below 15kWh.

Table 2: Number of residential consumers per electricity consumption block [Source: REG/EUCL]

Period	**0-15] kWh**	**]15-50] kWh**	**>50 kWh**
Jan-18	414,651	172,496	40,504
Feb-18	405,487	158,417	35,058
Mar-18	424,325	166,441	38,579
Apr-18	421,048	165,280	37,900
May-18	429,966	166,219	38,329
Jun-18	433,109	166,545	38,521
Jul-18	440,062	168,425	39,936
Aug-18	587,294	236,508	55,438
Sep-18	444,034	166,135	38,823
Oct-18	450,882	168,421	40,388
Nov-18	453,439	169,575	40,381
Dec-18	474,235	180,175	44,532
Number of consumers	5,378,532	2,084,637	488,389
Total number of consumers			7,951,558

Table 3: Electricity of residential consumers per block[Source: REG/EUCL]

Period	0-15] kWh	]15-50] kWh	>50 kWh
Jan-18	4,192,391.70	2,845,189.30	2,504,888.20
Feb-18	3,988,729.40	2,492,172.70	2,165,746.10
Mar-18	4,168,459.60	2,690,091.80	2,611,954.20
Apr-18	4,115,736.70	2,667,611.80	2,475,123.60
May-18	4,174,988.70	2,682,229.50	2,618,352.60
Jun-18	4,191,613.30	2,679,133.20	2,510,861.80
Jul-18	4,242,764.60	2,750,274.20	2,692,452.00
Aug-18	4,368,591.30	2,862,790.60	2,749,493.70
Sep-18	4,222,937.30	2,673,012.30	2,476,973.60
Oct-18	4,272,972.10	2,753,580.60	2,678,919.20
Nov-18	4,292,600.50	2,770,201.60	2,672,360.00
Dec-18	4,514,394.80	3,022,602.90	2,868,282.60
Total electricity consumption (kWh/year)/Block	50,746,180.00	32,888,890.50	31,025,407.60
Total annual consumption(kWh/year)			114,660,478.10

3.4 Building services

Samples taken on audits conducted in REG Headquarter, MININFRA, RDB to analyze energy consumption in public buildings and implementation of energy efficiency principles. Energy used is electrical energy and all electricity in Rwanda is supplied by the local supply network in the City of Kigali. The supply is done either by three-phase electricity or two-phase electricity in normal buildings at 240 volts. The billing is based on an electricity consumed and is measured by pre-paid meter called cash power which are installed on the building.

The primary categories of load in the assessed buildings include lighting, plug load (computers, printers, monitor, portable appliances) and air conditioning. The primary load in the REG building, excluding the data center, is plug load Peak load in the building is estimated to be 87 kW including the data center and 31 kW excluding the data center. The REG HQ is not equipped with any mechanical ventilation systems; offices are equipped with air conditions units and the plug load is the primary user of electricity energy at 41%% [25]. Most light fixtures in the REG HQ Building are surface-mounted strip fixtures equipped with 3' LED fixtures estimated to be rated at about 25 watts each. Lights in the hallways and about 75% of the offices used to be switched operating during the day and the lighting load is mainly estimated based lighting in the offices and found to contribute about 7.3 kW to the building's peak load and 17,519 kWh annually to energy consumption. The figure 19,20 and 21 shows the summary of energy end use in REG HQ% [25].

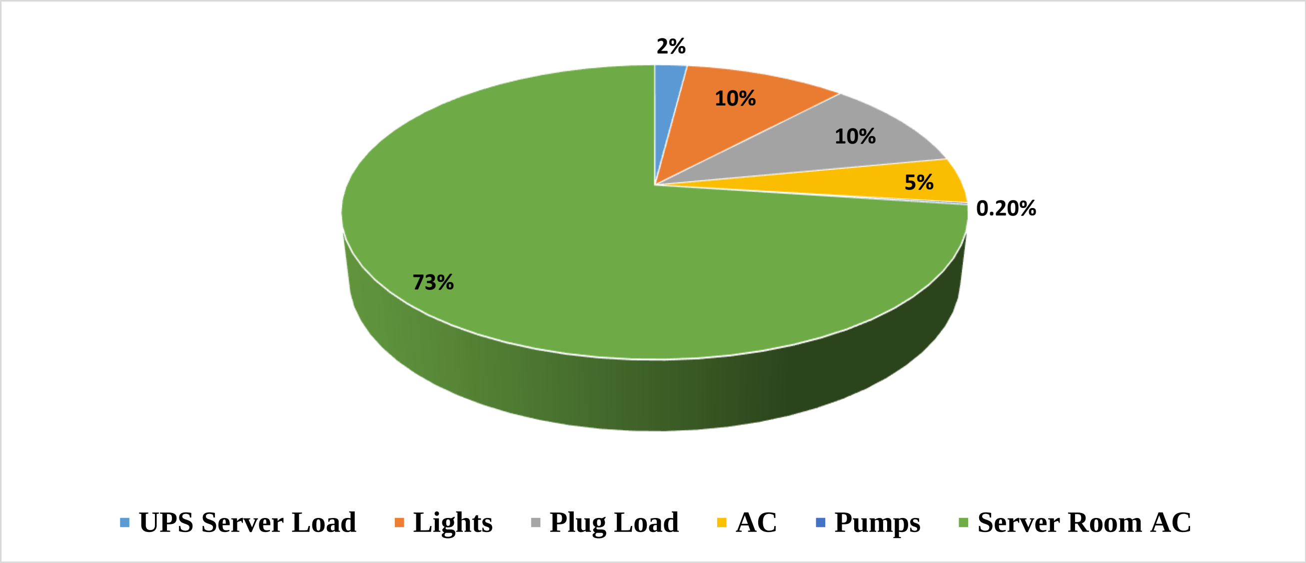

Figure 17: Electricity end use including data center% [25].

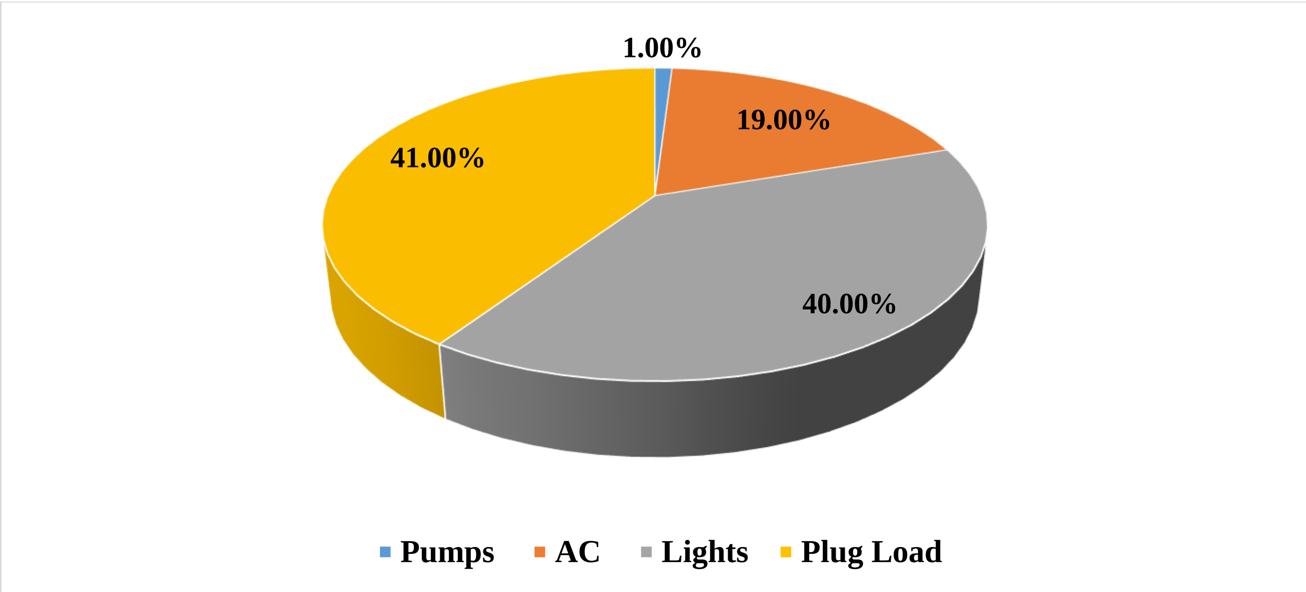

Figure 18: Electricity end use excluding data center [25].

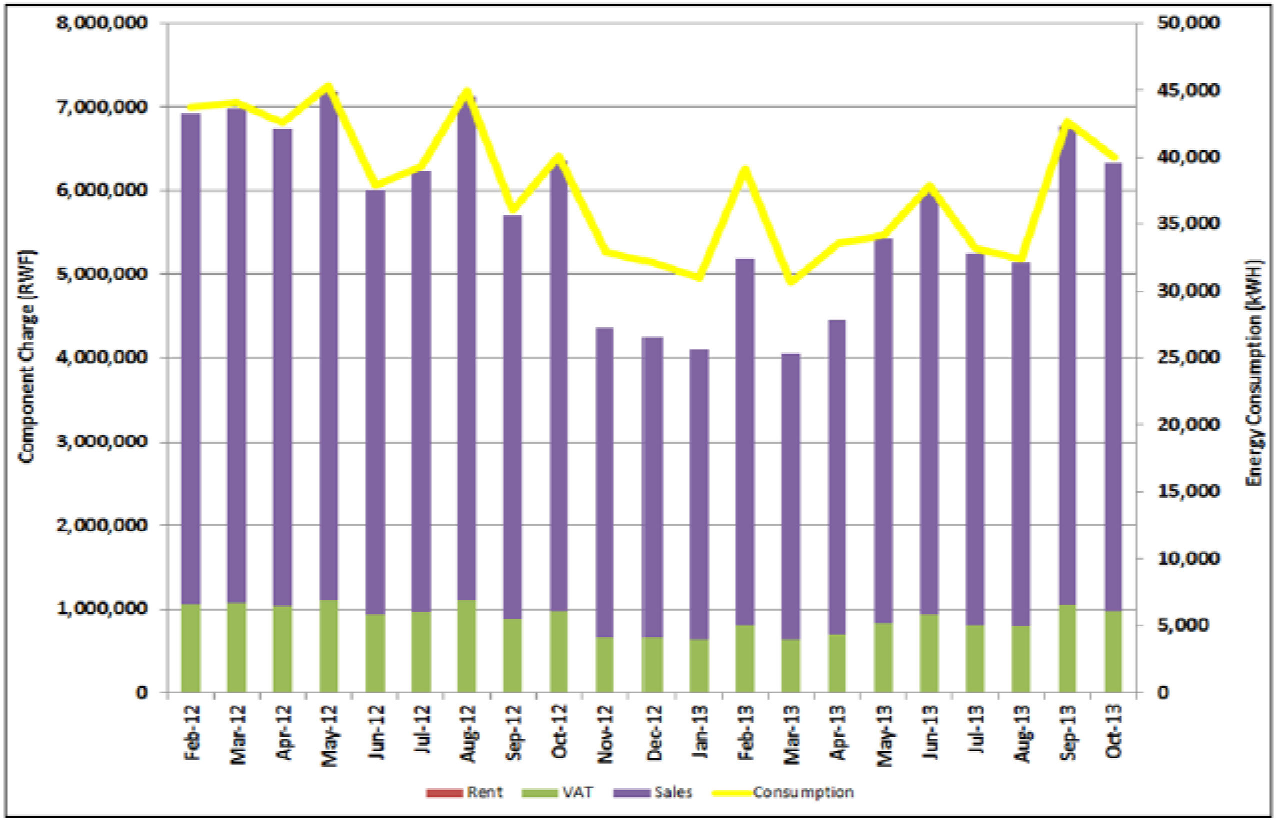

Figure 19: REG HQ Building utility billing history[25].

The energy end use for the Ministry of Infrastructure building is categorized as energy used for: Lights, Plug load, lifts, AC and pumps with the following distribution: Lights:4%; Plug load: 74%; Lifts:15%; AC:6% and Pumps:0.5%. The primary load in the MININFRA building is plug load peak load in the building estimated to be 68640 kWh. The figure 22 and 23 shows the summary of energy end use in MININFRA building.

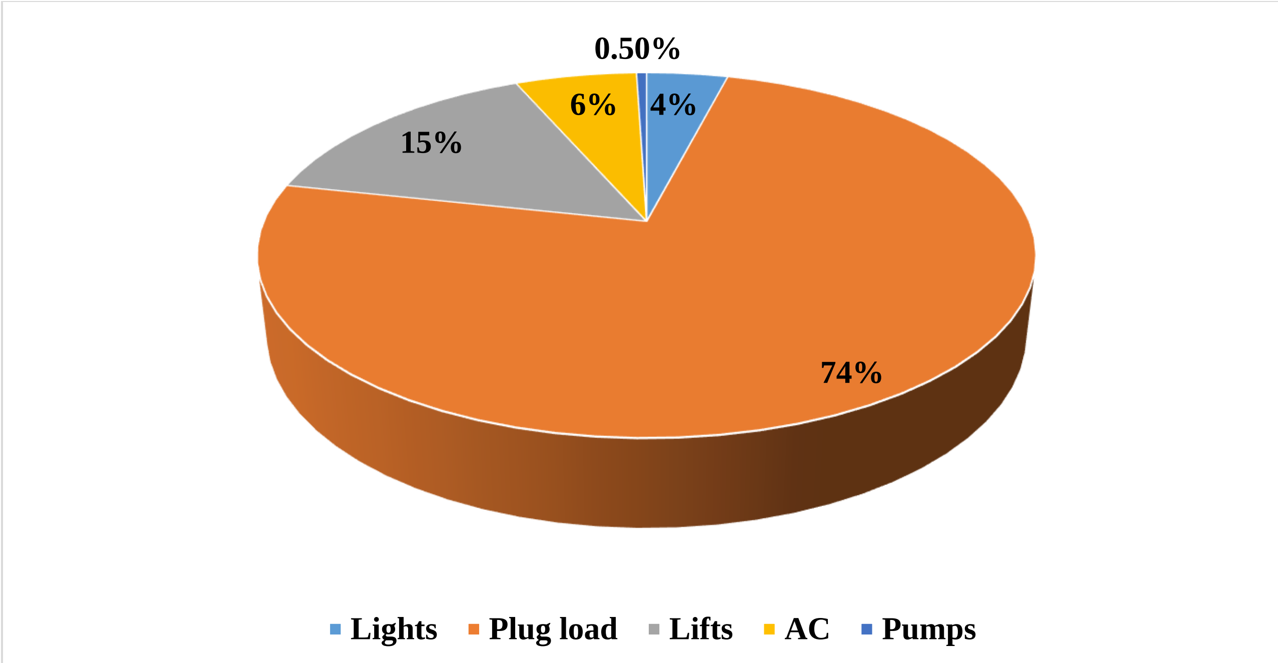

Figure 20: Electricity end use in MININFRA Building [26]

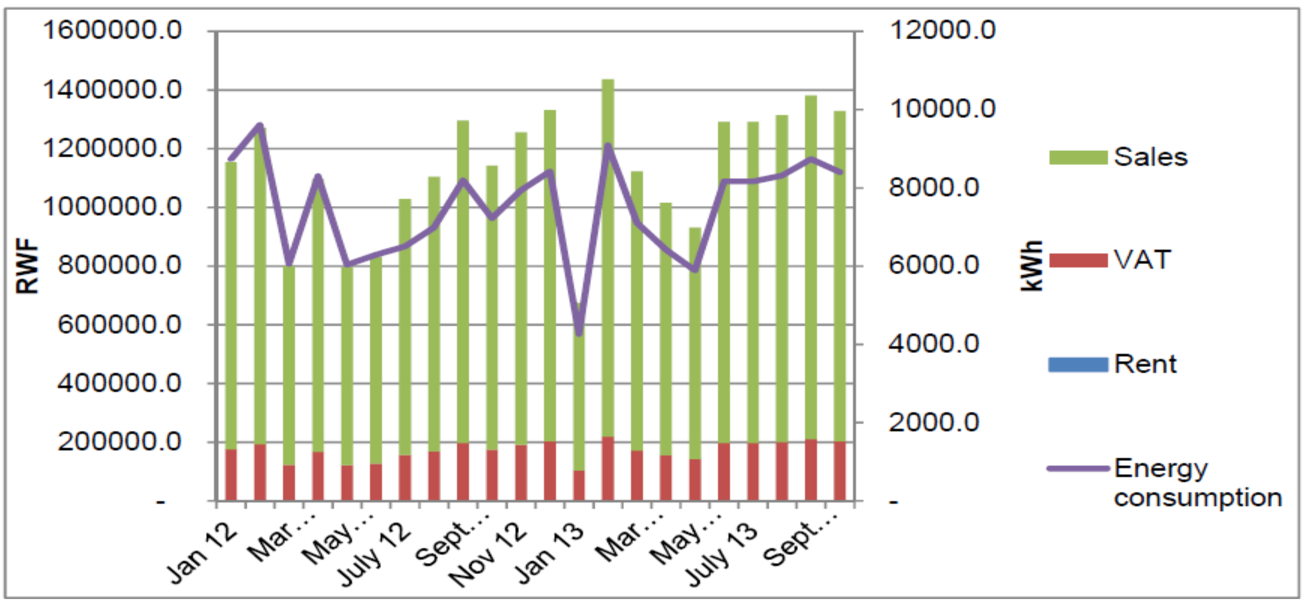

Figure 21: MININFRA building utility billing history [26]

Energy end use for the RDB building is categorized as energy for lighting, pumping, elevator, plug and load. The main consumer is plug and load, the distribution of consumption is as in the table below, with pumps:1%; AC:0.5%; Elevetor:6%; Internal lighting:56%; Plug load:36% and other (external lighting, scanners, etc.): 0.5%. The figure 24 and 25 shows the summary of energy end use in RDB building.

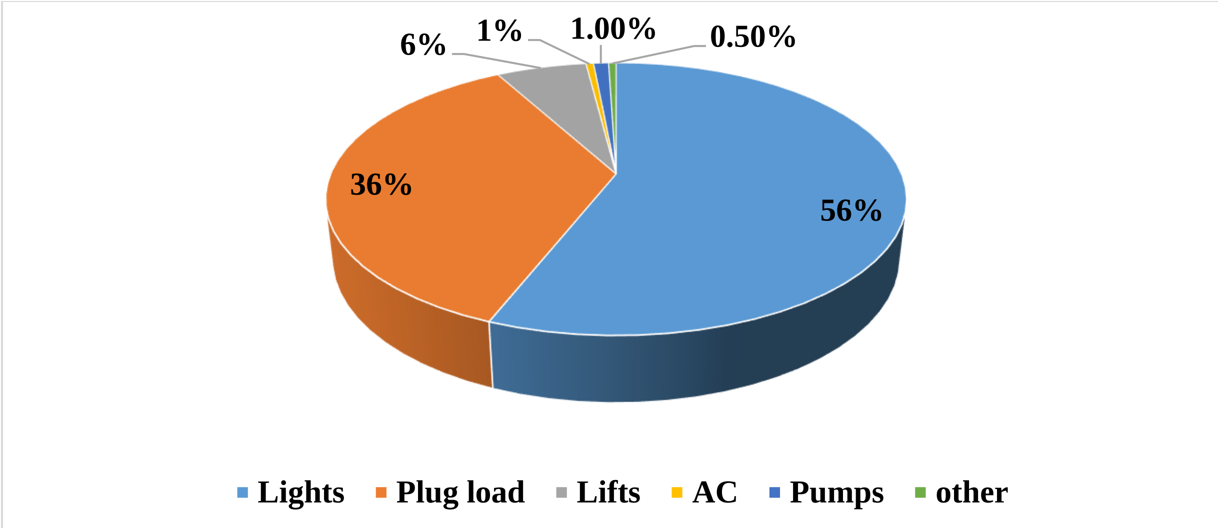

Figure 22: Electricity end use in RDB building [27]

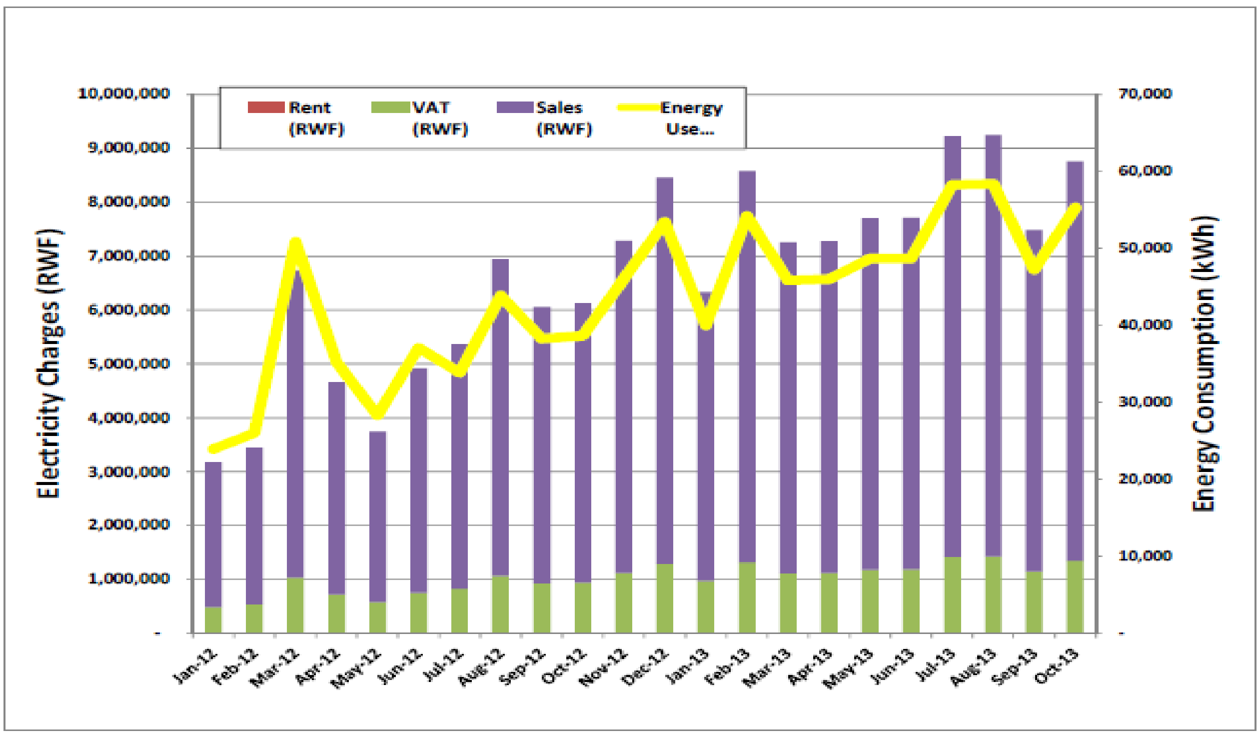

Figure 23: RDB building utility billing history [27]

3.5 Electricity energy user analysis

The REG Headquarters Building has an estimated energy intensity of about 250 kWh/m^2/year, including the server room computers and AC, which consume 96 kWh/m^2/year. Excluding the server room, as an office building, the REG Headquarters has extremely low energy intensity when compared to a range of energy intensity for buildings in the US at 200 kWh/m^2/year to 300 kWh/m^2/year [25].

The low energy intensity is attributable to the fact that almost no part of the building has any mechanical ventilation, spaces are rarely mechanically air-conditioned, and many of the perimeter light fixtures are turned off during the day. Excluding the data center, the primary energy efficiency opportunities for existing equipment in the building are retrofitting of the existing fluorescent lighting fixtures and retrofitting inefficient AC units.

The Ministry of Infrastructure Building is not equipped with any mechanical ventilation systems, and AC is limited to the few offices equipped with room AC units. 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 floors. Air flow from one floor to another is limited, as the two staircases are fully enclosed.

The Ministry of Infrastructure Building has an annual consumption of about 37 kWh/m^2/year, which is an extremely low energy intensity when compared to a range of energy intensity for buildings in the US at 200 to 300 kWh/m^2/year [26]. The low energy intensity is attributable to the fact that almost all of the Ministry of Infrastructure Building is without mechanical ventilation, spaces are not mechanically air-conditioned, few offices equipped with room AC units and few of the light fixtures are turned on during the day. The primary EE opportunities for existing equipment in the in the building are the retrofitting of existing fluorescent lighting fixtures and the removal of inefficient AC units.

The RDB building is not equipped with any mechanical ventilation systems and has almost no air conditioning except for a few computer server 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. Most office spaces are open plan with transparent glass wall partitions separating adjacent office areas from each other and corridors. 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.

At about 64 kWh/ m^2/year, the RDB 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 [27]. The low energy intensity is attributable to the fact that almost all of the RDB 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 existing fluorescent fixtures in the office areas, excluding the server room for REG HQ, are equipped with a single T8 lamp and magnetic ballasts with a total rating of about 42 watts including ballast losses. The existing 3' fluorescent fixtures could be upgraded, but the reduction in energy use compared to the investment is not attractive.

The office spaces, which all contain at least one window, receive a fair amount of daylight, and occupants often do not feel the need to turn on the lights as a result. The areas which could benefit from additional daylight include the hallways and the lobby on the ground floor. One way to improve this situation could be to separate offices from the hallway using transparent partitions. While this might not be desirable in individual offices where a higher level of privacy is required, this could be implemented in shared offices.

Considering the relatively dry climate of Kigali and the moderate temperatures, the need for cooling is limited. Assuming that cooling needs to be turned on when the outside temperature reaches 28°C, the total cooling degree day value per year in Kigali is 12°C. Consequently, it is feasible to avoid any air conditioning in office buildings if good passive ventilation strategies are used.

All office spaces are enclosed. and the small doors connecting them to the hallway on each floor do not allow air to flow from one side of the building to the other. To improve daylighting, limiting the amount of partitions between the offices or using movable partitions (or windows in interior walls) would improve air circulation and that will reduce the consumption of AC units.

The data center air condition system is the largest source of energy consumption in the REG HQ Building and represents an excellent opportunity to improve energy efficiency. Although the history of the data center is not clear, it seems that it was built on an ad-hoc basis as REG HQ transitioned from an operating model that relied on hand-written documentation to a more modern, data-driven model for customer and operations management. The facility was not purposely built for computing operations and the air conditioning was also installed in an ad hoc manner.

CHAPTER FOUR: KEY FINDINGS, RECOMMENDATIONS AND CONCLUSION

4.1 Key findings

Lighting systems exist in many differing configurations including recessed, surface mounted and suspended luminaires. Although luminaires types may be similar within a building, the type of lamps and ballasts used, lamp quantity and lensing may be different. Exterior lighting is provided primarily by a mixture of compact fluorescent and HID luminaires as well as incandescent light sources to a lesser extent. Exit signage is provided by single and double-faced rectangular exit signs. With the exception of a few units, all exit signs utilize LED lamps which are considered the most energy efficient lamps for this application.

Overall, lighting levels throughout the buildings vary from being slightly lower to slightly higher than acceptable for the tasks performed. Lighting level ranges differ from building to building; dependent upon lighting system in use, luminaire condition and lighting layout or pattern.

The fluorescent luminaires represent approximately 70% of the buildings‟ lighting energy demand and 60% of the lighting consumption. The greatest energy savings with regards to the lighting systems can be achieved by reducing the energy consumed by the fluorescent luminaires. The existing fluorescent lighting systems currently present three main measures for reducing energy usage: retrofit remaining T12 luminaires with more efficient T8 lamp and electronic ballast technology. New development in both fluorescent lamps and ballasts are continuously emerging in the marketplace. These include energy saving T8 lamps and high efficiency electronic ballasts – both of which can be directly retrofitted into the existing fluorescent lighting systems.

Incandescent lamps are considered inefficient and require frequent replacement because of short lamp life. Newer lighting technology such as compact fluorescent lamps can provide similar light output while drawing a fraction of the power as their incandescent counterparts. In areas where luminaires are controlled by dimmer switches it is not recommended to use compact fluorescent lamps. Dimmable ballasts can be installed in these luminaires but, due to the ballasts high costs and the lamps inability to operate at low dimmer settings they are not cost effective as a retrofit. The exit corridor fitted with normal lamps working 24 hours per day while using lamps with occupancy sensors.

Integrating automated controls into a lighting system can result in reduced energy consumption, and increase maintenance savings by extending in-service life of lamps and ballasts. Several options were considered for the lighting systems on this campus. These include occupancy sensors, daylight sensors and timer systems. Occupancy sensors are effective tools for reducing a lighting system hours as they help in ensuring that lights are on only when the lighting spaces are occupied. The sensors are working automatically by turn off lights when a space is not in use, and can be set to turn on lights when an occupant is sensed.

For public buildings, lighting programmable controller to switch "On" and "Off" in evening to prevent lights remain on during the night. We recommend reprogramming the control system so that lighting on and off times coincide more closely with hours of use in the building.

Increasing more awareness campaign focused on low energy use in buildings and the sustainability in young generation by targeting the schools, colleges and universities would be the best way of moving in the right direction, as it will open the minds of future generations for being more economic and environmentally friendly in terms of energy efficiency.

The energy management should be one of the building communication program. The program can consider for example, the encouragement of staff to shut off lights as well as to shut off the computer monitors and copiers while are not in use and also to shut off computers at the end of the day. Awareness on the costs for running plug load equipment and the environmental benefits of reducing energy use may encourage participation. Training casual operating staff, security and cleaners on the costs and benefits of energy management can deliver another means of energy performance improvement. The staff must be challenged and rewarded for any actions done towards the improvement of the building performance. In addition, increasing awareness for all building users of the relationship between energy use and the environment can raise better use of energy in the buildings.

The understanding of energy use in buildings requires having information on the amounts of energy and different fuels consumed by various end consumers. These data are very useful to determine the potential effects of energy efficiency improvements. Minimum Performance and labelling Standards needed to be considered while designing any installation in order to maximize energy efficiency and reduce the losses within installation as well as in transmission and distribution of electrical energy. The consideration of energy efficiency before maximizing the impact of renewable energy technology is very imperative.

The energy efficiency in a building may be influenced by the way any building was constructed and space within the building is exploited. In order to maximize energy efficiency within a building, heat losses within the building compound should be kept to a minimum level as much as possible. In order to minimize the use of electrical energy, the buildings must be designed and constructed in manner to allow outside natural lighting and ventilation enter within the building. For the purpose of rating the energy performance in buildings, it is very important to have in place a strategy for defining energy efficiency in building for successful rating. The defined strategy should consider the means and criteria of selecting the energy budget for energy efficient in building as well as criteria to evaluate the level of low energy, the absolute and relative energy efficiency. The compliance with energy management standards is still a handicap and more awareness is important tool to enhance implementation of energy efficiency measures in building sector.

4.2 Conclusion

With the increasing rate of urbanization in Rwanda and leading to the increase in energy demand, energy efficiency has a very important role to play in promotion of energy security. With the increase of cost for new energy sources and the escalating cost of energy, governments needs to share the burden and cost of ensuring security of supply with end users through energy efficiency.

The improvement of technology in building design, plan and appliances provide new opportunities for energy savings. Resistance to change and the cost of implementing energy savings means that unless a policy and regulatory framework is set up, there is unlikely to be any change. The lack of information on energy consumption trends in buildings and the opportunities and potential for energy savings is a significant barrier. Policy development should be consultative and involve all key stakeholders from different association in building sector such as architectural, developers, energy consultants, local authorities, electricity supply and distribution companies and any other energy service providers. There is a need of creation of a suitable institutional framework to implement policy.

Demand Side Management is an important tool that enabling a more efficient use of the energy resources existing to a country. The DSM can offer significant economic improvement and environmental benefits. Housekeeping and preventive maintenance are simple and cost-effective ways to minimize energy demand and improve other benefits such as the process improvement. It is therefore very imperative to market DSM program in order to show potential customers in energy use their daily life cycle benefits and the techniques and measures frequently quite simple for reducing energy demand.

Energy Efficiency Standards and Labelling are key instruments for promoting energy efficiency program, particularly in relation to lighting products, household appliances, automobiles industry and other mass-production consumer and commercial energy-using equipment and machinery. To guarantee effective implementation of energy efficiency requires the development and formulation of an energy efficiency policies and the performing of a strong legal and institutional framework as well as energy efficiency data management.

To promote energy efficiency in building, the following should be addressed:

a) The long term commitment of the Government for promotion of energy efficiency in building sector;
b) In order to have clear picture on what progress being made to improve energy efficiency in buildings, there is a need to carry out a better end-use analysis in the sector;
c) Certification program needs to be developed and implemented in parallel with effective campaigns to the wider public in order to inform them on the energy efficiency benefits in terms of economy and savings;
d) Commitment of the Government to promote implementation of energy management, minimum performance and labelling standards as well as testing facilities for conformity assessment.

4.3 Recommendations

This study can be considered as a starting point to more detailed research in the development of energy efficient in buildings. As technologies continue to improve from day to day, there is always opportunity for improvement, the research could be further extended to examine the impact on energy efficiency. When considering best practice with regard to energy efficiency data, indicators and monitoring, it is important to distinguish between the different reasons for monitoring energy efficiency:

a) individual firms and organizations may monitor the efficiency with which they use energy as part of an institution-wide energy management system, or to inform their reporting against corporate social responsibility targets;
b) monitoring may be undertaken by firms, government bodies or donors at the level of an individual energy efficiency measure, project or programme, with the purpose of determining the success of the particular intervention; at the sectoral and economy-wide level, monitoring of energy efficiency is necessary for assessing the effectiveness of an overall strategic or policy environment, and for informing the policy-making process.

The Government to promote the use of occupancy sensors and/or lighting programmable controller in order to minimize energy used for lighting within buildings

The Government in collaboration with stakeholders in energy sector to conduct more awareness campaign focused on low energy use in buildings.

References

[1] I. E. Agency, "Market Report Series:Energy efficiency 2018," International Energy Agency, 2018.

[2] IT Power of the United of Kingdom, Sustainable Energy Regulation and Policymaking for Africa, UNIDO, 2006.

[3] Bill Prindle and Maggie Eldridge and Mike Eckhardt and Alyssa Frederick, "The Twin Pillars of Sustainable Energy: Synergies between Energy Efficiency and Renewable Energy Technology and Policy," American Council for an Energy-Efficient Economy (ACEEE), Washington, DC 20036, May 2007.

[4] MININFRA, "Energy Efficiency Strategy," MININFRA, Kigali, 2017.

[5] MININFRA, "Infrastructure sector annual report for Fiscal Year 2017/18," MININFRA, Kigali, 2018.

[6] MININFRA, "Rwanda Energy Sector Strategic Plan 2018/19 -2023/24," MININFRA, Kigali, 2018.

[7] REN21, "Renewables 2018 Global Status Report," REN21 Secretariat, Paris, 2018.

[8] I. E. Agency, "World Energy Outlook 2018," International Energy Agency, 2018, 2018.

[9] W. E. Council, "World Energy Resources 2016," World Energy Council, London, 2016.

[10] I. E. Agency, "Energy Efficiency 2017,Market report series," IEA, 2017.

[11] G. E. &. S. R. 2017, "International Energy Agency," International Energy Agency, 2017.

[12] I. E. Agency, "The Energy Efficiency Indicators: Essentials for Policy Making," IEA, 2016.

[13] A. Allouhi, Y. El Fouih, T. Kousksou, A. Jamil, Y. Zeraouli and Y. Mourad, "Energy consumption and efficiency in buildings: Current status and future trends," J. Clean. Prod., 2015.

[14] W. E. Council, "World energy issue monitor 2018," World Energy Council, 2018.

[15] I. E. Agency, "International Energy Outlook 2017," EIA, U.S.Energy Information Administration, 2017.

[16] REN21, "Renewables 2017, Global Status report," REN21, 2017.

[17] A.-J. P.-M.-L. d. l. C.-F. A. A.-B. a. F.-A. Carmen de la Cruz-Lovera, "Worldwide Research on Energy Efficiency and Sustainability in Public Buildings," 28 July 2017.

[18] MININFRA, "Appliance Energy Labelling and Minimum Energy Performance Standards," MININFRA, Kigali, 2018.

[19] D. Morgando, Energy Efficiency Standards and Labellings(S&L), PEC University of Technology, Chandigarh, 2014.

[20] I. E. Agency, "Energy Labels and Standards," International Energy Agency , 2014.

[21] MININFRA, "Least Cost Power Development Plan," MININFRA, Kigali, 2019.

[22] R. E. G. (REG), "Annual Performance Report 2017-2018," Rwanda Energy Group, Kigali, 2018.

[23] c. w. gellings, Efficient use and conservation of energy in buildings, electric power research institute (epri), usa, 2018.

[24] R. U. R. A. (RURA), "Statistics in Electricity Sub-Sector as of March 2019," Rwanda Utility Regulatory Authority (RURA), Kigali, 2019.

[25] ECONOLER, "Energy Audit Report-REG HQ Building," ECONOLER, 2015.

[26] ECONOLER, "Energy Audit Report-MININFRA Building," ECONOLER, 2015.

[27] ECONOLER, "Energy Audit-RDB Building," ECONOLER, 2015.

Appendices

Table 4: List of generation plants and their capacity [21].

SNo	Plant Name	Installed capacity (MW)
Hydro		
1.	Ntaruka	11.25
2.	Mukungwa	12
3.	Nyabarongo	28
4.	Gisenyi	1.2
5.	Gihira	1.8
6.	Murunda	0.1
7.	Rukarara	9.5
8.	Rugezi	2.6
9.	Keya	2.2
10.	Nyamotsi I	0.1
11.	Nyamotsi II	0.1
12.	Agatobwe	0.2
13.	Mutobo	0.2
14.	Nkora	0.68
15.	Kimbiri	0.3
16.	Gaseke	0.582
17.	Mazimeru	0.5
18.	Janja	0.2
19.	Gashashi	0.2
20.	Nyabahanga	0.2
21.	Nshiri	0.4
22.	Rwaza Muko	2.6

23.	Musarara	0.45
24.	Mukungwa II	2.5
25.	Rukarara II	2.2
26.	Nyirabuhombohombo	0.5
27.	Giciye I	4
28.	Giciye II	4
29.	Rusizi II	12
S-Total		**100.562**
Diesel		
30.	Jabana	7.8
31.	Jabana II	21
32.	So Energy	30
S-Total		**58.8**
Peat		
33.	Gishoma	15
S-Total		**15**
	Methane	
34.	KP1	3.6
35.	Kivu watt Phase I	26.4
S-Total		**30**
Solar		
36.	Jali	0.25
37.	Giga Watt	8.5
38.	Nyamata Solar	0.03
39.	Nasho Solar PP	3.3
S-Total		**12.08**
Import		
40.	Rusizi I	3.5
41.	UETCL	2
S-Total		**5.5**
Grand Total		**221.942**