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Promove Energia I : Project Preparation Facility
Energy Resource Centre

ELABORATION OF A NATIONAL ENERGY EFFICIENCY STRATEGY AND ACTION PLAN FOR MOZAMBIQUE

Data collection on energy resources, supply and demand

Report

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ACTION 9: ELABORATION OF A NATIONAL ENERGY EFFICIENCY STRATEGY AND ACTION PLAN

Data collection on energy resources, supply and demand Report

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- AMT - Agência Metropolitana de Transportes de Maputo (Maputo Metropolitan Transport Agency)
- ARENE - Autoridade Reguladora de Energia (National Energy Regulator)
- AUTOGAS SARL
- CTA - Confederação das Associações Económicas de Moçambique (Confederation of Mozambique Economic Associations)
- DNE - Direção Nacional de Energia – National Directorate of Energy
- DPC - Direcção de Planificação e Cooperação do Ministério dos Recursos Minerais e Energia (Planification and Cooperation Directorate of the Ministry of Mineral Resources and Energy)
- EDM – Eletricidade de Moçambique (Mozambique Power Utility)
- ENABEL – Agência de Desenvolvimento da Bélgica (Belgian Development Agency)
- FUNAE - Fundo de Energia (Energy Fund)
- GET.INVEST/GIZ - Programa GET.invest/GIZ (GET.invest programme implemented by GIZ- German Corporation for International Cooperation GmbH)
- Green Lights Lda
- Green Watts Solar
- INATTER - Instituto Nacional dos Transportes Terrestres de Moçambique (Mozambique National Land Transportation Institute)
- INE - Instituto Nacional de Estatística (National Statistics Institute)
- INNOQ - Instituto Nacional de Normalização e Qualidade (National Institute for Standardisation and Quality)
- MIREME - Ministério dos Recursos Minerais e Energia (Ministry of Mineral Resources and Energy)
- MTC - Ministério dos Transportes e Comunicações (Ministry of Transportation and Communications)
- Solarworks
- Universidade Eduardo Mondlane

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Acronyms

AC	Air Conditioner
ADA	Austrian Development Agency
ADEL	Agência de Desenvolvimento Económico Local de Sofala - Sofala Local Economic Development Agency
AEE-INTEC	Austrian Institute for Sustainable Technologies

AMER	Associação Moçambicana de Energias Renováveis – Mozambican Renewable Energy Association
ARENE	Autoridade Reguladora de Energia – National Energy Regulator Authority
AVSI	Association of Volunteers in International Service
BAUS	Business As Usual Scenario
CFL	Compact Fluorescent Lamp
CHP	Combined Heat and Power
CLASP	Collaborative Labelling and Appliance Standards Program
CNELEC	Conselho Nacional de Eletricidade – National Electricity Council
CO_2	Carbon Dioxide
CTA	Confederation of Trade Associations
CTG	Central Térmica de Gigawatt – Gigawatt thermal power plant
CTM	Central Termoelétrica de Maputo – Maputo thermoelectric power plant
CTRG	Central Térmica de Ressano Garcia – Ressano Garcia thermal power plant
DMP	Demand Market Participation
DNE	Direção Nacional de Energia – National Directorate of Energy
DPC	Direção de Planificação e Cooperação – Cooperation and Planning Directorate
DSM	Demand Side Management
DSO	Distribution System Operator
E-bus	Electric Bus
EDM	Eletricidade de Moçambique – Mozambique National Power Utility
EE	Energy Efficiency
EEBC	Energy Efficiency Buildings Code
EED	Energy Efficiency Directorate
EELA	Energy Efficiency Lighting and Appliances
EESAP	Energy Efficiency Strategy and Action Plan
EEWG	Energy Efficiency Working Group
EMS	Energy Management System
ENABEL	Belgian Development Agency
EnDev	Energising Development Programme
EPC	Energy Performance Contracting
ESCOs	Energy Service Companies
EU	European Union
EV	Electric Vehicle
FUNAE	Fundo de Energia – Energy Fund
GDP	Gross Domestic Product
GHG	Green House Gas
GIS	Geographic Information System
GIZ	Deutsche Gesellschaf fur Internationale Zusammenarbeit
HESS	High Energy Savings Scenario

HCB	Hidroelétrica de Cahora Bassa - Cahora Bassa Hydroelectric Plant
HVAC	Heating, Ventilation, and Air Conditioning
HV	High Voltage
IEC	International Electrotechnical Commission
ICT	Information and Communications Technology
IEA	International Energy Agency
IMF	International Monetary Fund
INIR	Instituto Nacional de Irrigação (National Institute of Irrigation)
INATTER	Instituto Nacional dos Transportes Terrestres de Moçambique (Mozambique National Land Transportation Institute)
INE	Instituto Nacional de Estatística - National Statistics Institute
INTEC	Institute for Sustainable Development for Austria
IOF	Inquérito ao Orçamento Familiar - Family Budget Questionnaire
IPP	Independent Power Producer
ITC	Independent Transmission Company
Km	Kilometre
LCD TV	Liquid Crystal Display Television
LED	Light Emitting Diode
LESS	Less Energy Savings Scenario
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LV	Low Voltage
MEPS	Minimum Efficiency Performance Standards
MESS	Medium Energy Savings Scenario
MIREME	Ministério dos Recursos Minerais e Energia - Ministry of Mineral Resources and Energy
MITADER	Ministério da Terra e Ambiente - Ministry of Land and Environment
MO	Market Operator
MOTRACO	Mozambique Transmission Company
MV	Medium Voltage
NG	Natural Gas
NGOs	Non-Governmental Organizations
PAYG	Pay as You Go
PF	Power Factor
PROLER	Programa de Leilões de Energia Renovável – Renewable Energy Auctions Programme
R&D	Research and Development
S&L	Standards & Labelling
SADC	Southern Africa Development Community
SDG-7	Sustainable Development Goals nº7
SES	Sustainable Energy System
SHS	Solar Home System
SME	Small Medium Enterprises
SNV	Netherlands Development Organization

STTP	Solar Thermal Technology Platform
VAT	Value Added Tax
VCR	Video Cassette Recorder
VSD	Variable Speed Drive
TSO	Transmission System Operator
TOE	Ton of Oil Equivalent
UEM	University Eduardo Mondlane
UNFCCC	United Nations Framework Convention on Climate Change
UPS	Uninterruptible Power Supply
USD	United States Dollar

Units

GW	Giga Watt
GWh	Giga Watt hour
Ktoe	Kilo tons equivalent of oil
kW	Kilowatt
kWh	Kilowatt hour
MWh	Mega Watt hour
Litre	Litre
Litre/hour	Litre per hour
toe	tonne of oil equivalent
TWh	Tera Watt hour
W	Watt
Wh	Watt hour

Executive Summary

The Mozambican energy system is facing serious interrelated challenges of energy access, energy security and climate change adaptation and mitigation. To overcome this situation, the country is committed to develop several renewable energy and energy efficiency projects, which will help the country to reach in 2030 key top priority, 100% of the population having energy access. To achieve these objectives, the country needs to increase not only the rate of energy access by developing new generation capacity, but also by promoting Energy Efficiency (EE) policies and practices, such as energy labelling, Minimum Efficiency Performance Standards

(MEPS), etc. The national electrification strategy, launched in the end of 2018 under the national energy for all program, confirms the country commitment to this goal.
There are several different ways to improve energy efficiency, such as the use of innovative equipment or solutions that lead to equal or greater output with less energy being consumed, by reducing or cutting the "wasted energy" while maintaining the same output (e.g. adjusting time settings or equipment set points). Energy efficiency will contribute to reliability and security of energy supply, by decreasing losses at all links in the energy value chains. Additionally, it will also decrease dependency on fossil fuels and contributes to raise the population living standards, by reducing energy bills, and by making access to energy more affordable and easier, both in urban and rural areas.

The objective of this report is to support the establishment of a strong regulatory framework, helping the Ministry of Mineral Resources and Energy (MIREME) to create legal instruments to guide the activities related to the efficient use of energy in the country. This technical assistance is designed to launch a nationwide exercise to elaborate and adopt a national Energy Efficiency Strategy and Action Plan (EESAP). The EESAP will make a significant contribution into the creation of a favourable environment for private investments in energy efficiency and will spur industrial development and employment through the reduction of energy bills. This strategy will define an action plan with measurable targets. The EESAP will complement the existing array of Mozambique policies by addressing the challenge of making the most efficient use of the country energy resources. Together with the policies on energy access and renewable energy, it will constitute a comprehensive strategy and a set of recommendations to achieve the Sustainable Development Goal 7 (SDG-7) of universal access to electricity by 2030.

The current electricity context in Mozambique is characterized by several transformations in the sector with emphasis on strengthening its matrix source, especially the use of gas added to the high hydroelectric potential, mineral coal and renewable energy sources. Despite the vast energy potential, the current panorama in terms of consumption in the country is still quite unfavourable, the domestic access to electricity was 30% in 2018.
Mozambique does not have a specific program for coordinated development of Energy Efficiency activities. In practice, isolated initiatives on Energy Efficiency are carried out by different public and private entities mainly by the DNE (National Directorate of Energy), the Academia, EDM, FUNAE, in some cases with the support of cooperation partners (see section 3.5).
In the last decade, the Mozambican authorities made an important effort (through the expansion of the national power grid and through the installation of several off-grid projects) to improve the population energy access rate. In 2018 the national electrification rate was around 30% of the country population [24]. However, the fast population growth rate led in the following years to a slower electrification rate, as well as led to a higher demand for energy in the residential sector.
Currently the population access rate to electricity has increased to around 32%, according to EDM (Eletricidade de Moçambique) [24], which demonstrates the continued effort made by national authorities to increase the number of people with access to electricity. In urban areas the electrification rate is 67% and in rural areas is 8%, which means that although in both areas there is still a large percentage of the population without energy access, rural areas are in a critical situation.

Figure *57*ES-1 presents the scheme of the methodology used in the assessment of the country savings potential.

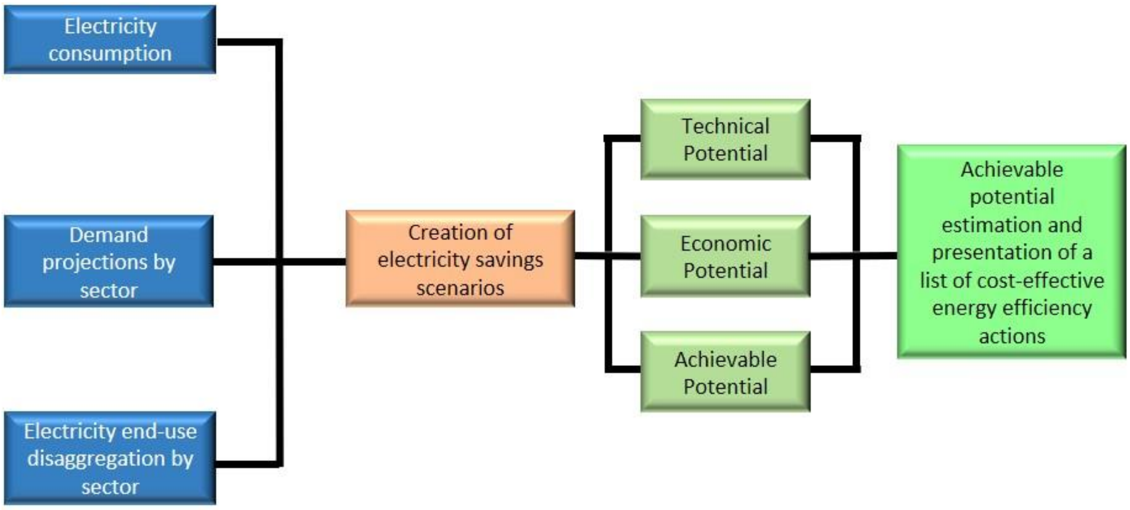

Figure ES-1- Framework for the methodology used in the estimation of Mozambique savings potentials

The assessment of the country savings potential began with the collection of the most relevant information, such as electricity consumption since 2009, demand forecast and the electricity end-use disaggregation for each economic sector. This information allowed to determine the amount of electricity used in each sector for each end-use which resulted in a detailed characterization of each sector. All this information resulted in a well-defined set of assumptions that allowed to define the electricity savings scenarios. These scenarios allowed to calculate the impact of moving forward to more energy-efficient equipment (e.g house appliances, lighting, electric motors, etc.). With these scenarios the country potentials (technical, economic and achievable) were calculated which allowed, to determine in Chapter 6 the impact (in terms of energy savings) and the cost effectiveness of the proposed actions/measures per economic sector.

The technical savings potential for each economic sector including the electrification of the transportation sector were evaluated. Regarding the transportation sector, a set of conditions is drawn for moving vehicles away from fossil fuels and into electric mobility. In this report four scenarios were considered to estimate the technical savings potential for the residential, non-residential, industrial and transportation sectors. These scenarios are:

- **BAUS – Business As Usual Scenario** – In this scenario no energy efficiency measures are implemented, and no significant transition is made to more efficient equipment models. Due to these constraints no relevant savings take place in this scenario;
- **LESS – Low Electricity Savings Scenario** – This is a conservative scenario where the electricity savings are smaller, due to a transition to equipment models that have the average efficiency of the models available in the market. Due to this fact, the energy savings are modest in this scenario;
- **MESS – Medium Electricity Savings Scenario** – In this scenario the electricity savings are higher due to the transition to equipment models that are half away between the ones being sold on average and the most efficient types;
- **HESS – High Electricity Savings Scenario** – This scenario considers the transition to equipment models that are the most energy efficient available in the market. Therefore the energy savings in this scenario are largest.

Considering the savings percentage per appliance/equipment in each scenario, an analysis was made for each economic sector electricity consumption between 2020 and 2050. Table ES-1 presents the country overall technical potential in the four selected scenarios for the 2020-2050 period.

TABLE ES-1- MOZAMBIQUE TECHNICAL SAVINGS POTENTIAL

Overall technical savings potential [2020-2050]					
	Sector	**BAUS[1] [TWh]**	**LESS [TWh]**	**MESS [TWh]**	**HESS [TWh]**
Grid Connected Systems	Residential Sector	107,69	37,74	47,55	60,32
	Non-residential Sector	42,92	15,05	20,11	24,10
	Industrial Sector	141,45	26,75	34,51	40,07
	Transportation Sector[2]	265,18	2,61	5,23	7,84
	Total	557,24	82,4	107,37	132,23

The cost-effectiveness of any energy efficiency measure strongly depends on the electricity price. Therefore, tariffs play a very important role in determining the economic potential. Table ES-2 presents the country overall economic potential in all economic sectors and taking in consideration the three evolution scenarios by decade and in the 2020-2050 period.

TABLE ES-2- COUNTRY OVERALL ECONOMIC POTENTIAL IN EACH SCENARIO BY DECADE AND FOR 2020-2050 PERIOD

All economic sectors	LESS	MESS	MESS
	Economic Potential in Millions $USD[3]	Economic Potential in Millions $USD	Economic Potential in Millions $USD
[2020-2029]	$1 769,4	$2 737,2	$3 734,7
[2030-2039]	$4 315,5	$7 209,0	$10 156,0
[2040-2049]	$8 172,2	$14 031,7	$19 978,5
[2020-2050]	$15 358,1	$25 884,3	$36 590,2

As experience in other countries shows, the achievable potential is at least 50% of the technical potential, depending on the above mentioned factors and in the implementation timeline of the proposed EE actions (see Chapter 6). As the analysis of the country technical and economic potential made in sections 5.1 and 5.2, considered three possible evolution scenarios (LESS, MESS and HESS), it is logical to make a similar estimation for the country achievable potential. The use of three scenarios will allow Mozambican authorities to continuously adjust the National Energy Efficiency Strategy and Action Plan to fit into the scenario that they considered the best for the countries according to its present conditions. The amount of effort and resources dedicated to the implementation the Energy Efficiency Plan will strongly influence the energy savings impact. Taking all these factors into consideration, Table ES-3 summarizes the estimation for the achievable potential.

TABLE ES-3 - MOZAMBIQUE ACHIEVABLE POTENTIAL [2020-2050]

Mozambique Achievable Potential [2020-2050]							
		LESS		**MESS**		**HESS**	
	Economic Sector	**Energy Savings [TWh]**	**Economic Savings $USD[4]**	**Energy Savings [TWh]**	**Economic Savings $USD[32]**	**Energy Savings [TWh]**	**Economic Savings $USD[32]**
	Residential Sector	18,9	$2 232,3	23,8	$2 812,3	30,2	$3 568,2

1 Without the implementation of any energy efficiency measures. In this scenario there are no energy savings.
2 The obtained savings are related with the benefits of moving from vehicles powered by fossil fuels (diesel e gasoline) into electric vehicles.
3 This potential represents the cost of the fossil fuel (diesel and gasoline) avoid.
4 In Millions of USD

Grid Connected Systems	Non-residential Sector	7,5	$445,2	10,1	$594,9	12,1	$712,8
	Industrial Sector	13,4	$659,4	17,3	$850,6	20,0	$987,7
	Transportation Sector[5]	1,3	$4 342,2	2,6	$8 684,3	3,9	$13 026,5
	Total	41,1	$7 679,1	53,8	$12 942,1	66,2	$18 295,2

Achieving higher levels of Energy Efficiency (EE) is a multi-effort endeavour that requires the combination of policy instruments in order to address market barriers and failures that hinder the energy efficiency investments. Cost-effective energy efficiency opportunities are present in all economic sectors and across many types of technologies and end-uses. In order to overcome the usual barriers to energy efficiency policy makers have three basic tools to address those barriers: knowledge dissemination, regulations, and financial incentives or subsidies [45]. In other developing countries the combination of these tools has shown that it accelerates the rate of energy efficiency implementation.

This report contains a set of 43 EE actions that are essential for the country to be able to reach the achievable potential. The most competitive and impactful EE opportunities include the following measures addressing the following end-uses:

- **Residential sector on-grid -** in lighting, refrigerators, freezers, solar water heating, cooking, fans and air conditioning;
- **Residential sector off-grid -** in lighting, refrigerators/freezers, solar water heating, cooking and fans. The adoption of super energy efficient technologies has as a major benefit in the substantial decrease of the investment cost of solar energy supply, including energy storage;
- **Non-residential sector:** in lighting, refrigeration systems, solar water heating, cooking, fans, distributed and centralized air conditioning (HVAC);
- **Industrial sector:** in lighting, electric motors, variable speed drives, refrigeration systems and cogeneration;
- **Transportation sector:** electric mobility, including urban buses, cars and two and three-wheel motor vehicles. Conversion of longer distance buses and trucks to natural gas is another possible option. Additionally, the introduction of electric vehicles into the country and the use of natural gas can be an important step to reduce the external oil dependence.

Mozambique has a huge potential to reduce its energy consumption and to improve the energy efficiency at all levels. However, to take advantage of these opportunities for energy savings, there is a need to create an institutional and regulatory framework:

- **MEEC – Mozambique Energy Efficiency Centre -** The creation of an institution focused on the development and implementation of energy efficiency in the country is essential to guarantee a successful programme implementation;
- **Environmental and Energy Efficiency Fund -** It is important to have a suitable funding mechanism to successfully implement the proposed energy efficiency actions. This fund will get its budgetary capacity through a series of taxes (on inefficient equipment, carbon tax, etc.), government funding and external donors, mentioned in each of the proposed action in Chapter 6;
- **Energy labels and Minimum Energy Performance Standards (MEPS) –** The introduction and enforcement of energy labelling and MEPS for energy related equipment across all economic sectors, as well as for the off-grid market is essential to remove the inefficient and used

5 The obtained savings are related with the benefits of moving from vehicles powered by fossil fuels (diesel e gasoline) into electric vehicles.

equipment from the market, most of it imported from Asian countries (e.g. China, Thailand, Korea, etc.);

- **Market surveillance and compliance agency -** The effective and timely use of market surveillance and compliance mechanisms are essential to avoid substandard products from entering the country. These mechanisms ensure the protection of other public interests such as the environment, security and fairness in trade. Additionally, market surveillance and compliance mechanisms include actions such as product withdrawals, recalls and the application of sanctions to stop the circulation of non-compliant products;
- **Building Energy Codes -** The building sector in Mozambique has also a huge potential for improvements. The introduction and enforcement of a building energy code made with the collaboration of all stakeholders will have a critical role to ensure that new buildings and major renovation are sustainable from the energy and environmental point of view. Considering the foreseen population growth, the creation of a building energy code will be essential to reduce the expected growth in energy demand in the next decades;
- **Capacity building -** The implementation of energy efficiency requires qualified and skilled professionals, for this capacity building initiatives are essential to improve the human resources competences. The cooperation with professional associations (e.g engineers, architects, maintenance technicians, etc.) is extremely important to improve these professionals knowledge level and expertise concerning energy efficiency. It is also essential to raise the population awareness about the availability of energy efficient technologies, together with its potential multiple benefits;
- **Energy audits and M&V plans –** The implementation of energy audits and M&V plan in large energy consumers will allow to reduce and optimize the energy use in the non-residential and industrial sector and can also lead to improvement in the industrial process efficiency and competitiveness;
- **Integration of renewable energy systems –** The integration of these systems will have an important role in driving buildings towards a nearly zero grid energy consumption. The inclusion of solar thermal systems for hot water production and solar photovoltaic for electricity production can be used to reduce the buildings increasing energy demand and also to reduce the carbon footprint of buildings;
- **Off-grid market equipment regulation –** This market also need to be regulated, through energy labelling and standards, to ensure lower investment costs to supply cost-effective energy services and to remove the poor quality and low efficiency equipment from the market.
- **ESCO framework –** The introduction of ESCOs into the energy sector is essential to leverage the energy services sector development. These companies are able to bring into Mozambique expertise, capacity building for the local workforce and capital to invest in energy efficiency. ESCOs can be a good opportunity for the renovation/rehabilitation of old inefficient buildings, street lighting and even for the industrial sector improvement/expansion.

1. Introduction

1.1. Report Structure and Methodology

This report is structured in six Chapters, according to the following content:

Chapter one - Contains a summary on the report structure and the methodology used. Additionally, it presents a brief introduction to the country objectives regarding energy access, energy security and climate change adaptation and mitigation. Furthermore, the main objectives of this assignment as well as the benefits that Mozambique will obtain from implementing energy efficiency strategies are specified in this Chapter;

Chapter two - In this Chapter a socio-economic characterization of the country is made by analysing the population and growth rate and geographic location by area (rural/urban). Moreover, in this Chapter an overview on Mozambique main economic activities and indicators (e.g. GDP- Gross domestic product evolution, economic growth rate, etc.) for the different sectors is made;

Chapter three - A detailed characterization of the Mozambican energy sector is made in this Chapter, by making a breakdown on the country energy production and consumption by energy source as well as, by sectors considering the scenarios for the electricity demand forecast for 2020-2030. Additionally, in this Chapter, a description on the current situation regarding energy efficiency implementation is presented;

Chapter four - This Chapter contains a detailed analysis on the energy being consumed by each economic sector (residential, non-residential, industrial and transportation). This analyse was made with the available breakdown on the energy being consumed by energy source, appliance/equipment, location, etc. in order to help assess the country savings potential, as well as the off-grid market characterization;

Chapter five - In this Chapter a full assessment on the country savings potential is made, in terms of electricity savings potential (technical, economic and achievable). By doing this assessment it will be possible to support the recommendations and define the necessary actions to achieve the considered potential;

Chapter six – A complete set of recommendations and specific actions per sector is made in this Chapter. These actions and recommendations are of the utmost importance to achieve the estimate country achievable savings potential.

Chapter seven – Contains a proposal for the energy efficiency action implementation timeline;

Chapter eight – Contains the main conclusions achieved in the course of the project.

The methodology, used to build this report is based on:

- Interviews and meetings with key stakeholders, including government authorities (e.g. MIREME, National Directorate of Energy (DNE), Cooperation and Planning Directorate (DPC), National Energy Regulator (ARENE), the electric utility Eletricidade de Moçambique (EDM), Energy Fund (FUNAE), Confederation of Trade Associations (CTA), etc.) in Mozambique requesting official data on energy consumption by sector, energy source, people location, appliance, equipment, etc.

- Data collection and an extensive review on the official documents/data provided by local authorities to create a document database which will help in the work development;

- The collected data is compiled into the mentioned document database which will be used to create the country energy balance sheets for the last ten years per sector and sub-sector of activity. This database containing the energy consumption disaggregation will be used in the estimation of the technical, economic and achievable electricity savings potential. Moreover, this data will be used as a reference for policy definition and for the development of sectorial actions to improve the energy efficiency in the country;

- The energy efficiency opportunities presented in this report include a set of representative energy efficiency measures that are broadly suitable to sub-Saharan Africa countries, as well as measures specifically designed for Mozambique. These measures apply to the residential, commercial, industrial and transport sectors. The technologies with the greatest opportunity to reduce energy demand in Mozambique were identified by gathering the following information:

- Electricity consumption and demand forecasts;
- Customer characterization by sector and location;
- Energy end-use disaggregation by sector and subsector;
- Market data on energy efficient technologies;
- Overall quality of appliances/equipment available in the market;
- Cost of energy-efficient and standard technologies;
- Characterization of available off-grid appliances in terms of overall quality and energy efficiency.

1.2. Purpose of this Report

The Mozambican energy system is facing serious interrelated challenges of energy access, energy security and climate change adaptation and mitigation. To overcome this situation, the country is committed to develop several renewable energy and energy efficiency projects, which will help the country to reach in 2030 key top priority, 100% of the population having energy access. To achieve these objectives, the country needs to increase not only the rate of energy access by developing new generation capacity, but also by promoting Energy Efficiency (EE) policies and practices, such as energy labelling, Minimum Efficiency Performance Standards (MEPS), etc. The national electrification strategy, launched in the end of 2018 under the National Energy for All programme, confirms the country commitment to this goal.

The objective of this report is to support the establishment of a strong regulatory framework, helping the Ministry of Mineral Resources and Energy (MIREME) to create legal instruments to guide the activities related to the efficient use of energy in the country. This technical assistance is designed to launch a nationwide exercise to elaborate and adopt a national Energy Efficiency Strategy and Action Plan (EESAP). The EESAP will make a significant contribution into the creation of a favourable environment for private investments in energy efficiency and will spur industrial development and employment through the reduction of energy bills.

The general objective of this report is to support MIREME and its EE Department in the creation of an environment through the elaboration of a national energy efficiency strategy that should be the backbone for creating appropriates EE policies and regulations. This strategy will define an action plan with measurable targets. The EESAP will complement the existing array of Mozambique policies by addressing the challenge of making the most efficient use of the country energy resources. Together with the policies on energy access and renewable energy, it will constitute a comprehensive strategy and a set of recommendations to achieve the Sustainable Development Goal 7 (SDG-7) of universal access to electricity by 2030. These policies will also contribute to the Southern Africa Development Community (SADC) goals, to the Africa-EU, USAID and UK Energy Partnership objectives and above all to the overall cooperation between the EU (European Union) and Mozambique. In conclusion the EESAP will become an essential part of the overall energy policy framework of Mozambique.

1.3. Benefits of Implementing Energy Efficiency Strategies

Energy efficiency (EE) is a measure of energy used for delivering a given service. Improving energy efficiency means getting more services from the energy that is used. There are several different ways to improve energy efficiency, such as the use of innovative equipment or solutions that lead to equal or greater output with less energy being consumed, by reducing or cutting the "wasted energy" while maintaining the same output (e.g. adjusting time settings or equipment set points). Energy efficiency will contribute to reliability and security of energy supply, by decreasing losses at all links in the energy value chains. Additionally, it will also decrease dependency on fossil fuels and contributes to raise the population living standards, by reducing energy bills, and by making access to energy more affordable and easier, both in urban and rural areas.

EE facilitates energy provision for essential public administration and services, including education, health and clean water supply. Moreover, energy efficiency reduces the negative environmental externalities (Green House Gas - GHG emissions, air, soil and water pollution, land degradation, etc.) and will contribute to higher levels of job creation, both in energy intensive sectors and in the energy efficiency supply chain.

The EESAP, previously mentioned, will be an integral part of the modernisation and greening of the Mozambican economy to address various technical, economic, financial, institutional, legal and capacity related constraints and gaps.

This report prioritizes recommendations for implementing energy efficiency measures by maximizing its benefits to meet the SDG goals, especially the SDG7. Moreover, this report will outline several actions through 2030 for building the three main energy pillars of sustainable development: energy access, energy efficiency, and renewable energy. The main focus of the study was on energy efficiency, rural electrification, efficiency opportunities in the appliances market (both grid connected and off-grid), transportation sector and those associated with other fuels switching (e.g. replacing biomass, kerosene, LPG and natural gas by renewable electricity).

2. Socio-economic Characterization of the Country

2.1. Population

Mozambique is a country located at the eastern coast of Africa with about 800.000 square kilometres of surface and has borders with Tanzania to the north, Malawi, Zambia and Zimbabwe on the west and South Africa and Swaziland on the south. The cost line to the east is 2500 km long on the Indian Ocean, as shown in Figure 1.

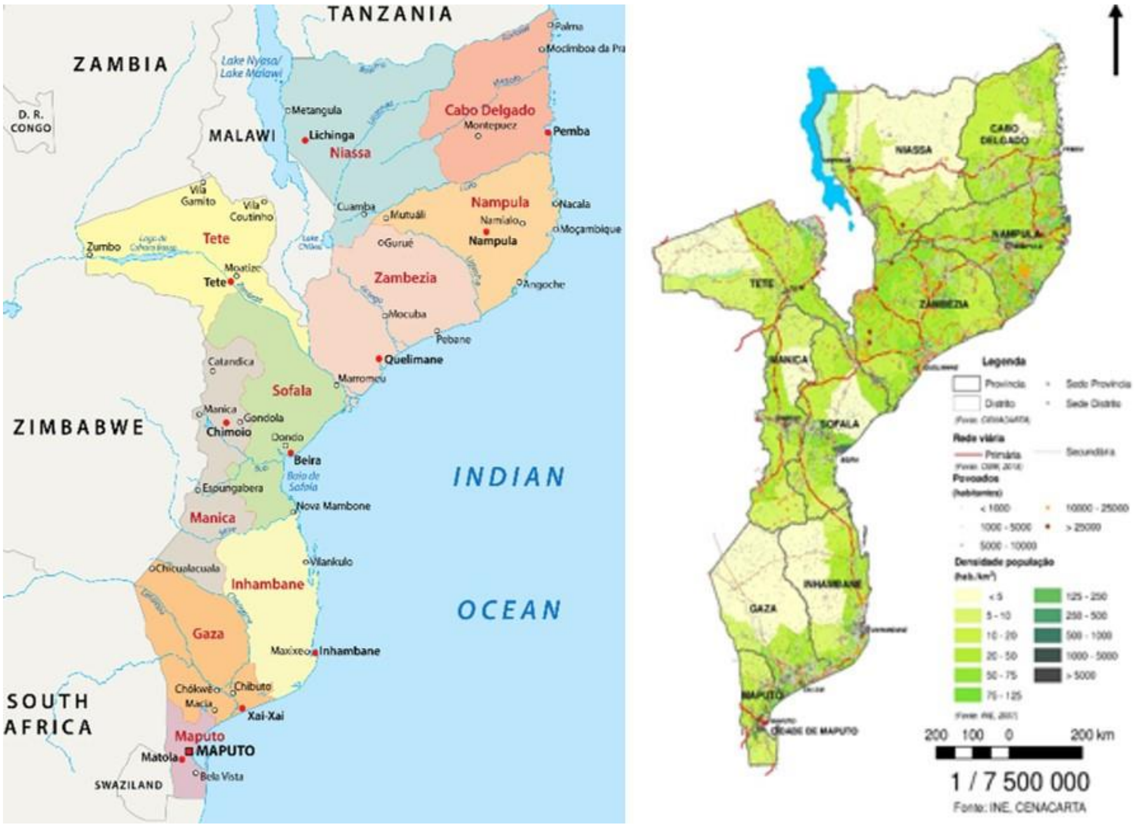

FIGURE 1- MOZAMBIQUE LAND BOUNDARIES (ON THE LEFT) AND POPULATION DENSITY AND SETTLEMENTS DISTRIBUTION (ON THE RIGHT). SOURCE: [1].

The 2017 population census reported that Mozambique at that time had 27,9 million inhabitants from which 48% were men and 52% women [2, 3]. The distribution of population by age indicates that the population has a significant youth profile, more than half of the population is under 19 years of age (see Figure 2).

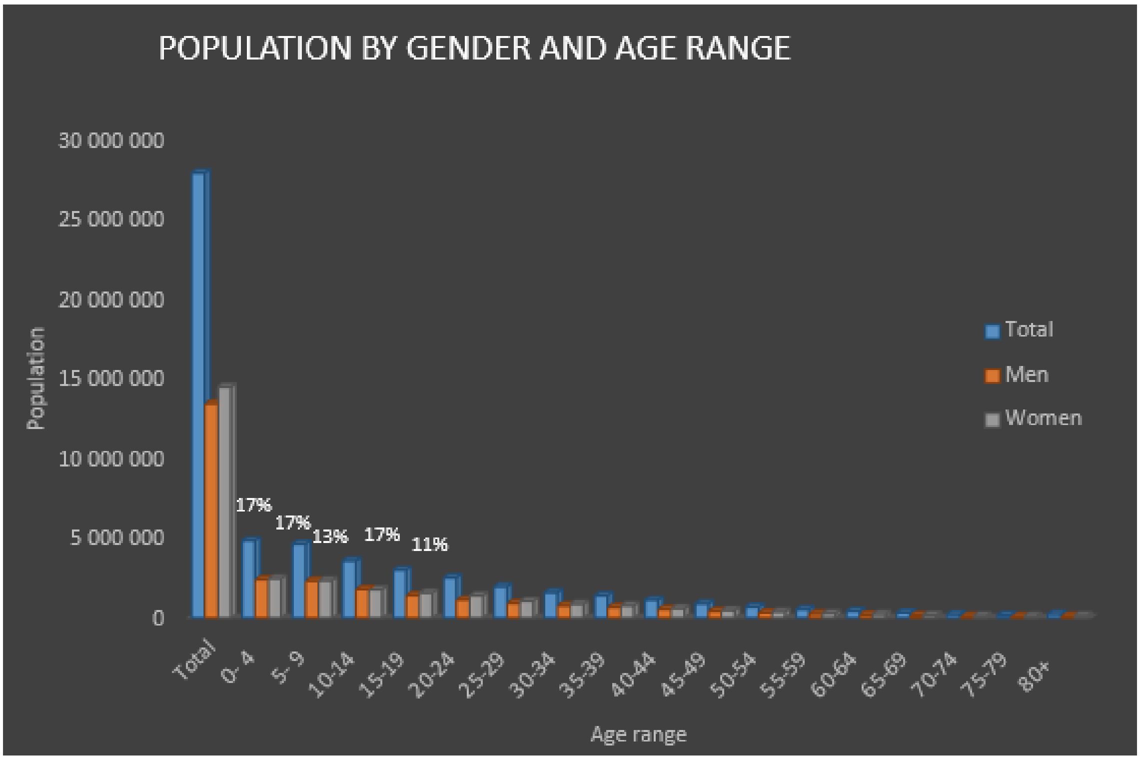

FIGURE 2 - POPULATION BREAKDOWN BY GENDER AND AGE RANGE IN 2017. SOURCE: [2, 3].

As presented in Figure 1 the higher population densities are found along the coastline and also close to the main transport corridors from Maputo, Beira and Nacala to the neighbouring countries. The overall country population density has been increasing and almost doubled over the last 20 years, as presented in Figure 3.

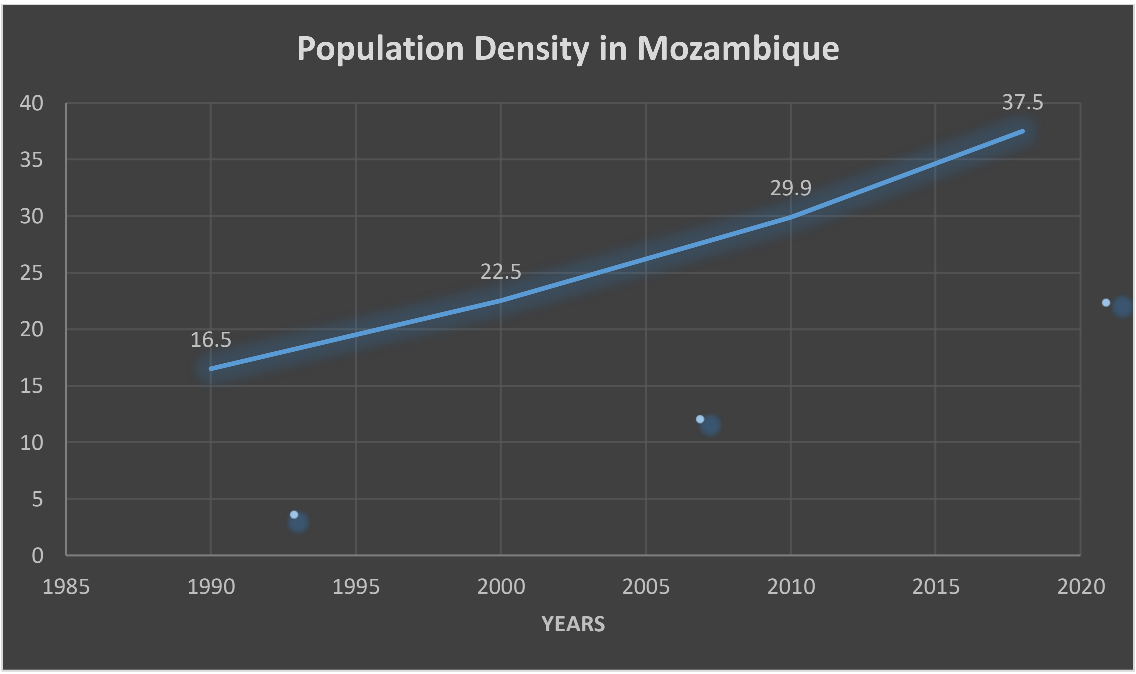

FIGURE 3 - EVOLUTION OF THE POPULATION DENSITY IN MOZAMBIQUE BETWEEN 1985 TO 2020. SOURCE: [3].

The Mozambican population is expected to reach a number close to 31 million inhabitants in 2021 according to demographic projections based on the 2017 census [2, 3]. These projections were made considering a population growth of 2,6%, gradually slowing 30 years from now to a steady rate of 1,75% as published by the National Statistics Institute (INE) and presented in Figure 4. Considering this, and according to Figure 4 the population will be double in the next 30 years, which means that country will face a tremendous challenge to respond adequately to the needs (education, healthcare, jobs, social inclusion, etc.) of such number of inhabitants.

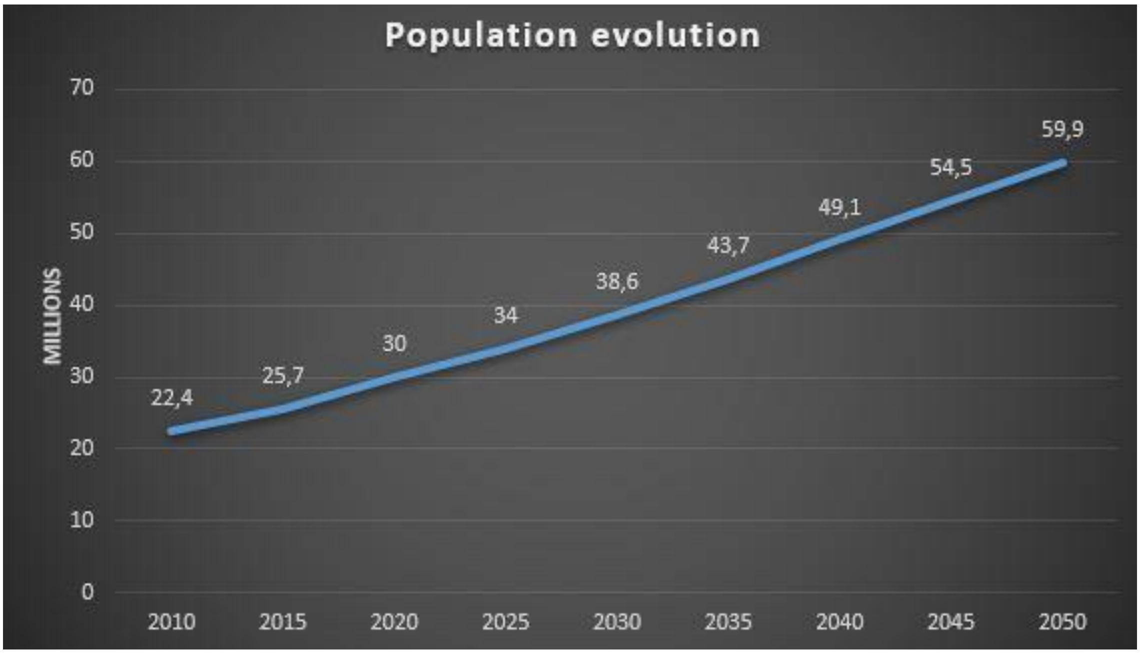

FIGURE 4- PROJECTED POPULATION GROWTH FOR 2010-2050.SOURCE: [2,3].

2.2. Economic Activity

Mozambique economy has been struggling since 2016 due to macroeconomic conditions mainly the decline on international commodity prices plus the effects of climate disasters. After recording average growth rates above 7% of Gross Domestic Product (GDP) over the period 2000-2016, supported by foreign investment, the rapid growth of the mining sector and the increase in coal and hydrocarbon reserves, the country has presented a growth of 2,3% of GDP in 2019.

The passage of two hurricanes notably affected agricultural performance. According to the updated International Monetary Fund (IMF) data for December 2020, growth should be -0.5% in 2020, due to the outbreak of the COVID-19 pandemic and will increase to 2.1% in 2021, supported by the post-pandemic global economic recovery, reconstruction efforts, the recovery of the agricultural sector, the gradual easing of monetary conditions, etc. Figure 5 presents the GDP evolution since 2015 to 2020, as well as the expected evolution until 2022 according to IMF forecast December 2020 [4].

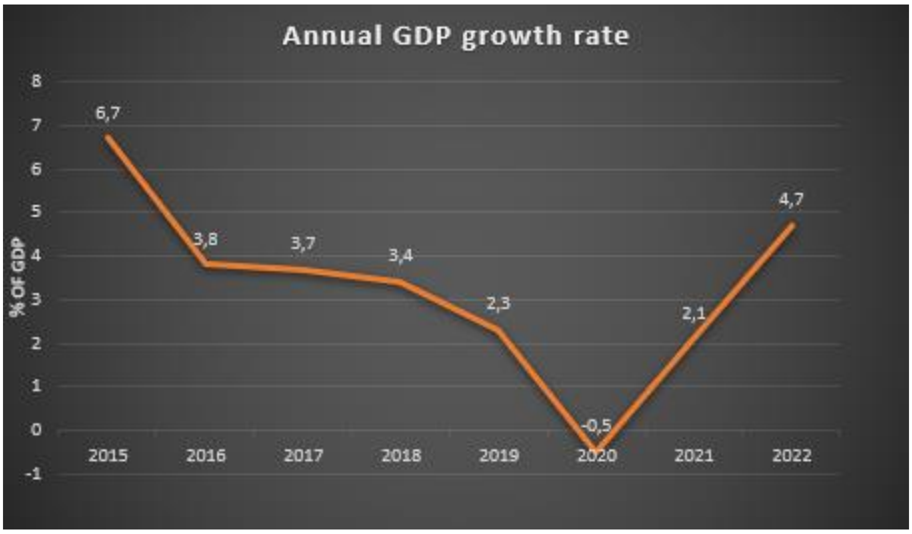

FIGURE 5- MOZAMBIQUE ANNUAL GDP GROWTH RATE IN 2015-2022. SOURCE: [4].

Figure 6 presents the evolution on the Mozambique GDP per capita in USD (in the left) and the country GDP evolution (on the right) [4].

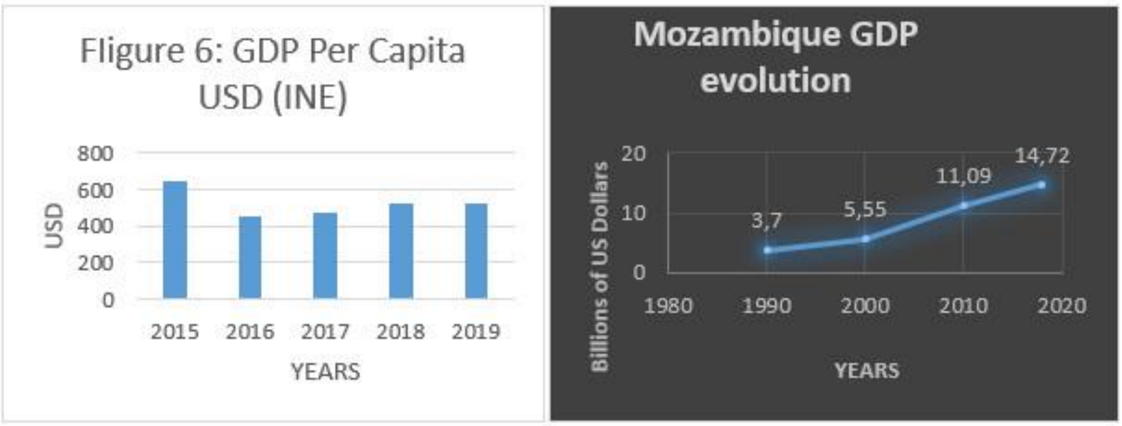

FIGURE 6- MOZAMBIQUE GDP AND GDP PER CAPITA EVOLUTION. SOURCE: [4].

It is possible to observe that the country GDP had a significant growth over the last 30 years, in 1990 the GDP was $3,7 billion USD (United States Dollar) to $14,72 billion USD in 2020. Regarding the GDP per capita, Figure 6 presents its evolution since 2015. In 2015 the GDP per capita presented a value of $647,6 USD and got reduced until 2017 ($474,2 USD). In 2018 the GDP per capita increased to $519,6 USD and in 2019 it was $521,7 USD. The reduction in the GDP per capita in 2016 can be related with the high population growth (most of it is not in working age). Since 2018 the GDP per capita is almost stable due a good economic environment mostly caused by high levels of foreign investment and rapid growth of the mining sector (coal and hydrocarbon reserves). Due to these factors the impact of the high population growth in the GDP per capita was attenuated.

Mozambique is rich in natural resources and produces a large variety of agricultural products. It benefits from huge offshore gas fields discovered in 2010, which could turn the country into one of the main LNG (Liquefied Natural Gas) producers in sub-Saharan Africa. It also has significant coal reserves, hydroelectric potential, and possesses the world largest reserves of tantalite. It is the 10th largest producer of cassava and the 18th producer of oilseeds [5]. Although agriculture employs 71% of the country's active population, it represents only 24,5% of GDP [6]. Most agricultural production comes from family farms, but the sector is particularly vulnerable to natural disasters such as droughts and floods. The main crops in the country are corn, cassava, peanuts, beans, rice, cotton, cashew nuts, sugarcane, tea, tobacco, coconuts, citrus and tropical fruits and a variety of vegetables and oilseeds.

Mozambique natural resources include also high-quality iron ore, gold, bauxite, graphite and marble. The manufacturing sector is still weak and is dominated by the production of the Mozal aluminium smelter. Overall, the industrial sector contributes to 24,3% of the country's GDP and employs 8% of the active population [6]. Tourism is the main industry, although it is still performing way below its potential. In addition to expanding financial services, the tertiary sector has a growing number of micro-scale retail businesses.

Apart from mineral resources and agriculture the country economy has an important fishery sector that involves more than 90.000 people (on fishing, gathering, processing and marketing). It means that about 500.000 people directly depend on fishing activities for their livelihood [5].

2.3. Average Monthly Expenditures and income of Mozambican Families

Expenditure and income of the family members living in the country is an important topic when checking the ability and willingness to pay for any goods or services. Looking at the findings of the IOF (Inquérito ao Orçamento Familiar, Family Budget Questionnaire in English) 2014/15 it shows that the household families in urban areas have more than double of the consumption expenditures than the rural area [7]. The less severe poverty rates are found in the south and gradually worsen in the northern direction. This report points out the fact that on average Mozambique lives below the poverty line, with the less severe poverty rates (32.8%) found in the south, followed by 46.2% in the centre and 55.1% in the north [7, 8, 9].

The World Bank report [10] mentions that concerning household income, the main economic activities responsible for the income are commerce, agriculture and formal/informal work. In peri-urban areas, people are mainly involved in informal work (28,5%), commerce (24,6%), formal work (21, 8%), agriculture (12,3%), and other types of work (7,8%). Around 5,03% of the population inquired in these study mentioned that have no work [10]. In rural areas, people inquired have indicated that their main activities are agriculture (32,4%), followed by commerce (22,1%), informal work (21%), formal work (15%) and other types of work (3,3%). In these areas around 6,1% of the people inquired mentioned that they did not work.

In general, 60% of the people inquired in this study [10] have a secondary economic activity such as agriculture, commerce or informal work. It is important to note that the monthly income may be over or underestimated as those who practice informal work do not have a standard monthly income, since their income is based on how much is made per day and informal work may not be available every day neither carried out on a regular basis. Moreover, these households do not keep a record of their daily earnings, which could allow to establish an accurate estimative on their overall monthly income. Considering all the above facts, Figure 7 presents the population distribution by location (rural and peri-urban) for each range of monthly income.

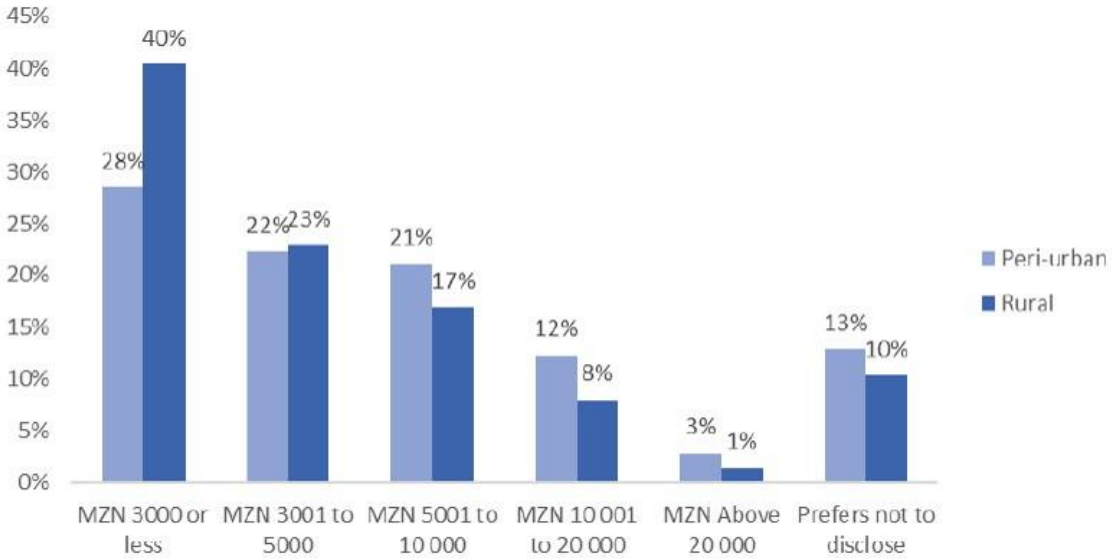

FIGURE 7- FAMILIES MONTHLY INCOME DISTRIBUTION BY LOCATION, $1 USD IS EQUAL TO 73 MZN. SOURCE: [10].

Table 1 presents the income threshold in Mozambique based on minimum wage [10].

TABLE 1- INCOME THRESHOLDS IN MOZAMBIQUE[6]

Income Threshold		(Monthly) Income Bracket
Low-income		< MZN 6.000
Low-middle income		MZN between 6001 – 20.000
Upper-middle income		MZN between 20.001 - 40.000
High-income		> MZN 40.001

The 2018 World Bank report on off-grid market assessment [8] presents information regarding families average monthly expenditures on different goods and services. This information is presented in Table 2 below.

[6] Updated from: http://www.salaryexplorer.com/salary-survey.php?loc=147&loctype=1

Table 2 - *Average household monthly expenditure[7]. Source: [Adapted from 10]*

Expenditure	Peri-urban	Rural	Overall
Average monthly expenditure on rent	MZN 57.49	MZN 49.48	MZN 53.14
Average monthly expenditure on cooking fuels	MZN 562.16	MZN 224.52	MZN 378.70
Average monthly expenditure on energy for light and food conservation	MZN 346.84	MZN 291.55	MZN 319.20
Average monthly expenditure on food	MZN 2,561.30	MZN 1,784.95	MZN 2,139.45
Average monthly expenditure on healthcare	MZN 176.27	MZN 152.75	MZN 163.49
Average monthly expenditure on transportation	MZN 683.06	MZN 369.44	MZN 512.65
Average monthly expenditure on mobile phone credit	MZN 454.01	MZN 277.40	MZN 358.04
Average monthly expenditure on charging phone battery	MZN 164.36	MZN 189.74	MZN 177.05
Average monthly expenditure on schooling	MZN 121.73	MZN 78.82	MZN 98.42
Average monthly expenditure on entertainment	MZN 363.44	MZN 239.56	MZN 296.13
Average monthly expenditure on batteries for the radio	MZN 284.11	MZN 248.82	MZN 266.46
Estimated average monthly expenditure per household	MZN 5,774.77	MZN 3,907.03	MZN 4,762.73

The number of families in each income range combined with the average expenditures gives a good indication of the market conditions and also on families purchasing capacity for a potential implementation of energy efficiency programme.

2.4. Institutional and Legal Framework

The key players in the power sector of Mozambique are described below and summarized in Figure 8.

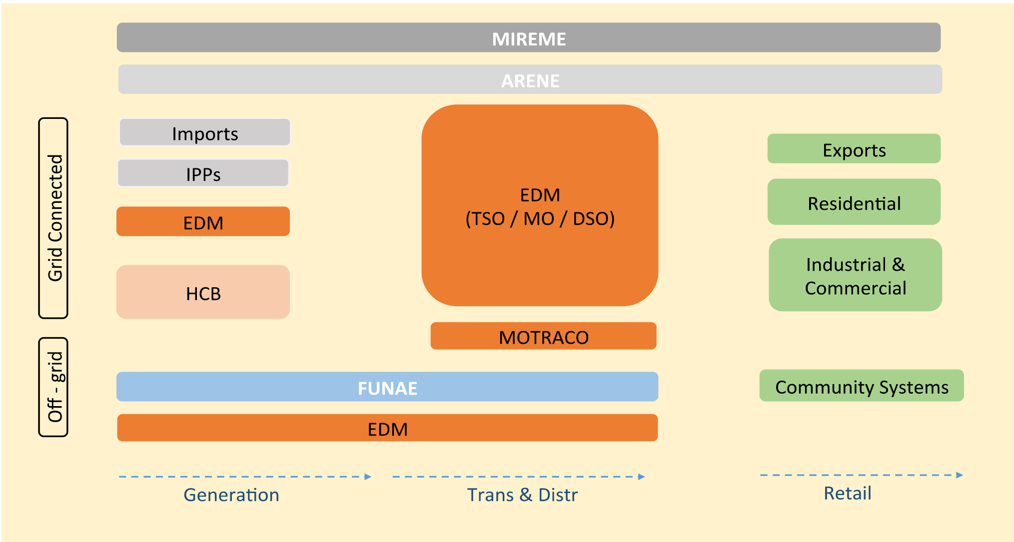

FIGURE 8- MOZAMBIQUE KEY STAKEHOLDERS IN THE ENERGY SECTOR[8]. SOURCE: [11].

[7] The values in Table 2 are related to the Average income of 2018. More recent data could not be obtained

[8] *TSO: Transmission System Operator; MO: Market Operator; DSO: Distribution System Operator*

MIREME

The Ministry of Mineral Resources and Energy (MIREME) is responsible for national energy planning, policy formulation and overseeing the operation and development of the energy sector.

One of the major governmental objectives is to achieve the target of universal access to energy by 2030. MIREME is currently working on the review of the electricity law (originally drawn up in 1997) to adapt the legal framework to the current context and country needs. The new electricity law is expected to be completed somewhere in 2021.

ARENE

In August 2017, the Parliament approved a Law (Law Nr. 11/2017, of 8 September) that created an independent Energy Regulatory Authority, ARENE, to oversee the power sector. ARENE activities are supervised by the Minister of Energy and Natural Resources. Among the main responsibilities that were given to ARENE by the Law include: setting and approval of tariffs, tendering process for new projects as well as the performance monitoring of the regulated concessionaires.

To become a fully operational Regulatory Authority in the energy market, it is crucial to open the market to the private sectors for a fair and transparent competition. Indeed, the role of regulators in non-competitive markets is to "simulate” competitive market environment, enforcing non-monopolistic behaviours by the service providers.

EDM

Electricidade de Mocambique (EDM) was founded in 1977. The decree 28/95 from 17th of July 1995 transformed EDM into a state-owned company regulated by Law regarding “State Owned Companies” (17/91). EDM is a legal entity of public law, granted administrative and financial autonomy and currently dependent on the Ministry of Mineral Resources and Energy. EDM is the major electricity supplier and also maintains the national grid system.

EDM is in charge of generation, transmission and distribution, although it only has a limited generation capacity of its own. Hidroeléctrica de Cahora Bassa (HCB), a company jointly owned by Portugal and Mozambique, is the major generator and the largest hydroelectric scheme in Southern Africa providing almost 80% of the installed capacity in the country.

FUNAE

The Energy Fund (Fundo de Energia, FUNAE) is a Public Fund (Fundo Público) endowed with legal personality, administrative, financial and patrimonial autonomy. Recently, the Government adjusted FUNAE's attributions, management mechanisms, budgetary regime, supervision, organization and functioning.

Among its attributions, FUNAE can do the design, implementation and development of energy projects and services in rural areas. So, while under the previous legislation one could contest the legal foundations under which FUNAE could carry out the development of energy project, the new legislation came to clarify and expressly provide for that possibility.

FUNAE is dedicated to expanding the energy access at low cost to rural and urban areas, it operates two types of grids systems:

- Mini grids
- Solar home systems.

HCB

HCB is the operator of the Cahora Bassa Dam that was built in 1969. It is the largest power producer in the country with an installed capacity of 2,075 MW. The Mozambican government has increased its stake over the decades, and currently owns 92.5% of the company.

MOTRACO

MOTRACO is an Independent Transmission Company (ITC) owned in equal shares by EDM, ESKOM and SEB. MOTRACO is responsible to provide reliable supply of electricity to MOZAL and is wheeling power to EDM in Mozambique and SEC in Eswatini (ex-Swaziland). The main grid connected Independent Power Producers (IPP) are:

FIGURE 9- MAIN IPP STAKEHOLDERS. SOURCE: [11, 12, 13, 14, 15,16].

Hidroeléctrica de Cahora Bassa(HCB) an Independent Power Producer (IPP) that was owned (92.5%) by the Government of Mozambique and REN of Portugal (7.5) the hydroelectric plant in 2019 sold 2.5% of the shares representing its share capital to Mozambican citizens and companies
Central Termoelétrica de Ressano Garcia (CTRG) an Independent Power Producer (IPP). Owned 51% by EDM. 49% by SASOL. responsible for the generation of electricity in region south (175 MW)
Central Térmica de Gigawatt (CTG) an Independent Power Producer (IPP). Owned Old Mutual Ltd. Gigajoule Inter. MGC. responsible for the generation of electricity in region south (120 MW)
Kuvaninga Gas fired power Plant: Independent Power Producer (IPP). Owned by Investec. Eventure and SPI for the generation of electricity in region south (40 MW)
Central Térmica de Maputo (CTM): Gas fired Power generation. Owned 100% by EDM. responsible for the generation of electricity in region south (106 MW)
Mocuba Solar Plant: Independent Power Producer (IPP). Owned 25% by EDM. Scatec 52.5% and Norfund 22.5%. responsible for the 41 MW generation of electricity in northern region
Metoro Solar Plant: 40MW Owned 75% by Neon and 25% by EDM

Most relevant legislation and regulations

- **Law 21/97 (Electricity law)** opens the electrical sector to private initiatives and sets the legal framework for the activities of production, transmission, distribution and trading of electricity, as well as their import and export and creates the National Electricity Council – CNELEC (now ARENE). This Electricity Law has been under revision due to the need to adjust the general legal framework of the electrical energy sector in Mozambique, consistent with the evolving changes in the domestic and regional electricity sector;

- **Biofuels Policy and Strategy** - The Biofuels Policy and Strategy defines the most relevant policy guidelines and measures for biofuels development. The main objectives of this strategy include the promotion of energy security using local resources, rural development, diversification of the energy matrix, increase the productivity and promote sustainable development and preservation of the environment;

- A new proposal for the Electricity law is expected to be approved during 2021;

- **Decree 8/2000**, establishes the responsibilities and procedures for granting of concessions for generation, transmission, distribution and sale of electricity, as well as import and export;

- **Decree 42/2005,** establishes the rules on planning, financing, construction, ownership, and maintenance of production, transmission, distribution and sale of electric energy as well as the standards and procedures for the management, operation and overall development of transmission national grid;

- **Decree 43/2005**, Appoints Electricidade de Moçambique (EDM), State Own Company, as the manager of the Transmission National Grid, with the role of Market and System Operator;

- **Act No. 15/2011**, Law of public-private partnerships, establishes the guidelines of the contracting process, implementation and monitoring of projects of public-private partnerships, to large projects and business concessions;

- **Law 11/2017,** establish the energy regulatory authority (**ARENE**) for the subsectors of electricity, renewable energy, liquid fuels and the distribution and sale of natural gas;

- **Resolution 10/2009**, Energy Strategy, it reaffirms the determination to provide disadvantaged populations with access to modern energy and to diversify the national energy matrix, with particular emphasis on renewable sources.

Renewable Energy Strategy

- Aims to introduce substantially the clean energy technology over 15 years period (2011 – 2025);

- It recognizes accelerating electrification efforts giving priority to rural areas, through the expansion and intensification of the national grid, the utilization of renewables, the optimization of low-cost solutions;
- The introduction of measures which will ensure productive and efficient use of electricity;
- It recognizes the relevant role of the private sector participation in development of the renewable energy projects.

Other strategic documents in the power sector and relevant programmes

- Integrated Master Plan for Energy Infrastructure 2018-2043 - It aims to increase the country's capacity to generate, consume and export electricity. It includes the national investment plan in the areas of Production, Transportation and Distribution of electricity, including generation electricity mixt (matrix);
- National Electrification Strategy and Plan 2018 – 2030 - Launched by the GoM (Government of Mozambique) in November 2018, under the National Energy for All Program, with the aim to reach all Mozambicans with electricity access by 2030;

- EDM 10 Years Strategy 2018-2028 - Adopted to respond to the GoM commitment to grant universal access to electricity by 2030. The need to integrate renewables with the national grid is highlighted and also development of commercial off-grid systems for remote areas;

- PROLER (Programa de leilões de energia renovável or renewable energy auctions in English)- Is a programme financed by EU/AFD (European Union and the Agence Française de Développement or French Development Agency in English) for the development of the technical, financial and legal framework for competitive auction schemes for renewable energy projects. This project already launched in 2020 the first national auction for 1 solar and is expected to launch another 2 solar and 1 wind projects in Mozambique (large projects of 40 MW each);

- GET.invest (mini-grids, solar home, lanterns) - Is a European programme to support investment in decentralized renewable energy systems in partner countries. In Mozambique, the project is involved among others on:

    - Mobilize the market: Market Insights, Events, B2B matchmaking, Support to AMER (Associação Moçambicana de Energias Renováveis or Mozambican renewable energy Association in English);
    - Support pipeline of projects: Finance Catalyst, Project Documentation Development;
    - Support favorable enabling environment: Training with Government, Businesses, Financiers, Workshops, etc.;

- GetFit - Creates a platform for Mozambique to harness potential for renewable energy. The programme includes the preparation of the technical, financial and legal frameworks for launching auctions for solar and wind projects (small scale) in Mozambique. This platform allows to:

    - Creates a financing mechanism to leverage private investment for infrastructure projects;
    - Standardized PPA template (with PROLER);

- Invest up to 90 Million Euros and leverages at least 220 Million Euros private investments for the installation of 130 MW of renewable energy which will serve up to 300.000 Mozambicans in the poorest areas;
- Reduce at least 350.000 tons of CO_2 emission per year;

- Brilho (Solar Home Systems and lanterns) - This programme is supported by the United Kingdom and aims to increase domestic and commercial energy access in the rural communities through private sector innovation and investment, and government support, through supply of dispersed off-grid energy solutions (solar home systems and mini-grids) and improved cook stoves;

- **Energy for all (ProEnergia) - Environmental and Social Management Framework –** This project started in 2019 and had a duration of four years. It intends to intensify the access to electricity for households, enterprises and communities. The ProEnergia project represents the operationalization of the National Electrification Strategy. Its main objective is to connect households and companies through grid connected and off-grid systems, based on a sustainable electrification approach incorporating proven international experience, technical assistance and capacity building support;

- RERD2+ - Rural Electrification for Rural Development phase 2 - This programme is the second phase of the RERD programme and includes embedded technical assistance to FUNAE on the implementation of mini-grids and solar irrigation systems. The collaboration between FUNAE and Enabel started in 2011, the programme is funded by the Belgian Government and implemented by Enabel, the Belgian Development Agency, with FUNAE and INIR (Instituto Nacional de Irrigação or National Institute of Irrigation in English). It aims to increase domestic and commercial energy access in rural communities by supplying hybrid mini-grids and solar irrigation systems in three provinces, and technical assistance to FUNAE and INIR with embedded experts to improve the technical and financial sustainability of existing systems and the capacity of FUNAE in planning and project management.

3. Mozambique Energy Sector Characterization

3.1. Electricity Sector in Mozambique

The current electricity context in Mozambique is characterized by several transformations in the sector with emphasis on strengthening its matrix source, especially the use of gas added to the high hydroelectric potential, mineral coal and renewable energy sources. Despite the vast energy potential, the current panorama in terms of consumption in the country is still quite unfavourable:

- Domestic access to electricity was 30% in 2018 (see Figure 10);

FIGURE 10- EVOLUTION OF THE ACCESS TO ELECTRICITY (URBAN AND RURAL) IN MOZAMBIQUE BETWEEN 1980 TO 2018. SOURCE: [6].

- The situation is even worse in rural areas where 66% of the Mozambican population live, with an electricity access rate below 7% (see Figure 11) [6, 7, 17, 18];

FIGURE 11 - EVOLUTION OF THE ACCESS TO ELECTRICITY IN RURAL AREAS IN MOZAMBIQUE BETWEEN 1990-2018. SOURCE: [6].

- Most of the population still uses firewood and charcoal as their main energy sources for cooking, and oil for lighting (Figure 12) [6, 17, 18].

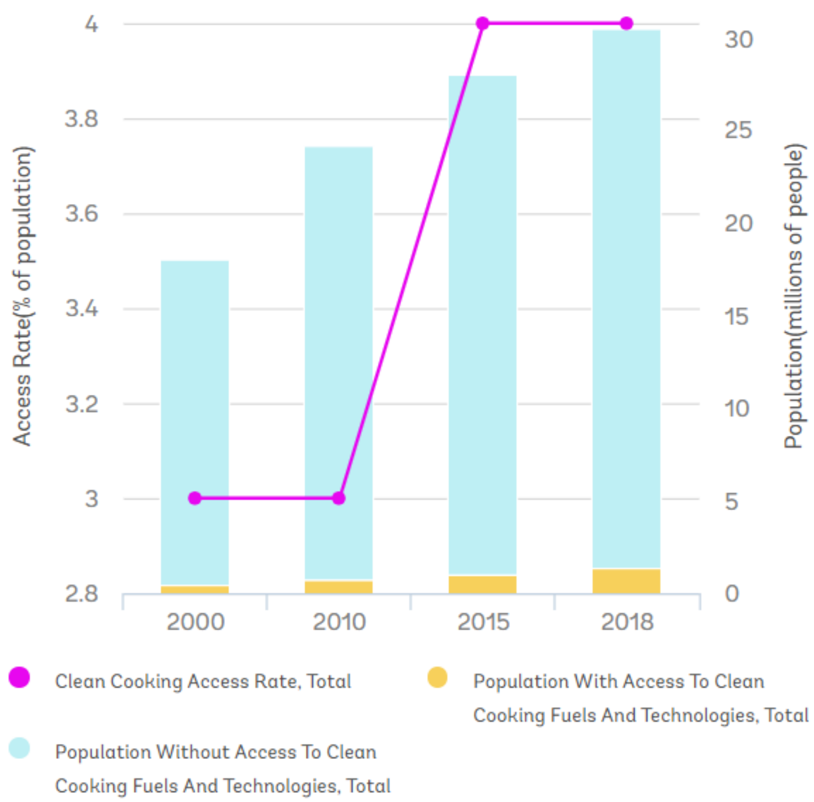

FIGURE 12 - ACCESS TO CLEAN COOKING IN MOZAMBIQUE BETWEEN 2000-2018. SOURCE: [6].

Table 3 presents Mozambique total installed capacity by energy source, ownership of the project and type of producer (Independent Power Producer- IPP or Eletricidade de Moçambique- EDM).

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Table 3- Mozambique total installed capacity

PROJECT NAME	INSTALLED CAPACITY [MW]	SOURCE	OWNERSHIP	TYPE OF PRODUCER
HCB	2075	HYDRO	HCB	IPP
MAVUZI	52	HYDRO	EDM	EDM
CHICAMBA	44	HYDRO	EDM	EDM
CORUMANA	16,6	HYDRO	EDM	EDM
CUAMBA	1,09	HYDRO	EDM	EDM
LICHINGA	0,76	HYDRO	EDM	EDM
MAPUTO, CTM	24	DIESEL	EDM	EDM
PEQ.LIBOMB	1,5	HYDRO IPP	ARA SUL	IPP
SEMBEZEIA	0,062	HYDRO	FUNAE	IPP
MUOHA	0,1	HYDRO	FUNAE	IPP
ELGAS	1,5	GAS	ELGAS	IPP
TEMANE	11,6	GAS	EDM	EDM
CTRG	175	GAS IPP	EDM-SASOL	IPP
GIGAWATT	120	GAS IPP	GIGAWATT	IPP
CTM	106	CCGT, GAS	EDM	EDM
KUVANINGA	40	GAS IPP	KUVAN	IPP
MUEMBE	0,4	SOLAR	FUNAE	IPP
MAVAGO	0,55	SOLAR	FUNAE	IPP
MECULA	0,35	SOLAR	FUNAE	IPP
MARAGRA	10	BAGASSE	MARAGRA	IPP
GT35 BEIRA	14	DIESEL	EDM	EDM
MOCUBA	40	SOLAR	IPP	IPP
NACALA SHIP	100	HPO, IPP	KARPOWER	IPP
MAIAUA, ZAMBEZIA	0,6	HYDRO,IPP	FUNAE	IPP (Off-Grid)
ROTANDA, MANICA[9]	0,57	HYDRO,IPP	FUNAE	IPP

In 2016, Mozambique installed generation capacity was 2.6GW, and Cahora Bassa the largest hydro plant was responsible for 78% of this capacity. The remaining capacity was comprised of thermal plants and small hydro.

EDM oversees around 20% of the country generating capacity and purchases power from IPP (Independent Power Producers) and the 2.1GW HCB facility (Cahora Bassa Hydro). HCB vast size means that hydroelectric generation dominates Mozambique energy sector, with 70% of the capacity mix in 2019. However, natural gas and renewable energy occupy a growing share of Mozambique energy mix [11].

[9] Under rehabilitation

Most of the electricity produced is largely exported to neighbouring countries, such as South Africa and Zimbabwe. From Table 3 above it is possible to observe that the total installed capacity is around 2835 MW, of which 2191MW have hydroelectric source and 454MW are from natural gas.

3.2 Country Energy Production

The Country energy production from 1971 to 2013 is presented in the Figure 13 where it stands out the exponential growth as from 1997 [19].

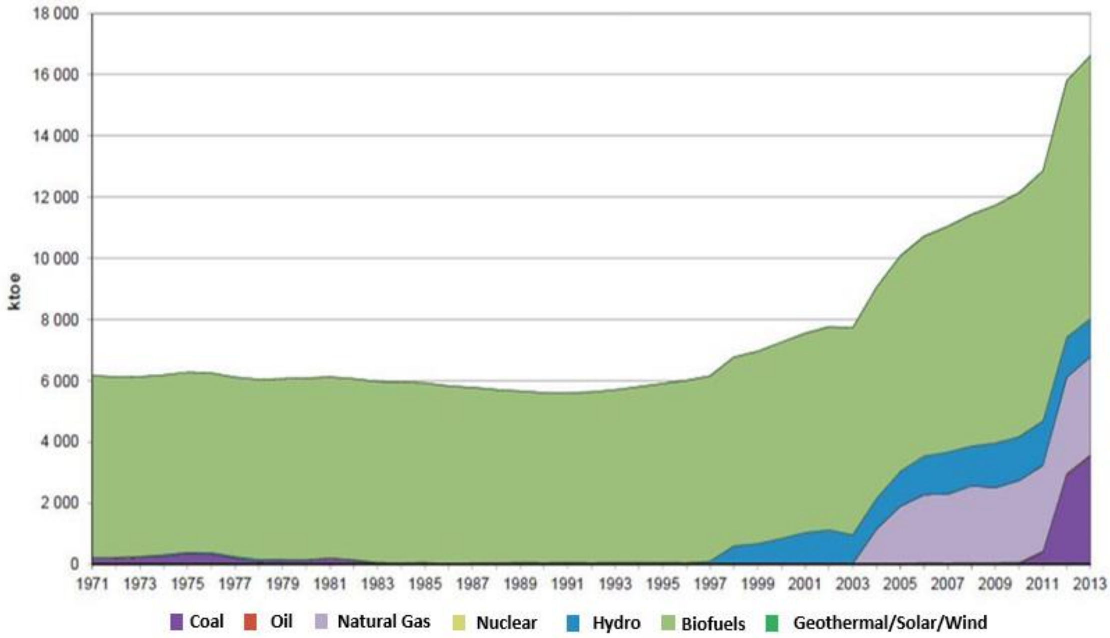


FIGURE 13- MOZAMBIQUE ENERGY PRODUCTION MIX. SOURCE: [19].

The renewable energy source, biomass (charcoal and fuelwood) has been the main source of energy. From 1997 hydropower has become important, the year HCB resumed its operation. In 2013 the total energy production was around 16,700 ktoe. The natural gas was produced by SASOL since 2004 and more than 90% exported to South Africa. Regarding coal, a number of mining companies started operating in 2011 mostly for export.

3.3. Country Energy Consumption

Figure 14 presents the historic data from 2000 to 2014, the average energy consumption rate was 3% per year on that period. Biomass is by far the energy source most consumed in the country, but its growth rate was only 2% per year on average. Electricity is the energy source that has increased the most with 8%, followed by oil products 7% [19, 20, 21].

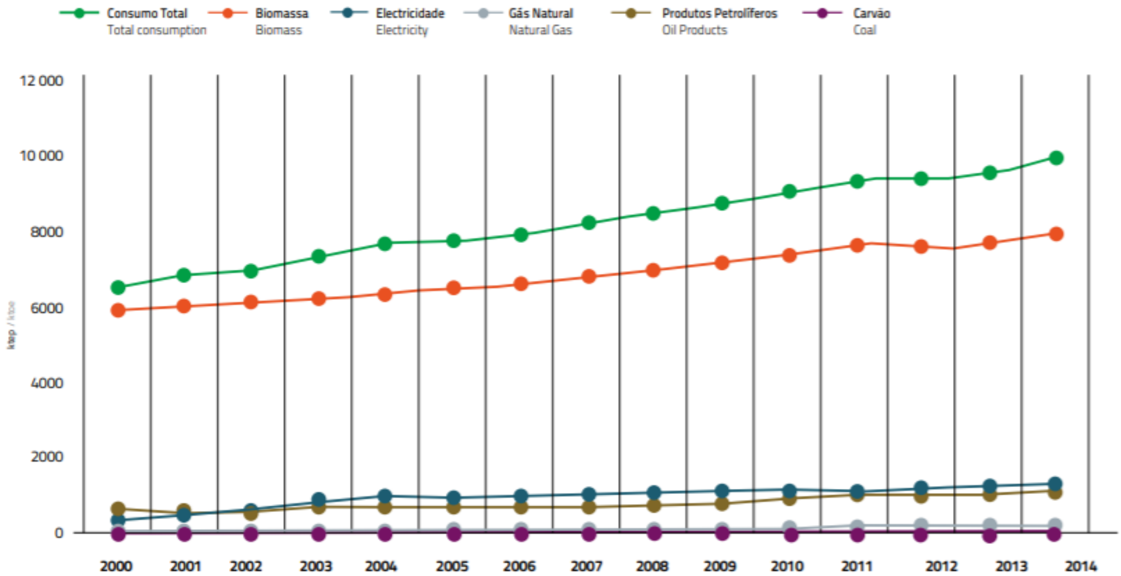


FIGURE 14- MOZAMBIQUE ENERGY CONSUMPTION PROFILE. SOURCE: [19].

3.4. Electricity Demand Forecast 2020-2030

Figure 15 presents the power availability and demand forecast for the 2007-2027 period. After this period, the least-cost generation expansion plan predicted in the Mozambique Integrated Master Plan [20, 22] will allow Mozambique to have an energy surplus which can be traded at a competitive price in the regional market.

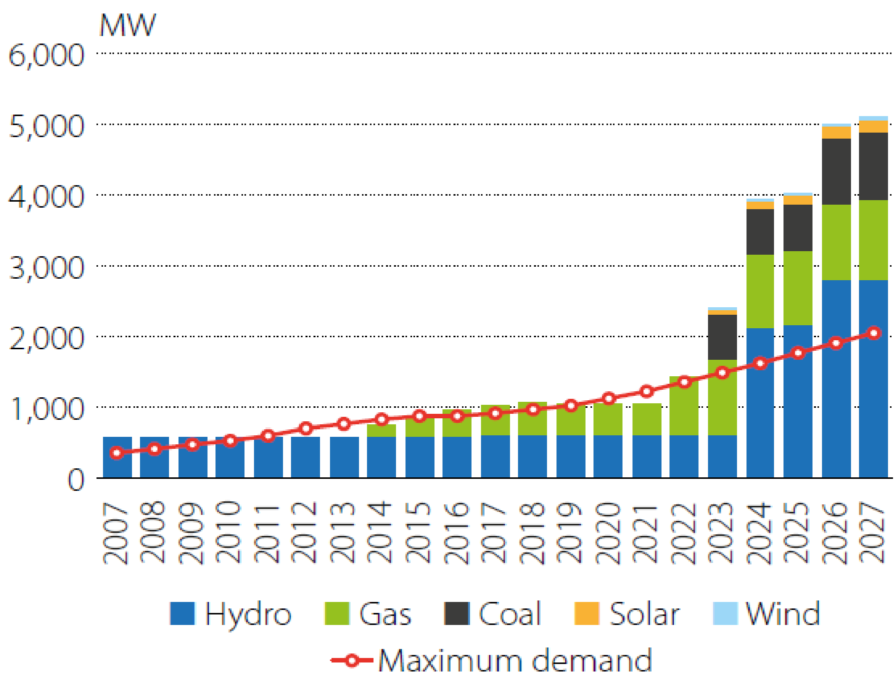


FIGURE 15 - MOZAMBIQUE ENERGY CONSUMPTION VERSUS ENERGY DEMAND 2007-2027. SOURCE: [22].

Different scenarios have been considered to establish the load demand forecast: Low case, Base Case and High Case scenarios. The Integrated Master Plan [22] study will be updated accordingly on a yearly basis as of Figure 16.
Figure 16

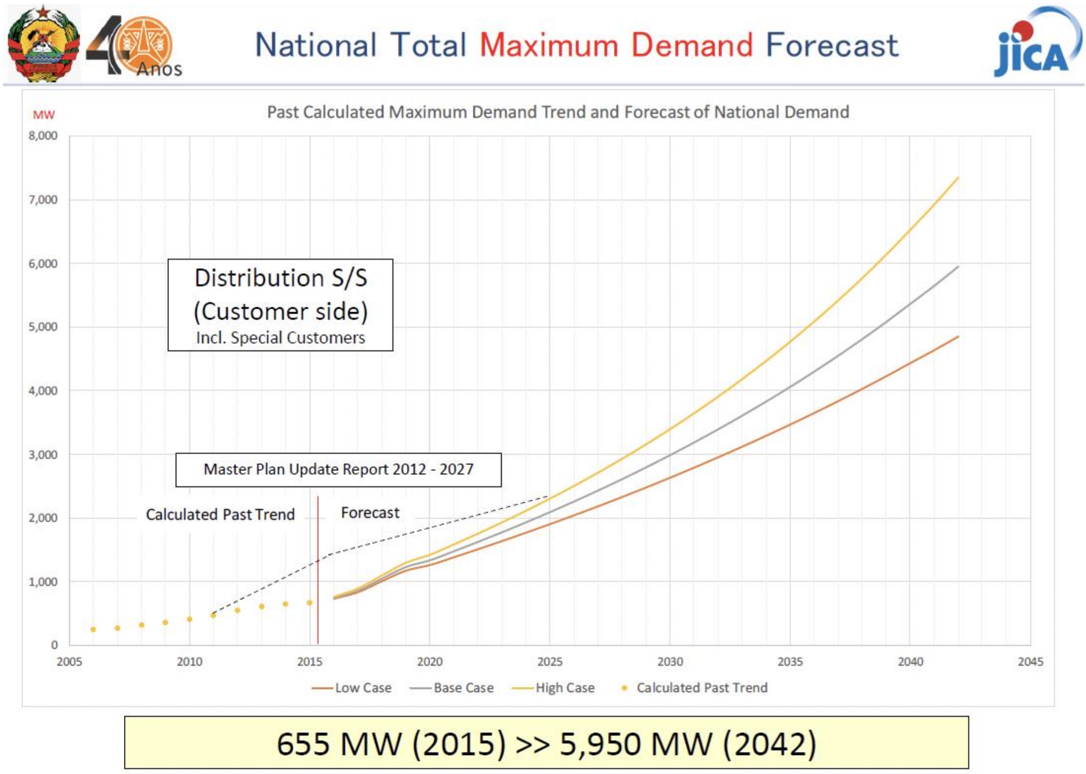


FIGURE 16- CALCULATED MAXIMUM DEMAND AND FORECAST OF NATIONAL DEMAND. SOURCE: [22].

3.5 Energy Efficiency Current Implementation

Mozambique does not have a specific program for coordinated development of Energy Efficiency activities, although there is a reference in the Energy Strategy of the importance and necessity to observe the good practices for the sustainable and efficient use of the country energy resources.

In practice, isolated initiatives on Energy Efficiency are carried out by different public and private entities mainly by the DNE (National Directorate of Energy), the Academia, EDM, FUNAE, in some cases with the support of cooperation partners. Here are some examples:

- From 1999 to 2006 a programme on Energy Management was carried out jointly by DNE/MIREME and the Faculty of Engineering from University Eduardo Mondlane, contemplating Training, Survey to Determine the Potential on EM in the provinces of Manica, Sofala and Nampula, Promotional Seminars, Workshop on EM in Buildings, Pilot program on EM in Public Buildings, seminars for awareness and energy audit and reporting. During that period personnel from different industries were trained including Mabor, Riopele, FASOL, Lusalite, Companhia Industrial da Matola, Indústria Moçambicana de Aço, Texlom, Ceres, Ginwala & Filhos, Protal, Cimentos da Matola, *Cimentos de Dondo, Açucareira de Mafambisse, Moçambique Industrial, Coca Cola, Mobeira, Cervejas de Moçambique, etc.;*

- EDM realized DSM (Demand Side Management) is one of the effective approaches against the demand increase and organized a department, Energy Efficiency Directorate (EED), in 2010, so that EDM could promote the activities on energy efficiency especially. In addition, EDM prepared the Energy Efficiency and Demand Side Management Strategy / Master Plan, Demand Market Participation (DMP) Strategy based on the proposal of the consultant to accelerate DSM activities[10];

- EDM have conducted a project in the northern region, Nampula, Nacala and Pemba in which incandescent lamps were changed with CFL (Compact Fluorescent Lamp) for free. The project replaced about 550,000 lamps and about 22MW power reduction has been achieved. Amount of CO_2 emission was reduced 45,250 tons/year as well. In this project, EDM held on-site meetings to get the residents understandings in advance[2]. There are ongoing initiatives of replacing high pressure sodium lamps by LED in the street lighting and so far more than 7,000 fixtures have been replaced in Maputo and Matola;

- Mozambique trough DNE, EDM and the private sector is involved in the EELA (Energy Efficiency Lighting and Appliances) project that provides support for innovative delivery models for energy efficient services and products such as those provided by Energy Service Companies (ESCOs) and other Public-Private Partnerships or private initiatives. EELA mission is to support the development of vibrant markets where suppliers are delivering high-quality services and products for energy efficient lighting and appliances to increasingly aware households, businesses and public facilities across East and Southern Africa.

- An Energy Efficiency working group (EEWG) has been active for many years mainly on lobbying activities and proposals to develop a National Energy Efficiency Roadmap. The members of EEWG are volunteers from DNE, EDM, UEM (University Eduardo Mondlane), CTA (Confederation of Mozambique Economic Associations) and Petroauto.

- The Energising Development (EnDev) programme, managed by the Deutsche Gesellschaft fur Internationale Zusammenarbeit (GIZ), supports the local production of improved cook stoves and the improvement of their quality, the importation of industrial stoves and the marketing of these technologies. To this end, it cooperates with strategic Non-Governmental Organizations (NGOs) such as Sofala Local Economic Development Agency (ADEL), KULIMA, Association of Volunteers in International Service (AVSI) and the Netherlands Development Organization (SNV) [15] ;

- Also integrated in the EnDev programme, SNV developed a programme to produce, distribute and sell efficient charcoal cook stoves, such as the Mbaula stove, which is 40% more efficient than traditional stoves in terms of coal consumption and toxic smoke emissions. The objective of this initiative is to provide access to efficient cooking solutions to 150000 families in the southern region of Mozambique thus fuelling the development of this market and enabling it to expand on its own and benefit the rest of the country3;

- Moreover, SNV implemented the Mozambique Improved Cooking Solutions Initiative (MICSI), to establish local production and commercially viable supply chains for selling improved cook stoves in Maputo province. The project, which finished in December

10- https://openjicareport.jica.go.jp/pdf/12318606.pdf

2017 should reach cumulative results of 195000 beneficiaries, or 32500 improved cook stoves3.

- Soltrain Project[11]

The Austrian Development Agency (ADA) and AEE - INTEC (Austrian Institute for Sustainable Technologies) set up a three year solar thermal energy project in cooperation with Southern African educational institutions, renewable energy institutions and companies in South Africa, Mozambique, Namibia and Zimbabwe;

Soltrain builds on a previous project, which ran from 2009 – 2012. The main activities of project are focused awareness campaigns on focuses on increasing awareness, capacity building, strengthening sustainable institutional structures and developing a road map for solar thermal energy use. It will inform all relevant stakeholders and the interested population about the different applications of solar thermal energy and the related impact on security of energy supply, poverty, employment and on the environment.

Another major activity is to implement a sustainable institutional structure and focal points for solar thermal information, training, support for industry and policy as well as for applied research. The Centres of Competence will be implemented in institutions of higher education in each country. The Centres of Competence are going to carry out a comprehensive training programme, ranging from practical hands-on training to University level courses.

Furthermore "Solar Thermal Technology Platforms" (STTP) will be implemented into all Centres of Competence in each partner country. These national platforms will be cross-linked to a Southern African Solar Thermal Technology Platform in order to enhance the information exchange and the cooperation between the platforms.

In order to apply the knowledge gained during the training courses, and to increase the public awareness, 40 to 50 solar thermal demonstration systems of different sizes and applications will be installed at social institutions and small and medium enterprises.

- ENABEL projects of capacity strengthening MIREME, ARENE and FUNAE: The Belgian Development Agency ENABEL supports the energy sector in Mozambique through two bilateral interventions, Capacity buildings Mireme/Arene and RERD2. These interventions aim to contribute to the economic productivity and social service delivery in rural Mozambique through the provision of access to sustainable, affordable and environment-friendly energy. Emphasis is put on capacity development, energy efficiency and access to off-grid renewable energy. At present, major relevant initiatives relate to improved data collection, management, analysis and storage and enhanced, including Geographic Information System (GIS) applications, investment in solar and hydro-minigrids, dissemination of simplified information on renewable and efficient energy, enhanced human resources capacity in energy sector modelling and planning, gender mainstreaming, as well as support to regulatory development and monitoring capacity within both MIREME and ARENE.

11 - https://www.soltrain.org/news/new-report-from-wwfsa-industrial-scale-solar-heat-in-sa

The following list presents some of initiatives under implementation:

1. ***Lighting***

a) Replacement of 550000 Incandescent bulbs by CFL in the North Region (Nampula, Nacala and Pemba) with estimated savings of 22MW (EDM);
b) Under study (through Sweden Embassy support) a Project Document for Replacement of all outstanding incandescent bulbs in domestic customers (Final Report to be handed over to EDM in February 2021) (EDM);
c) Ongoing (through EDM Funds) replacement of 7000 Sodium High Pressure Luminaries by LED Luminaries in the Cities of Maputo and Matola (EDM);
d) Installation of 50 Pilot Solar Streetlights with LEDs. Ongoing tests and evaluation;
e) Ongoing development of MEPS for lighting through SACREEE EELA Project (MIREME - DNE).

2. ***Reactive Power Compensation***

a) EDM is conducting free energy audits and advising services to customers with very low power factor and high demand (EDM);
b) Under structure a financial scheme to EDM major customers for power factor correction (through UNFCCC by using the article 6 of the Paris Agreement) (EDM, MIREME, ARENE, MITADER – Ministry of Land, Environment and Rural Development).

3. ***Demand Side Management***

a) Ongoing (through EU Project Preparation Facility - Energy Resource Centre) Development of Time-Of-Use Tariffs Study with aim to level the load profile, reduce peaks and improve the systems load factor (EDM);
b) Awareness Campaigns (through TV and radio Spots and exhibition fairs) (EDM).

4. Sectoral Status Assessment

In Mozambique, according to EDM reports the clients are not categorized by activity sectors (e.g. Agriculture, residential, non-residential, and industrial). However, in our analysis we manage to group these clients according to their main activity and divided them by sector, this division is presented by Table 4.

TABLE 4 - CLIENT CLASSIFICATION ACCORDING TO EDM AND THE CLIENT CATEGORIZATION CONSIDERED IN THIS REPORT.

Type of Client	EDM Category	Sector
Regulated Clients	Domestic	Residential
	General-Commercial	Non-residential
	Low Voltage – Large Consumers	Non-residential
	Agriculture	Agriculture
	MV/HV (medium Voltage/High Voltage)	Industrial
Non-regulated Clients	Special Clients	Industrial

The electricity consumption in the agriculture sector was in 2019 only 0,5% (27 GWh) of the total energy sold by EDM [23]. Since the information regarding the end-use of this energy is not available and its weight in the total electricity consumption is quite small, decision to aggregate it in the non-residential consumption was made.

4.1. Characterization of the Residential Sector

The International Energy Agency (IEA) defines residential energy access as "a household having reliable and affordable access to both clean cooking facilities and to electricity, which is enough to supply a basic bundle of energy services initially, and then an increasing level of electricity over time to reach the regional average" [19].

The provision of secure, affordable and modern energy services for everyone is essential to improve the population quality of life, reduce poverty and improve the economic growth. Traditionally, the pathway to economic growth is a consequence of shifting from traditional agriculture and manufacturing to efficient agriculture and advanced industrialized processes, in the context of a knowledge-based economy. These structural changes are reflected in the energy consumption levels, in the used energy carriers and also in the energy technologies.

Economic and social development usually tends to go hand-in-hand with energy sector transformation. In developing countries, such as Mozambique, as families income starts increasing they usually start leaving the traditional use of biomass or low efficiency stoves for cooking and start buying appliances with high efficiency. This transformation makes the biomass consumption decline but the energy consumption (using other energy carriers such as electricity and gas) and the per-capita energy use rises, as presented in Figure 17 [22].

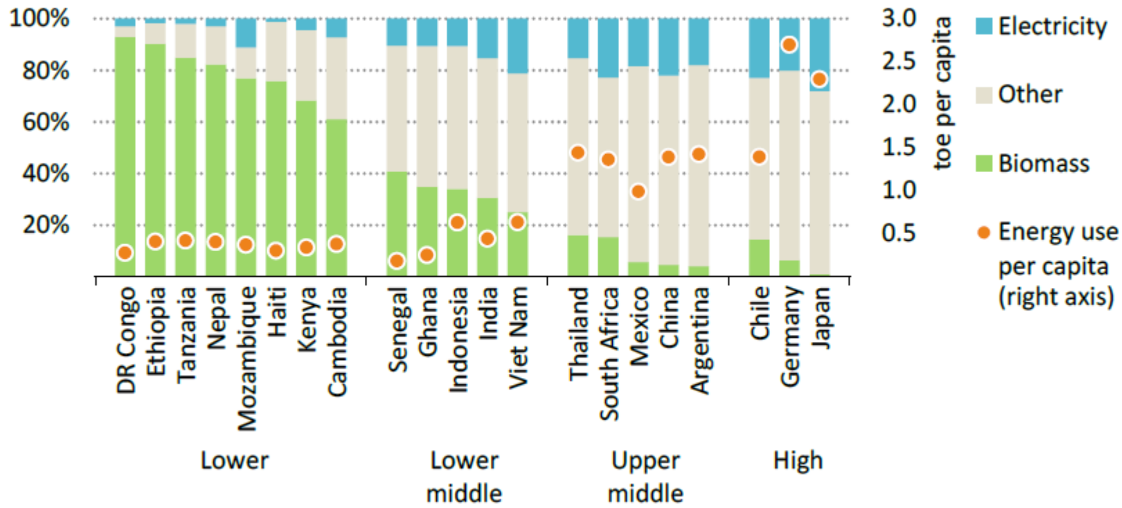


FIGURE 17 - FINAL ENERGY USE PER CAPITA AND FUEL MIX IN SELECTED LOW, MIDDLE AND HIGH-INCOME COUNTRIES IN 2015. SOURCE: [25].

In the last decade, the Mozambican authorities made an important effort (through the expansion of the national power grid and through the installation of several off-grid projects) to improve the population energy access rate. In 2018 the national electrification rate was around 30% of the country population [24]. However, the fast population growth rate led in the following years to a slower electrification rate, as well as led to a higher demand for energy in the residential sector.

In the end of 2020, the population access rate to electricity was around 32%, according to EDM (Eletricidade de Moçambique – Power utility) [24], which demonstrates the continued effort made by national authorities to increase the number of people with access to electricity. In urban areas the electrification rate is 67% and in rural areas is 8%, which means that although in both areas there is still a large percentage of the population without energy access, rural areas are in a critical situation.

The implementation of additional projects either on the expansion of the electric grid or on off-grid systems will increase the number of people being able to access electricity. As previously mentioned, it is probable that the demand of electricity will increase very fast in the residential sector, due to a strong population growth. The increase in the number of people having access to energy and the improvement of their socio-economic situation will also lead to an increase on appliances sales. It is important to prepare the appliances and lighting market with high efficiency products in order to reduce the impact of a larger number of equipment types consuming energy and prevent extremely high peaks of energy demand, which could lead to technical problems or even lack of ability to provide energy to all customers.

In Mozambique the residential sector represents around 30% of the country total electricity consumption [22]. Considering the foreseen growth in electricity demand it is important to establish a framework which will drive the market (appliances, lighting products, etc.) into high efficiency products allowing the country to increase the industrial competitive edge, decrease the pollution levels and provide families with ways to reduce their electricity bills.

4.1.1. Energy Consumption Disaggregation by Energy Source

In 2018 the number of households connected to the power grid was around 2,38 million (see Table 5) [23] and the number of households being supplied by off-grid systems was around 10 000, all in rural areas.

The following table presents the residential energy consumption by energy source and also the number of households per source of energy. The energy consumption presented in Table 5 is only for grid connected systems.

TABLE 5 - RESIDENTIAL SECTOR ENERGY CONSUMPTION DISAGGREGATION BY ENERGY SOURCE AND NUMBER OF HOUSEHOLDS IN 2018. SOURCE: [23].

Residential Sector - Energy consumption disaggregation by energy source						
	Number of households			**Total consumption per year [GWh/year]**		
Energy source	**Urban areas**	**Rural areas**	**Urban + Rural areas**	**Urban areas**	**Rural areas**	**Urban + Rural areas**
Electricity	1 680 000	350 000	2 030 000	1 199,9	300,0	1 499,9
Gas - LPG (Liquefied Petroleum Gas)	1 390 000	660 000	2 050 000	484,4	121,2	605,6
Gas - Kerosene	N/A[12]	N/A	N/A	85,6	81,0	166,6
Gas - Natural gas	N/A	N/A	N/A	419,2	0	419,2
Biomass - Wood	N/A	N/A	N/A	666,9	15 111,7	15 778,6
Biomass - Charcoal	N/A	N/A	N/A	3 153,3	1 624,2	4 777,5
Biomass - Agriculture residuals and wastes	N/A	N/A	N/A	4,2	411,1	415,3
TOTAL				6 013,5	17 649,2	23 662,7

From Table 5 it is possible to observe that electricity is the most widely used energy source in urban areas. Regarding gas, the most used type is the LPG (in bottles). However, in urban areas natural gas (NG) is available and its consumption is similar to LPG consumption. Biomass wood and agriculture residuals and wastes are still mostly used in rural areas. Kerosene is still used in urban areas for water heating and in rural areas for lighting.

Looking at Table 5, it is possible to observe that on average each household in rural areas consumes more electricity than urban households[13]. The reason for this might be the fact that families in urban areas typically have higher income and the equipment/appliances including lamps, used in their homes are more energy efficient and consuming less energy. Moreover, the electricity being consumed in urban areas could be higher if non-technical losses are considered in those areas (e.g. across the country these losses are close to 30% of the supplied electricity and more than 80% of those losses are believed to be in urban areas). These non-technical losses include illegal connections, which are more likely to exist in urban areas and are more difficult to be detected due to the very high number and density of consumers. In economic terms, Table 2 mentions that the average monthly expenditure on energy for lighting and food conservation is lower in rural areas than in urban areas. The reason

12 N/A – Not Available. This Information was not available during the elaboration of this document.

13 In average in urban areas the number of people per household is 4,5. In rural areas the number of people is 4,3.

for this, is the fact that most households in rural areas have access to social tariff, which is significantly lower than the domestic tariff widely used in the residential sector in urban areas.

4.1.2. Electricity Consumption Disaggregation by Appliance Type

Considering the electricity consumption in Table 5, it is important to understand which are the most energy consuming appliances/equipment types are used in the residential sector (see Table 6).

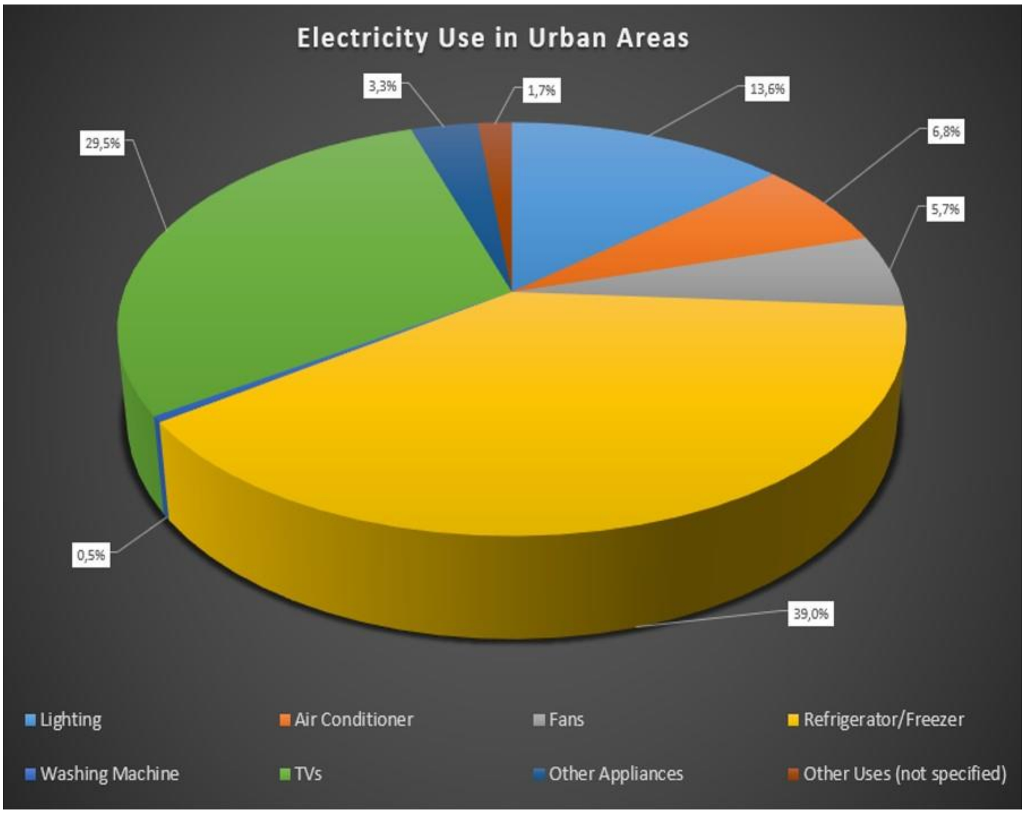
TABLE 6- RESIDENTIAL SECTOR DISAGGREGATION OF THE ELECTRICITY CONSUMPTION BY APPLIANCE/EQUIPMENT AND NUMBER OF HOUSEHOLDS IN 2018. SOURCE: [23].

Residential Sector - Electricity consumption disaggregation by appliance/equipment						
	Number of households			**Total consumption per year [GWh/year]**		
Type of Load	**Urban areas**	**Rural areas**	**Urban + Rural areas**	**Urban areas**	**Rural areas**	**Urban + Rural areas**
Refrigerators and Freezers	1 080 000	134 000	1 214 000	467,7	52,8	520,5
Lighting	1 680 000	350 000	2 030 000	163,0	95,2	258,2
Washing Machines	86 000	12 000	98 000	5,5	0,7	6,2
Air Conditioners	147 000	24 000	171 000	82,1	12,0	94.1
Televisions (TVs)	1 228 000	379 000	1 607 000	354,2	99,4	453,6
Fans	734 000	63 000	797 000	68,2	5,3	73,5
Electric Stoves	N/A	N/A	N/A	N/A	N/A	N/A
Water Heaters	N/A	N/A	N/A	N/A	N/A	N/A
Other appliances (not specified)	N/A[14]	N/A	N/A	39,3	23,0	62,3
Other uses (not specified)	N/A	N/A	N/A	19,9	11,6	31.5
TOTAL				1 199,9	300,0	1 499,9

Table 6 shows that in urban areas the most energy consuming appliances are the refrigerators and freezers, followed by televisions and lighting. In rural areas the televisions are responsible for the largest consumption, followed by lighting and refrigerators and freezers. This difference between urban and rural might be explained by the fact that usually people in cities have better economic situation, which allows them to buy appliances with higher acquisition costs (e.g. refrigerators and freezers) and also because in rural areas the access/availability to electricity is limited in power.

Figure 18 presents a percentage breakdown on the electricity use by appliance type in urban and rural areas.

14- N/A – Not Available. This Information was not available during the elaboration of this document.



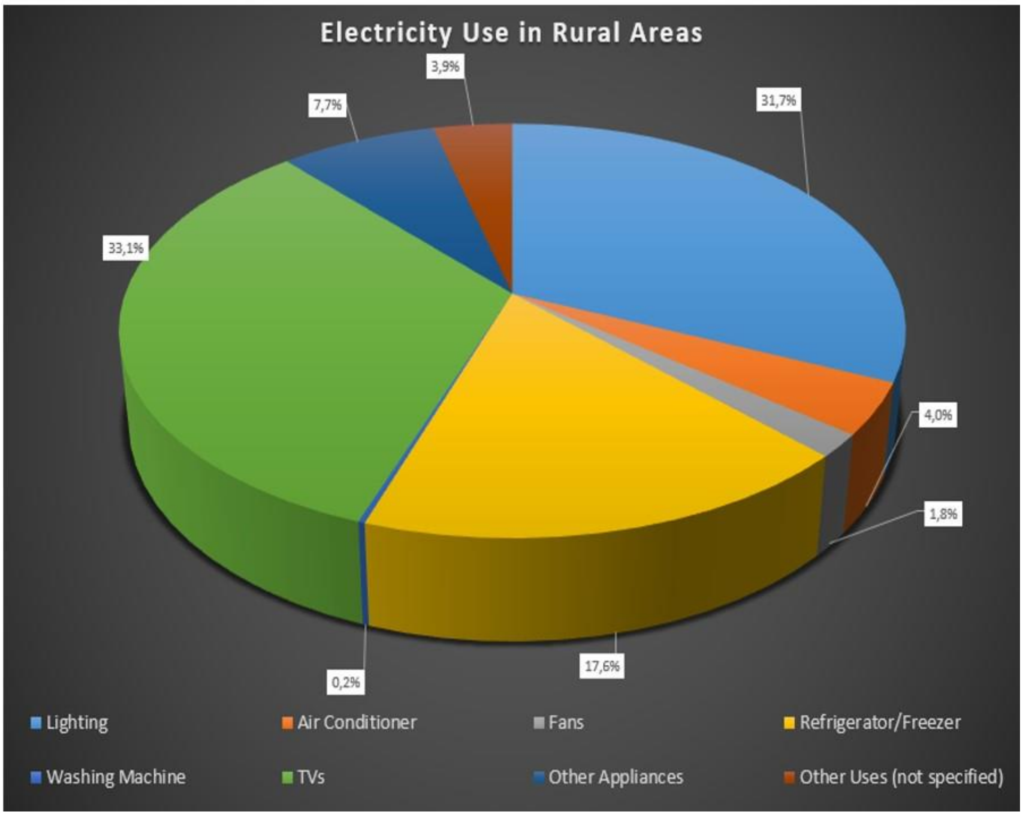


FIGURE 18 - ELECTRICITY USE BY LOCATION (URBAN ON THE TOP AND RURAL ON THE BOTTOM). SOURCE: [23].

As previously mentioned, in urban areas the most electricity consuming appliances are the refrigerators and freezers with 39% of all electricity consumption, televisions represent 29,5% and lighting 13,6%. In rural areas televisions consume 33,1%, lighting 31,7% and refrigerators and freezers 17,6% of all electricity.

4.1.3. Gas Consumption Disaggregation by Equipment

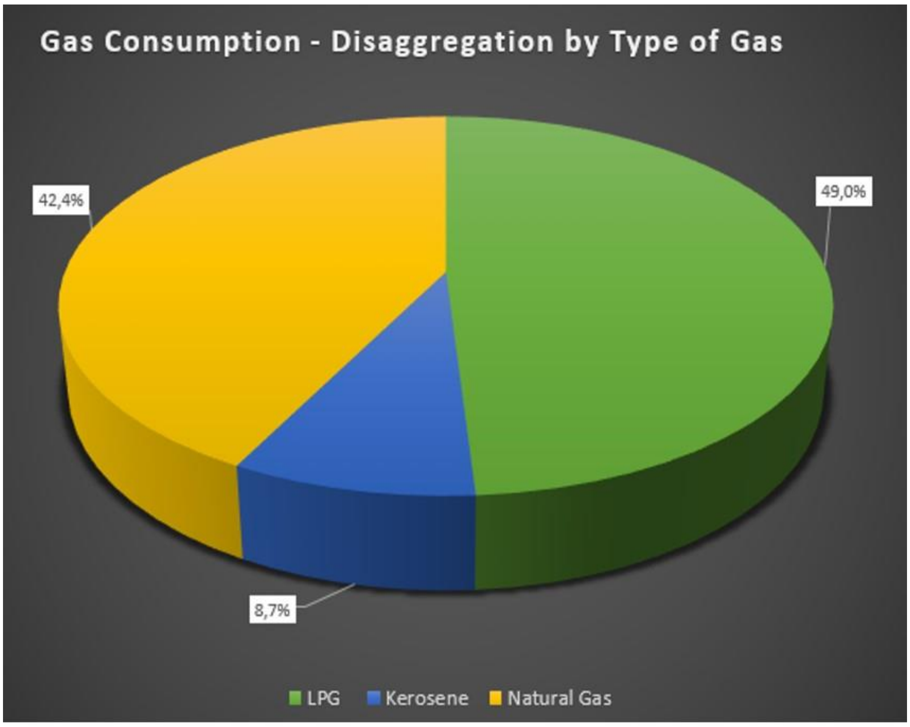
In the residential sector in Mozambique, gas is mainly used for cooking and water heating. Table 7 presents the gas consumption disaggregation by load type (equipment) and by the type of gas, as well as the number of households in urban and rural areas using each type of gas.

TABLE 7- RESIDENTIAL SECTOR DISAGGREGATION OF THE GAS CONSUMPTION BY USE AND NUMBER OF HOUSEHOLDS IN 2018 SOURCE: [23].

Residential Sector - Gas consumption disaggregation by load type (equipment) and type of gas						
	Number of households			**Total consumption per year [GWh/year]**		
Type of Load	**Urban areas**	**Rural areas**	**Urban + Rural areas**	**Urban areas**	**Rural areas**	**Urban + Rural areas**
Cooking - LPG	1 390 000	660 000	2 050 000	326,9	103,1	430
Cooking - Kerosene	N/A[15]	N/A	N/A	0,3	0	0,3
Cooking – Natural gas	N/A	N/A	N/A	398,3	0	398,3
Gas water heaters - LPG	N/A	N/A	N/A	36,3	18,1	54,4
Gas water heaters - Kerosene	N/A	N/A	N/A	0,5	4,2	4,7
Gas water heaters - Natural Gas	N/A	N/A	N/A	20,8	0	20,8
Lighting - Kerosene	N/A	N/A	N/A	3,4	77,2	80,6
TOTAL				786,5	202,6	989,1

From Table 7 it is possible to observe that in urban areas the two most used types of gas are NG and LPG for cooking. In rural areas the most used are LPG for cooking and kerosene for lighting. In both areas (urban and rural) LPG still has a significant use for water heating. Figure 19 presents a percentage breakdown, on the type of gas used in Mozambique (at the top) and on the gas consumption by geographic location (at the bottom).

[15] N/A – Not Available. This Information was not available during the elaboration of this document



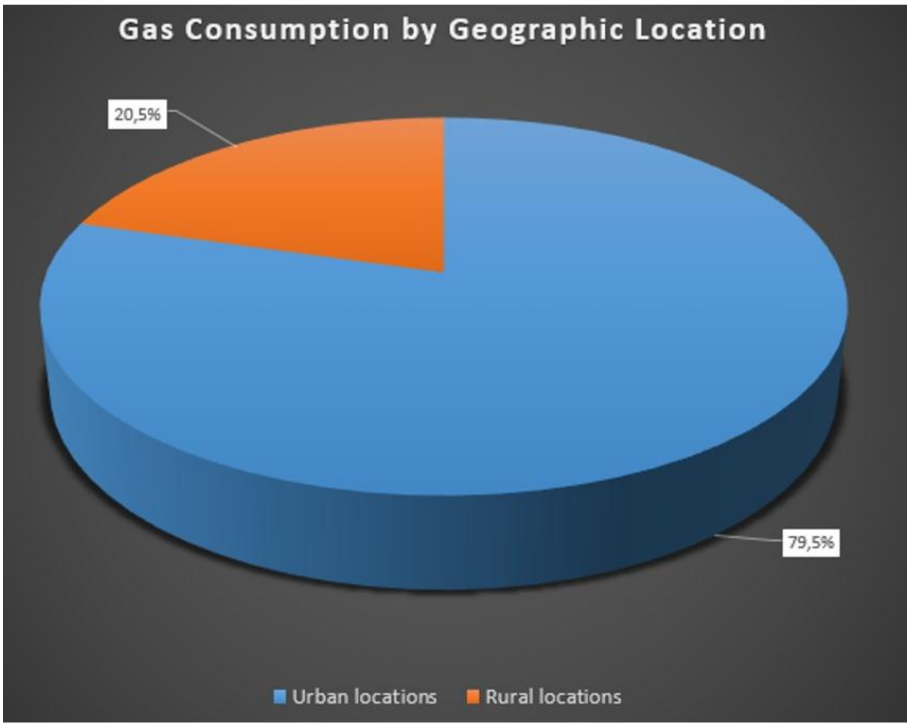
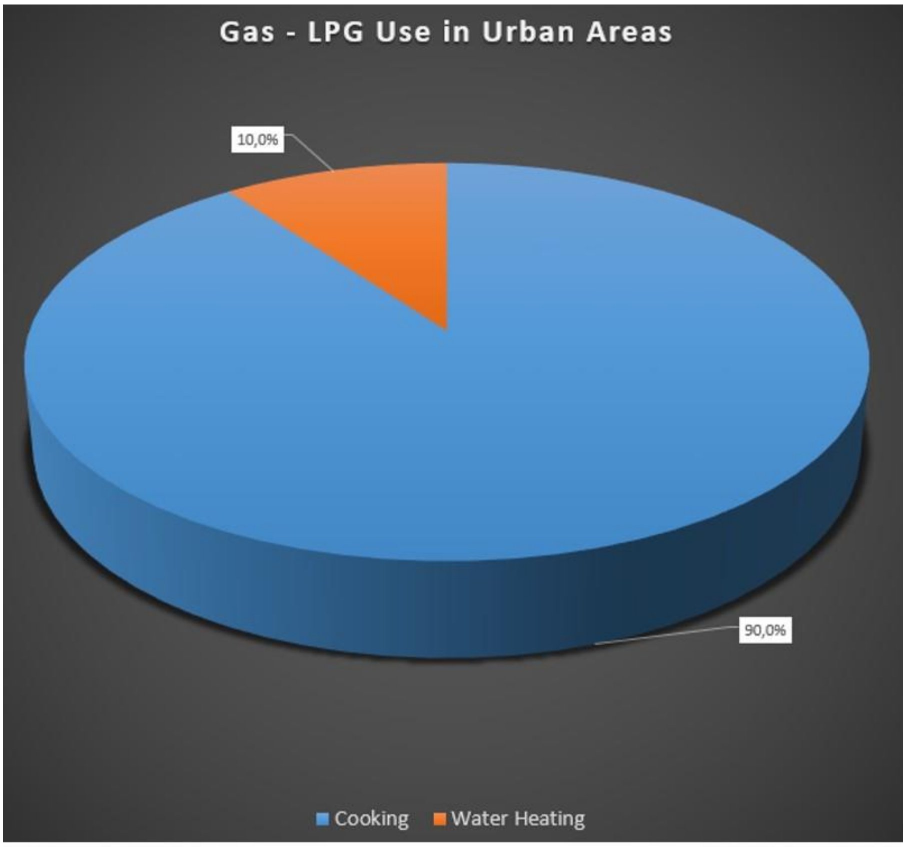


FIGURE 19- GAS CONSUMPTION BY TYPE OF GAS (ON THE TOP) AND LOCATION (ON THE BOTTOM). SOURCE: [23].

In the graphic on the top of Figure 19 it is possible to observe that LPG is the most used type of gas in the country, 49% of all gas consumed is LPG. The NG consumption is 42,4%, which is very close to the LPG consumption, but NG is only available in urban areas. There is still an 8,7% of kerosene consumption mostly used in rural areas to provide lighting for families. The graphic in the bottom of Figure 21 presents the gas consumption distribution between rural and urban locations.

It is also important to make a disaggregation for each type of gas by the consumption location and by its use. The following figures present these disaggregation for LPG (Figure 20), kerosene (Figure 21) and for natural gas (Figure 22).

FIGURE 20 - LPG GAS CONSUMPTION BY END-USE AND LOCATION (URBAN AREAS ON TOP AND RURAL AREAS ON THE BOTTOM). SOURCE: [23].



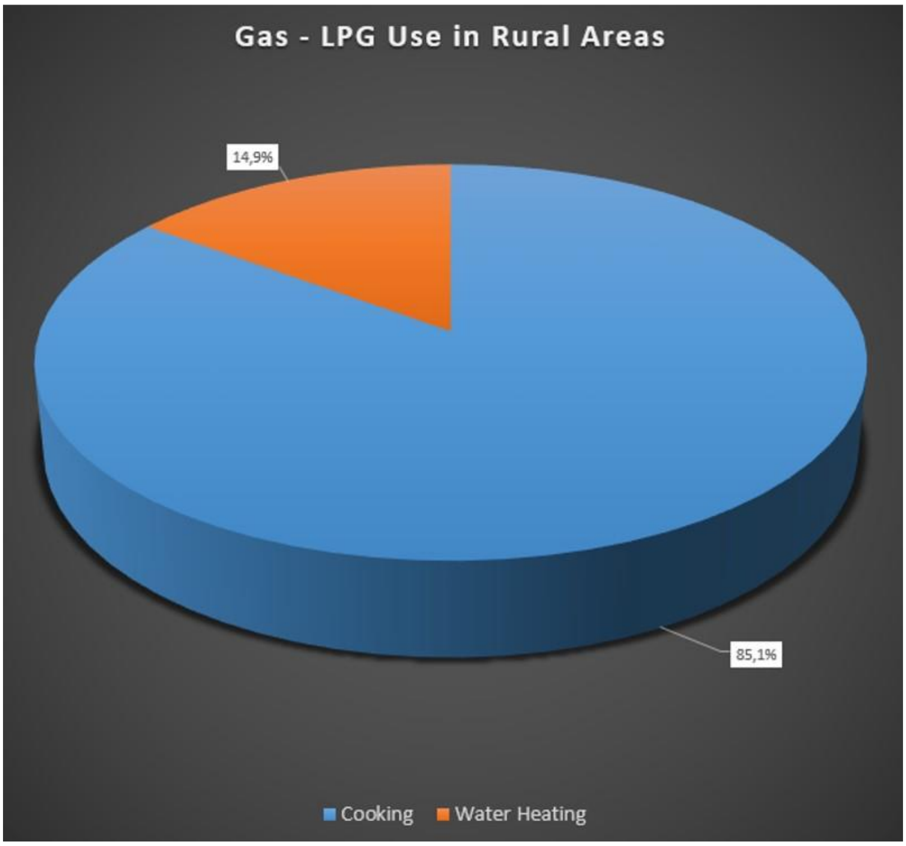
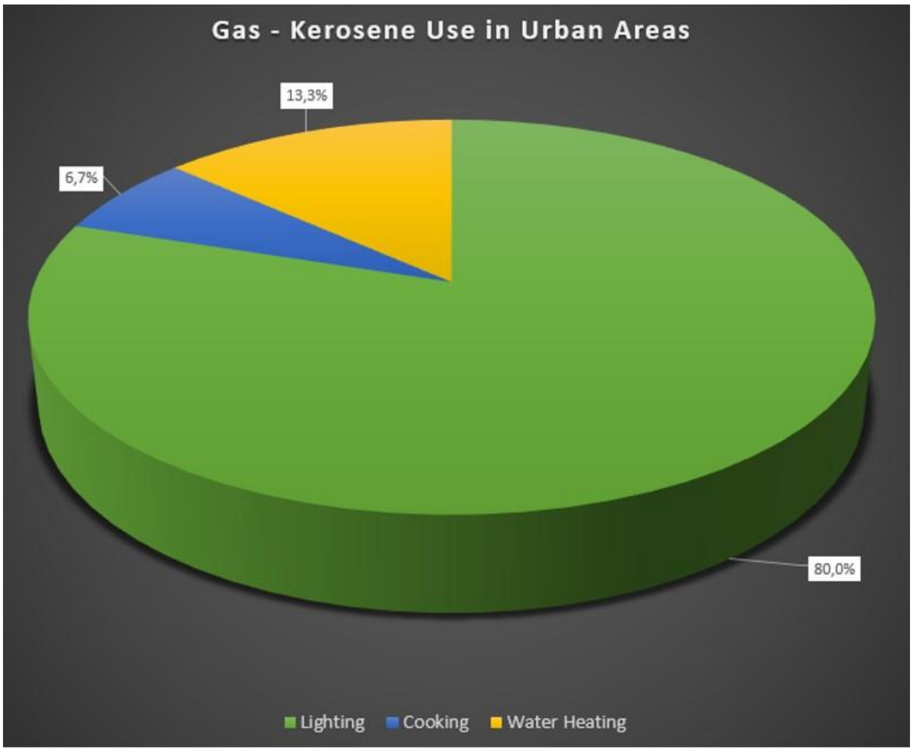


FIGURE 20 - LPG GAS CONSUMPTION BY END-USE AND LOCATION (URBAN AREAS ON TOP AND RURAL AREAS ON THE BOTTOM). SOURCE: [23].

The LPG both in urban and rural areas is used only for two purposes, cooking (90% in urban and 85,1% in rural areas) and water heating (10% in urban and 14,9% in rural areas).



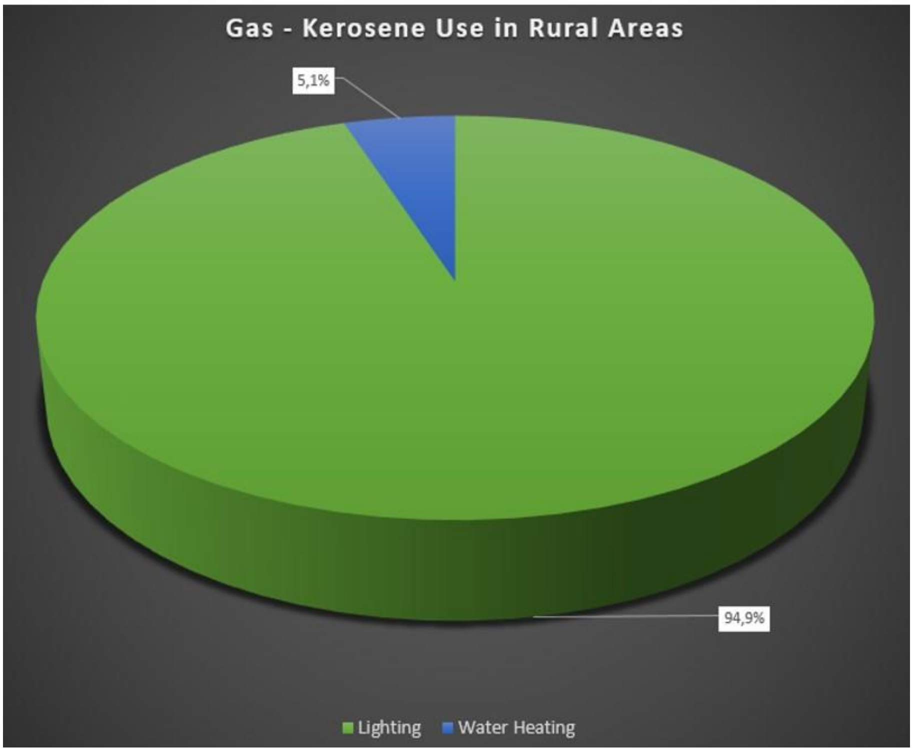


Figure 21 - Kerosene gas consumption by end-use and location (urban areas on top and rural areas on the bottom). Source: [23].

In urban areas, the kerosene consumption is very small (4,2 GWh/year) compared to rural areas (81,4 GWh/year). In urban areas kerosene is mainly used for lighting (80%), water heating (13,3%) and cooking (6,7%). In rural areas kerosene is only used for lighting (94,9%) and water heating (5,1%). Despite the percentage breakdown looking similar in urban and rural areas it is important to keep in mind that consumption in rural areas is almost 20 times higher than in urban areas. Figure 22 presents the NG consumption breakdown by end-use, it only presented for urban areas because in Mozambique NG is only available in those areas.

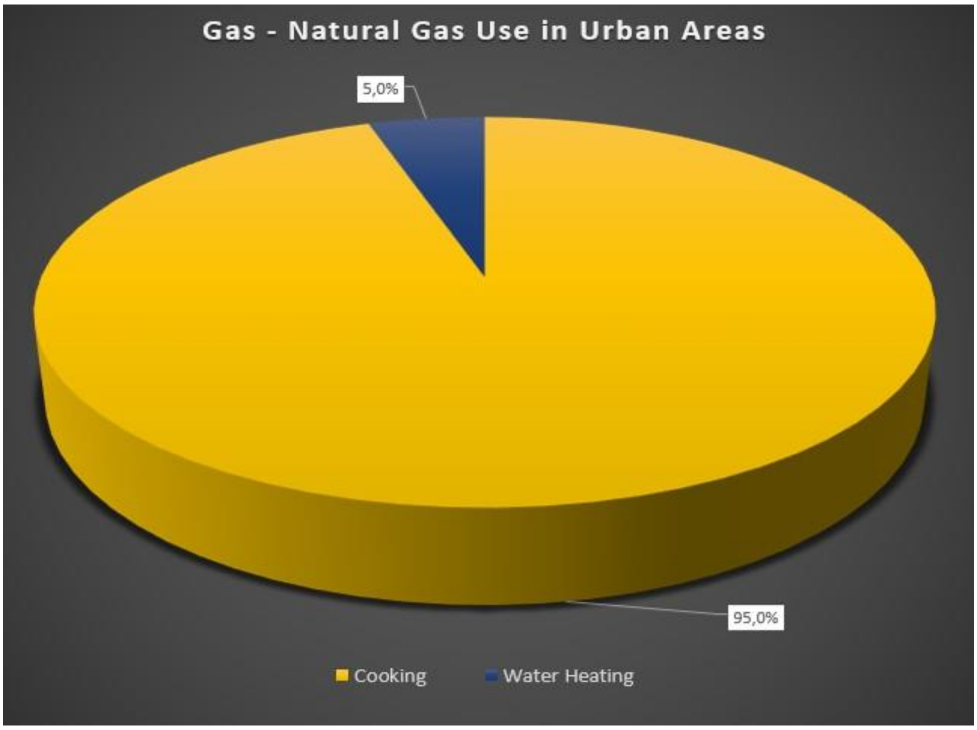


FIGURE 22 – NATURAL GAS CONSUMPTION BREAKDOWN BY END-USE AND LOCATION (URBAN AREAS). SOURCE: [23].

As previously mentioned, all NG consumption is made in urban areas for cooking (95%) and water heating (5%), as presented in Figure 22. Usually the implementation of gas distribution networks is only viable, from an economic point of view, in cities with a large number of users which, makes possible to implement such networks with good cost-benefit ratios.

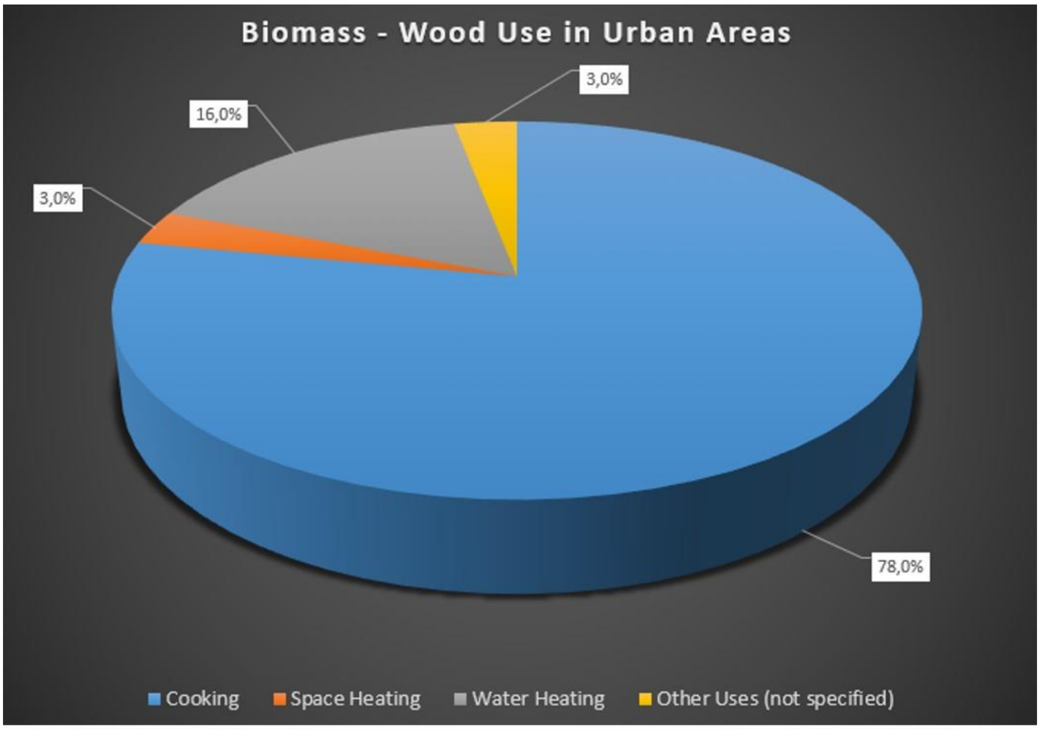
4.1.4. Other sources of energy used in residential sector

In the residential sector there are other sources of energy being used, such as biomass wood, charcoal and agriculture residuals and wastes.
Table *8* presents the biomass consumption disaggregation by biomass type and its end-use.

TABLE 8 - RESIDENTIAL SECTOR BIOMASS CONSUMPTION DISAGGREGATION BY BIOMASS TYPE AND END-USE. SOURCE: [23]

Residential Sector - Biomass consumption disaggregation by type of biomass and End-use							
	Total consumption per year [GWh/year]						
	Wood		**Charcoal**		**Agriculture residuals and wastes**		**Total**
End-use	**Urban areas**	**Rural areas**	**Urban areas**	**Rural areas**	**Urban areas**	**Rural areas**	**Urban + Rural areas**
Cooking	393,6	13 056,6	2 383,8	1 403,4	0,3	44,4	17 282,1
Space Heating	15,0	816,0	102,3	52,5	0,3	310,8	1 296,9
Water heating	80,7	1 632,0	102,3	122,7	3,9	44,4	1 986,0
Other uses (not specified)	15,0	816,0	817,2	175,5	0	44,4	1 868,1
TOTAL	504,3	16 320,6	3 405,6	1 754,1	4,5	444,0	22 433,1

Table 8 is possible to see that all types of biomass have a larger consumption in rural areas, where are mostly used for cooking. Agriculture residuals and wastes are also very used in rural areas for space heating.
Figure 23 presents the percentage breakdown in the biomass-wood end-use in urban and rural areas.



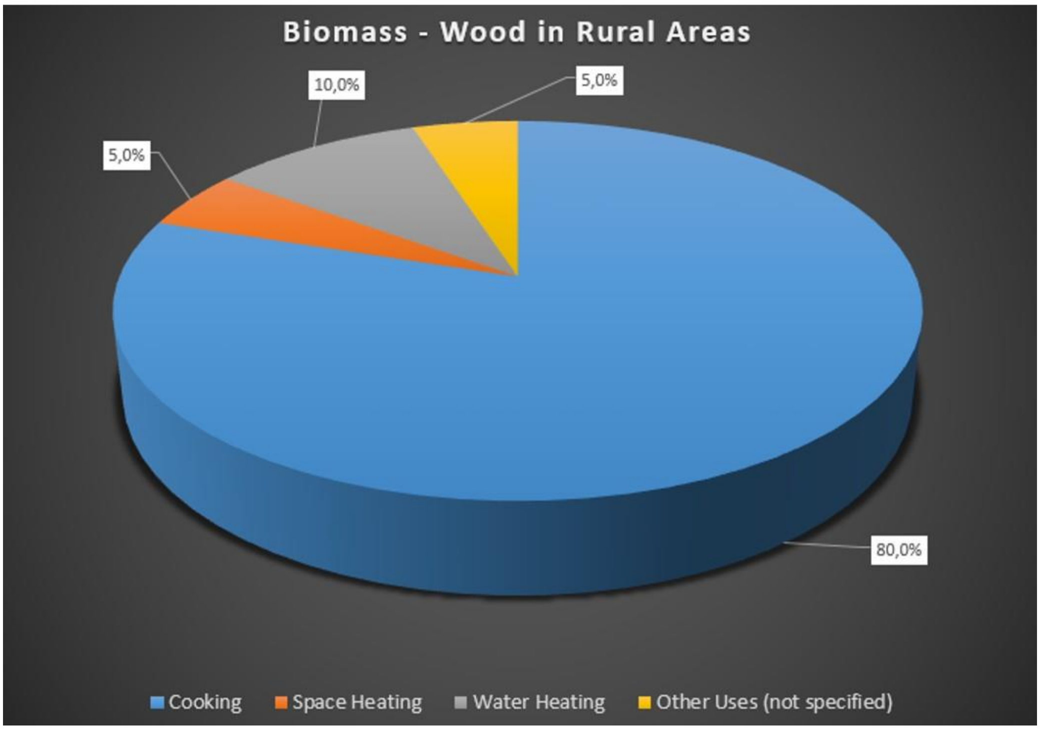
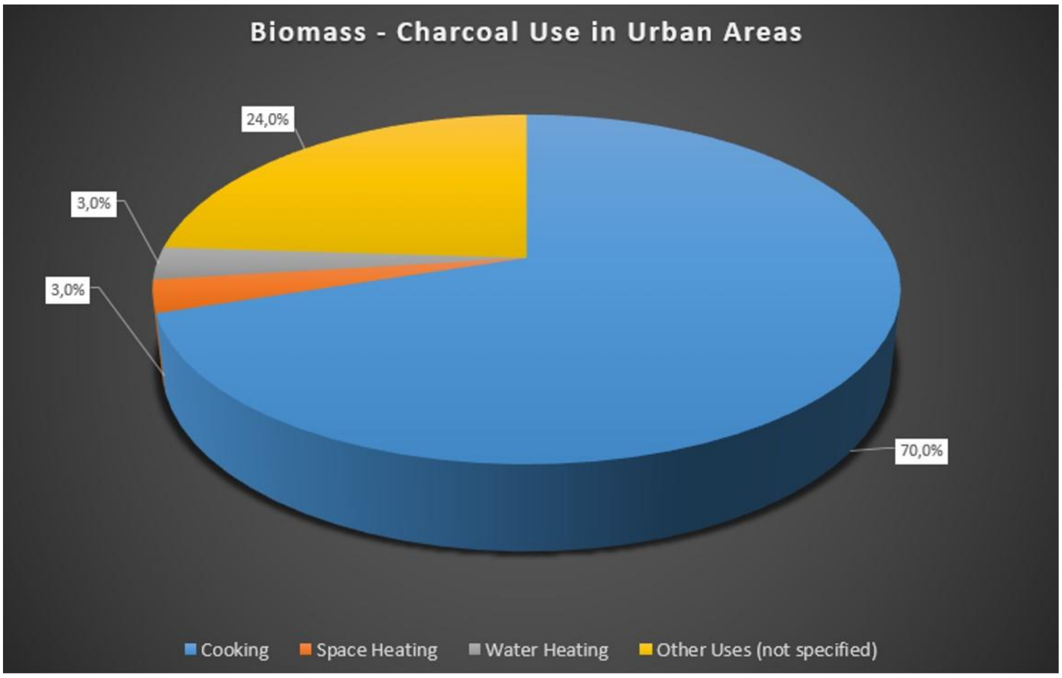


FIGURE 23 – BIOMASS - WOOD CONSUMPTION BY END-USE AND LOCATION (URBAN AREAS ON TOP AND RURAL AREAS ON THE BOTTOM). SOURCE: [23].

In both areas biomass-wood is used for the same purposes, cooking (78% in urban and 80% in rural areas), space heating (3% in urban and 5% in rural areas), water heating (16% in urban and

10% in rural areas) and for other uses not specified (3% in urban and 5% in rural areas). Once again, the percentage breakdown is quite similar in both areas, but it is important to keep in mind that the biomass-wood consumption in rural areas is almost 3 times higher than in urban areas.

Figure 24 presents the percentage breakdown on biomass-charcoal end-use in urban and rural areas.



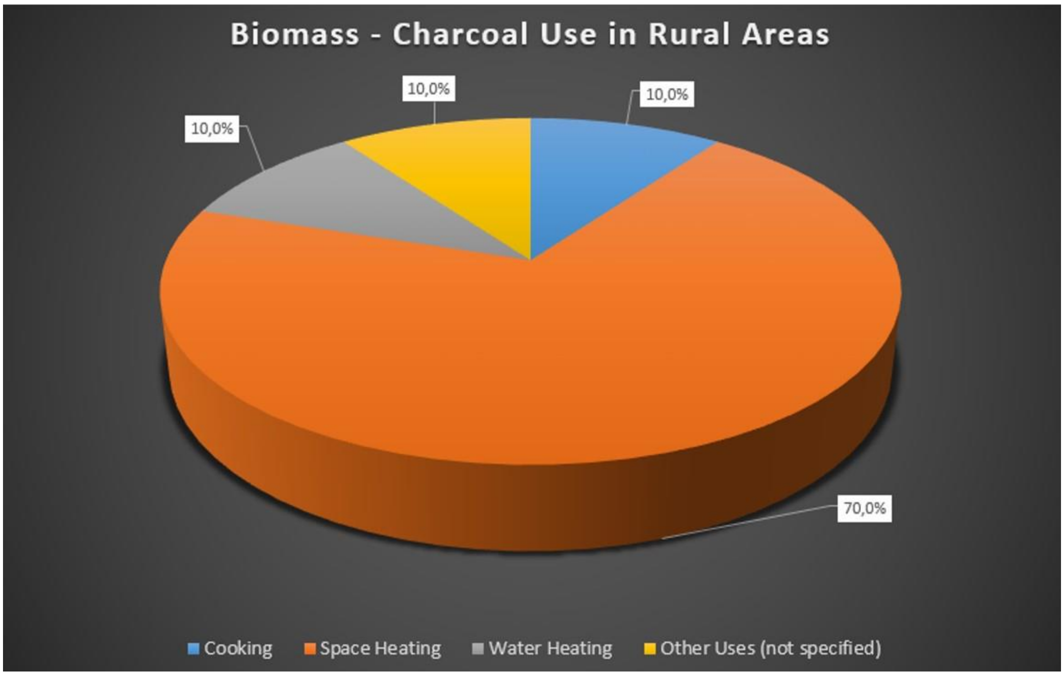
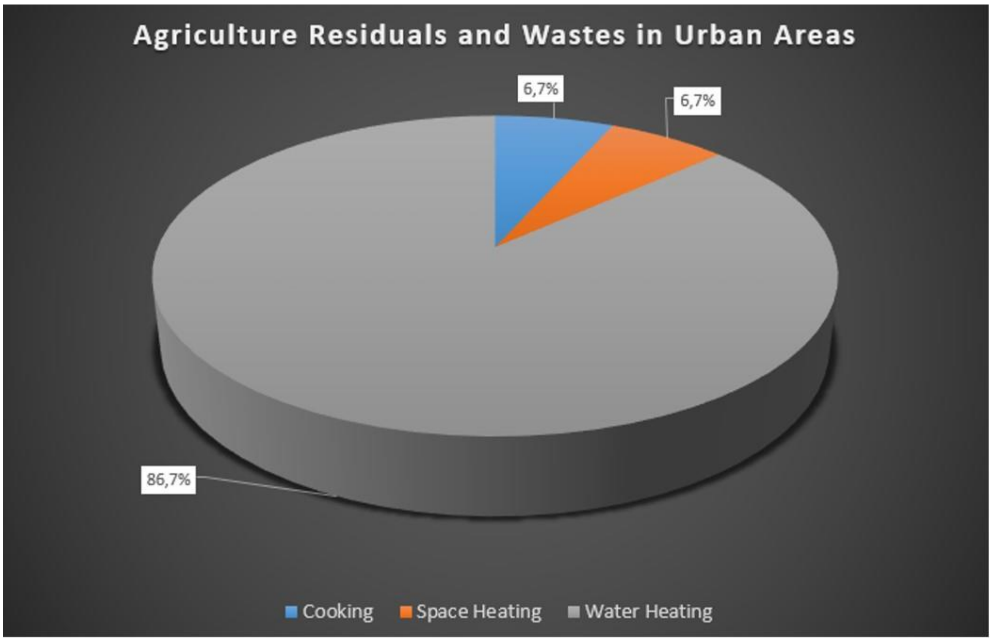


FIGURE 24 - BIOMASS - CHARCOAL CONSUMPTION BY END-USE AND LOCATION (URBAN AREAS ON TOP AND RURAL AREAS ON THE BOTTOM). SOURCE: [23].

In both areas biomass-charcoal is used for the same purposes, but with different percentages of end-use. In urban areas 70% of charcoal is used for cooking, 3% for space heating, 3% for water heating and 24% for other uses (not specified). In rural areas cooking represents 10% of the charcoal consumption, space heating 70%, water heating 10% and other uses (not specified) another 10%. Please note that biomass-charcoal consumption is almost 2 times higher in urban than in rural areas.

Figure 25 presents the percentage breakdown on biomass-agriculture residuals and wastes consumption in urban and rural areas by end use.



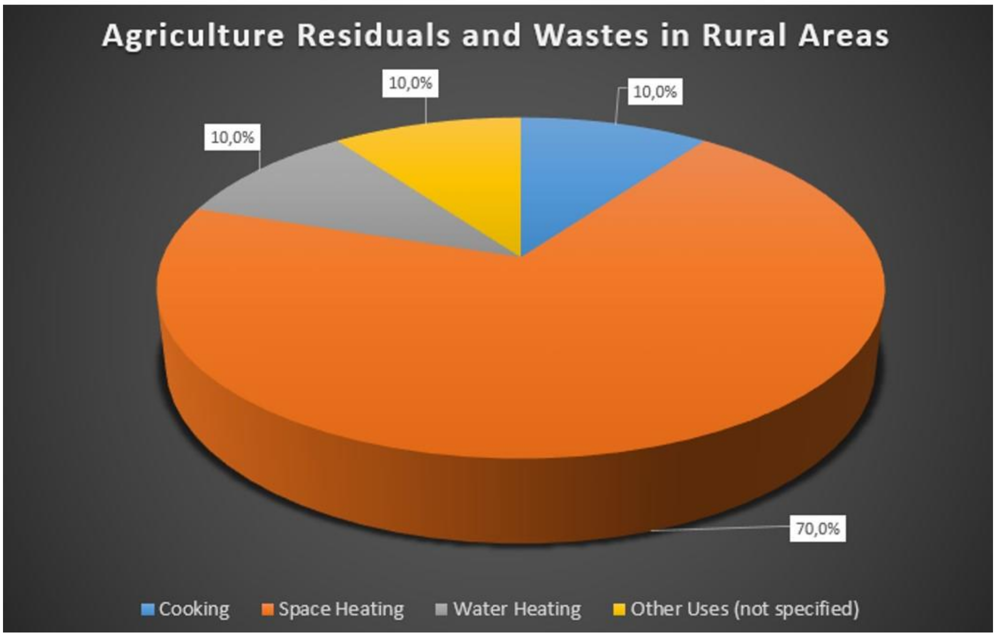


FIGURE 25 – AGRICULTURE RESIDUALS AND WASTES CONSUMPTION BY END-USE AND LOCATION (URBAN AREAS ON THE LEFT AND RURAL AREAS ON THE RIGHT). SOURCE: [23].

Biomass-agriculture residuals and wastes have different uses in urban and rural areas. In urban areas are they used for cooking and space heating with 6,7% of consumption for each these uses and 86,7% of the residuals and wastes are used for water heating. In rural areas 10% of this residuals and wastes are used for cooking, 70% for space heating, 10% for water heating and the remaining 10% for other uses (not specified). Please note that biomass-agriculture residuals and wastes consumption is almost 100 times higher in rural than in urban areas.

4.1.5 Residential Appliance Market

To characterize the residential sector, it is important to analyse the appliances market, and its weight in terms of electricity consumption. Regarding the number of appliances used in Mozambican households, this information is given by the country appliance ownership rate, published in the 2017 population census [2, 3, 23] and presented in
Figure *26*.

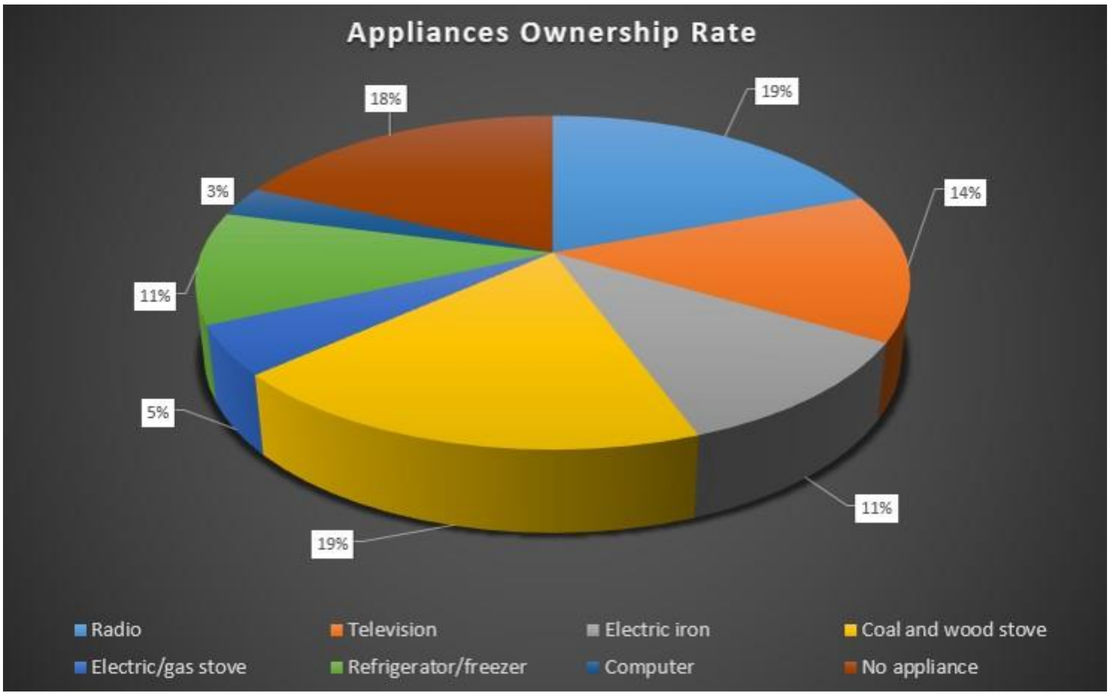


FIGURE 26 - APPLIANCE OWNERSHIP RATE IN MOZAMBIQUE BY HOUSEHOLD IN 2018. SOURCE: [2, 3, 23]

From
Figure *26* is possible to observe that radios and coal/wood stoves possibly have a higher ownership rate (19% for both) because they are cheap and easy to purchase, and do not need access to electricity (radios typically use AA or AAA batteries). Televisions and electric irons have an ownership rate of 14% and 11% respectively. Refrigerators/freezers still have a low ownership rate (11%), most likely due to high acquisition cost and/or lack of suitable energy access. Electric/gas stoves have 5% ownership rate and computers with 3%. There is still a considerable percentage of people, 18%, without any type of appliance, most likely because they do not have access to electricity, or they cannot afford it.

In order to further characterize the appliance market a local survey among the biggest appliance stores was conducted in Maputo. This survey allowed to collect valuable information (e.g. brands, energy consumption, price range, etc.) to describe the appliances market. Table 9 and Table 10 present the results of this survey.

TABLE 9- MAIN CHARACTERISTICS OF SOME OF THE APPLIANCES AVAILABLE IN MOZAMBIQUE – PART 1

Appliance type	Description	Brand	Energy Consumption	Average Cost [$USD[16]]
Refrigerator 1 door	Energy Class A+ 120 litre	Hisense	113 kWh/year	$ 158,00
Refrigerator 2 doors	Energy Class A+ 323 litre	Defy	306 kWh/year	$ 470,00
	Energy Class A 298 litre	KIC	341 kWh/year	$ 356,00
Refrigerator 2 vertical doors	Energy Class A 365 litre	Defy	635 kWh/year	$ 890,00
Freezer	Energy Class A --- litre	Defy	266 kWh/year	$ 248,00
	Energy Class B --- litre	KIC	387 kWh/year	$ 274,00
Washing machines	Energy Class A+++ 8 KG	Samsung	0,75 kWh/cycle	$ 685,00
Dish washer	Energy Class N/A	Bosch	1,02 kWh/cycle	$ 424,00
Air-Conditioners	Energy Class N/A 9000 BTU/h	Super-General	900 Wh	$ 260,00
	Energy Class N/A 12000 BTU/h		1200 Wh	$ 315,00
	Energy Class N/A 18000 BTU/h		1877 Wh	$ 438,00
	Energy Class N/A 24000 BTU/h		2486 Wh	$ 562,00
	Energy Class A 9000 BTU/h	Nikai	816 Wh	$ 267,00
	Energy Class A 12000 BTU/h		1092 Wh	$ 288,00
	Energy Class N/A 18000 BTU/h	Samsung	N/A	$ 1000,00

16- USD- United States Dollars. ($1= 73,0 Mozambican Metical)

TABLE 10- MAIN CHARACTERISTICS OF SOME OF THE APPLIANCES AVAILABLE IN MOZAMBIQUE – PART 2

Appliance type	Description	Brand	Energy Consumption	Average Cost [$USD[17]]
Televisions	32'' inch – Series 5000 – Non-Smart TV	Samsung	45 kWh/year18	$ 210,00
	32'' inch – Series 5300 – Non-Smart TV		39 kWh/year10	$ 300,00
	43'' inch – Series 7000 – Smart TV		101 kWh/year[10]	$ 601,00
Fans	45 cm of diameter	Logik	120 Wh	$ 84,00
	105 cm of diameter		50 Wh	$ 59,00
Electric Stoves	Energy Class A 4 heating places and oven	Defy	0,82 kWh	$ 248,00
			0,890 kWh	$ 445,00
Electric Water Heaters	Energy Class B - 50 litres	N/A	N/A	$226,00
	Energy Class B - 100 litres			$ 255,00

17- USD- United States Dollars. ($1= 73,0 Mozambican Metical)
18- Measured according to EU living standards.

From Table 9 and Table 10 it is possible to observe that considering the average living standards the cost of most appliances (e.g. refrigerators, freezers, washing machines, etc.) are still quite high for most of the population. Please note that the appliances in the mentioned tables are the ones being sold at the moment, in most households the existing appliances are not as energy efficient as those in Table 9 and Table 10.

Some of the appliances considered (e.g. air-conditioners) are also used in other type of buildings (commercial stores, offices, etc.) however it was not possible to make such disaggregation. In those sectors the energy consumption for those equipments will be estimated.

The number of appliances sold, as well as their end-use (e.g. residential, non-residential, or industrial use) was not disclosed by the stores where this survey was conducted and such data disaggregation is not available in the country. To overcome this information gap, this report will consider (in the energy savings calculation in Chapter 5) an estimation based on the number of appliances imported into Mozambique and it will consider an appliance/equipment breakdown for each economic sector. Another way to estimate the energy savings for Chapter 5 is to use the information regarding families ownership rate of appliances which is available in INE. However, these statistics do not include several appliances/ equipment models (AC units, fans, etc.). Based on the available information a miscellaneous of both sources (customs and INE) will be used.

4.1.6. Consumption Trends

In last three years, according to EDM (Eletricidade de Moçambique), the total electricity sold has been growing at a steady rate, around 12% per year. However, in the same period the electricity consumption in the residential has grown at a much slower rate, around 2% per year. Figure 27 presents the electricity consumption evolution over the last ten years (2009-2019).

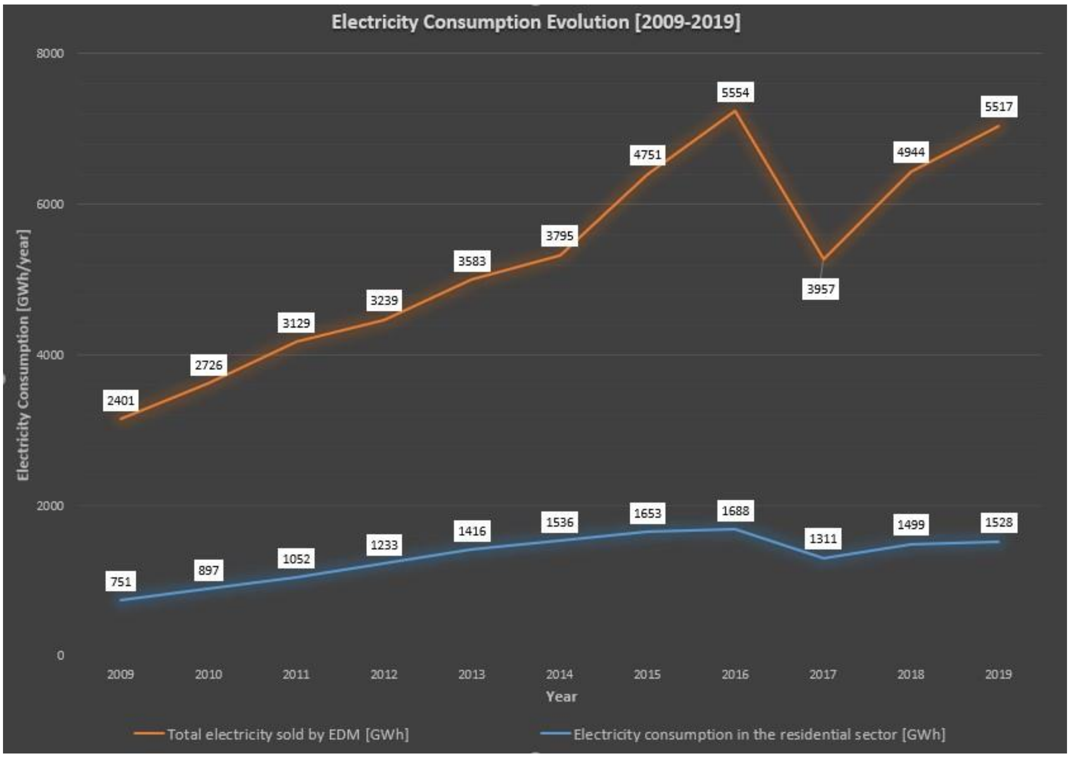
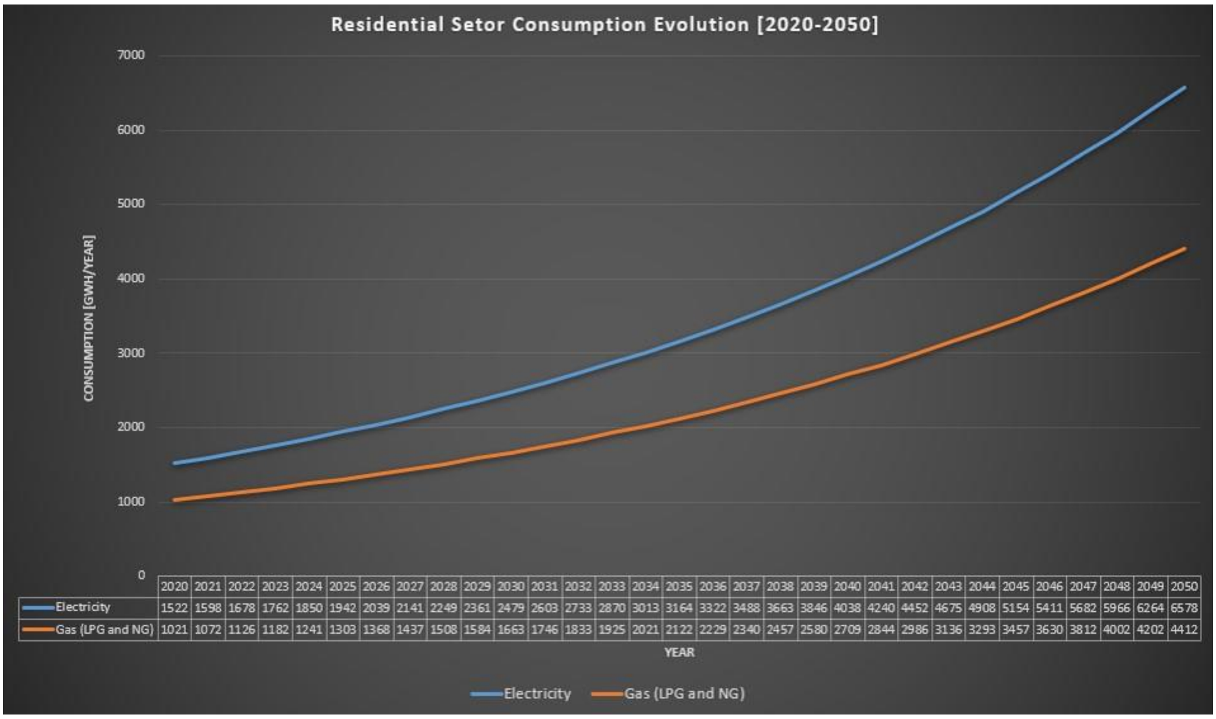


FIGURE 27 - EVOLUTION ON THE TOTAL ELECTRICITY SOLD BY EDM AND IN THE RESIDENTIAL SECTOR ELECTRICITY CONSUMPTION IN THE LAST TEN YEARS [2009-2019]. SOURCE: [23]

To estimate the energy demand evolution on the residential sector, it is important to analyse the last ten years, to establish a suitable evolution scenario. Figure 27 presents the evolution on the total energy sold by EDM (orange line) as well as evolution in the residential sector electricity consumption (blue line) in the last ten years (2009-2019).

The electricity consumption in the residential sector has been growing at a steady rate in the 2010-2013 period, around an average of 15% per year. Between 2014-2016 the consumption growing rate had a reduction to an average of 6% per year. In 2016-2017 the residential consumption suffered a significant reduction (11% in 2016 and 2% in 2017). This situation might have been caused by severe tropical depression with heavy rains and flooding in the provinces of Maputo, Gaza, Inhambane and Nampula, causing damage in housing and power grid which resulted in non-availability of power for the population. In 2016 the total electricity sold had a substantial reduction (visible in the orange line) caused by a severe reduction in electricity exportation. This reduction happened because most of Mozambique neighbouring countries (Angola, Botswana, Malawi, Namibia and Zimbabwe) were also affected by the same tropical depression and had severe damages in their power grids. In 2018 the electricity consumption has resumed the growth trend and in 2019 reached 1528 GWh per year.

The World Bank estimates that Mozambique will resume its economic growing trend in 2021 with a rate of 2.8%. For the purpose of this analysis and considering a favourable economic scenario and steady population rate according to INE of 2,6% per year, an average growing rate of 5% per year for electricity and gas (LPG + NG) consumption in the residential sector was considered. Figure 28 presents the estimated evolution in the residential energy consumption (electricity and gas) between 2020 and 2050.



	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Electricity	1522	1598	1678	1762	1850	1942	2039	2141	2249	2361	2479	2603	2733	2870	3013
Gas (LPG and NG)	1021	1072	1126	1182	1241	1303	1368	1437	1508	1584	1663	1746	1833	1925	2021

	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Electricity	3164	3322	3488	3663	3846	4038	4240	4452	4675	4908	5154	5411	5682	5966	6264	6578
Gas (LPG and NG)	2122	2229	2340	2457	2580	2709	2844	2986	3136	3293	3457	3630	3812	4002	4202	4412

FIGURE 28- ESTIMATED EVOLUTION ON THE ENERGY CONSUMPTION OF ELECTRICITY AND GAS (LPG AND NG) IN THE RESIDENTIAL SECTOR BETWEEN 2020-2050

Another important equipment with a significant weight in terms of consumption in the residential sector is lighting. According to the existing data in 2014 around 16,5 million Compact Fluorescent Lamps (CFL) existed in Mozambique. The introduction of this type of lamps, should had some impact in terms of energy savings. However, that did not happen because between

2010 -2014 the residential electricity consumption kept growing at an average of 13% per year. This situation is potential explained due to the fact that a high increase in the number of new clients being connected to the power grid (an average of 12% increase per year, around 150 000 per year), specially between 2010 and 2014. It is important to consider that lighting has one of the largest potential concerning energy savings.

4.1.7. Considerations

The residential demand for electricity is directly connected with the population number, quality of life (monthly income) and the rate of electrification (energy access). If more people gain access to electricity and at the same get better living standards, with better or steadier jobs and higher wages they will be able to provide their families with more comfort. This comfort usually means better homes, with electricity and appliances to help them in the day-to-day life. Considering all the above factors, the electricity demand in the residential sector has a strong connection with the energy access rates, but there is another factor that needs to be taken under consideration, which is the large population growth.

In Mozambique, the population growth rate is 2,6% per year (in 2021 there were around 31 million people and in 2040 there will be around 46 million) [2, 3]. This population growth will certainly have a large direct impact in energy demand of the residential sector, which will be compounded if the energy access rate continues to increase. Additionally, if the country is able to reduce the unemployment rate, the production levels will increase giving companies higher turnovers that will increase the energy demand in all other sectors (agriculture, industrial, commerce, etc.).

Foreseeing this future increase in energy demand in all sectors, the country national authorities need to prepare the electrical infrastructures (on-grid and off-grid systems) as well as the transition to a more sustainable energy mix, which will allow them to deal with all the constraints caused by this situation.

4.2. Characterization of the Non-residential Sector

For the purpose of this report, the energy consumption considered in this Chapter includes clients/businesses from different economic areas (e.g. agriculture, commercial stores, Small and Medium Enterprises (SME) providing services to the population, public service buildings, offices, schools, hospitals and other healthcare facilities and other non-specific consumers).

The energy consumption related to agriculture is included this Chapter having a very low value, of only 0,5% of the total electricity supplied by EDM in 2019. This extremely low value means that agriculture in Mozambique is notoriously underdeveloped, even though agriculture employs around 71% of the active population and represents almost 25% of the country Gross Domestic Product (GDP).

Recent offshore gas discoveries are estimated at 5,1 trillion cubic meters, if used to boost the exports the country may have the opportunity to diversify the economy while enhancing its resilience and competitiveness. Revenues from the gas sector could be used to support an upgrade into the subsistence agriculture transforming it into agribusiness and at the same time support Mozambique electrification effort through different energy solutions.

4.2.1. Consumption Disaggregation by Energy Source

According to the available information, there is only data for electricity in the energy consumed in the non-residential sector. This sector includes economic activities such as hotels and restaurants where the use of natural gas, propane, butane, is likely to exist. However, there is no information to support this assumption. Taking this under consideration, the analysis in this Chapter will only consider the electricity consumed. The non-residential sector represented in 2019, 11% of the total electricity supplied by EDM.

Figure 29 presents the electricity consumption breakdown by economic sector.

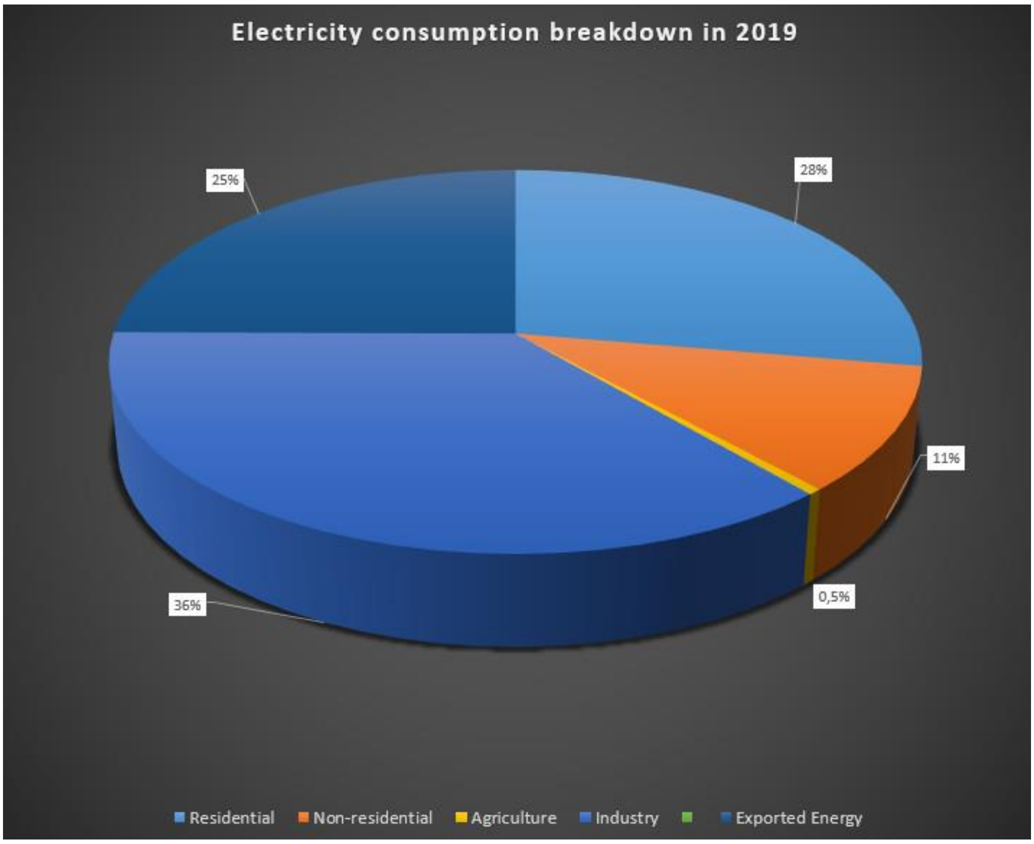


FIGURE 29- MOZAMBIQUE ELECTRICITY CONSUMPTION BREAKDOWN (INCLUDING EXPORTED ENERGY) IN 2019. SOURCE: [24]

Figure 30 presents the electricity consumption evolution between 2006 and 2019 in the non-residential sector in Mozambique.

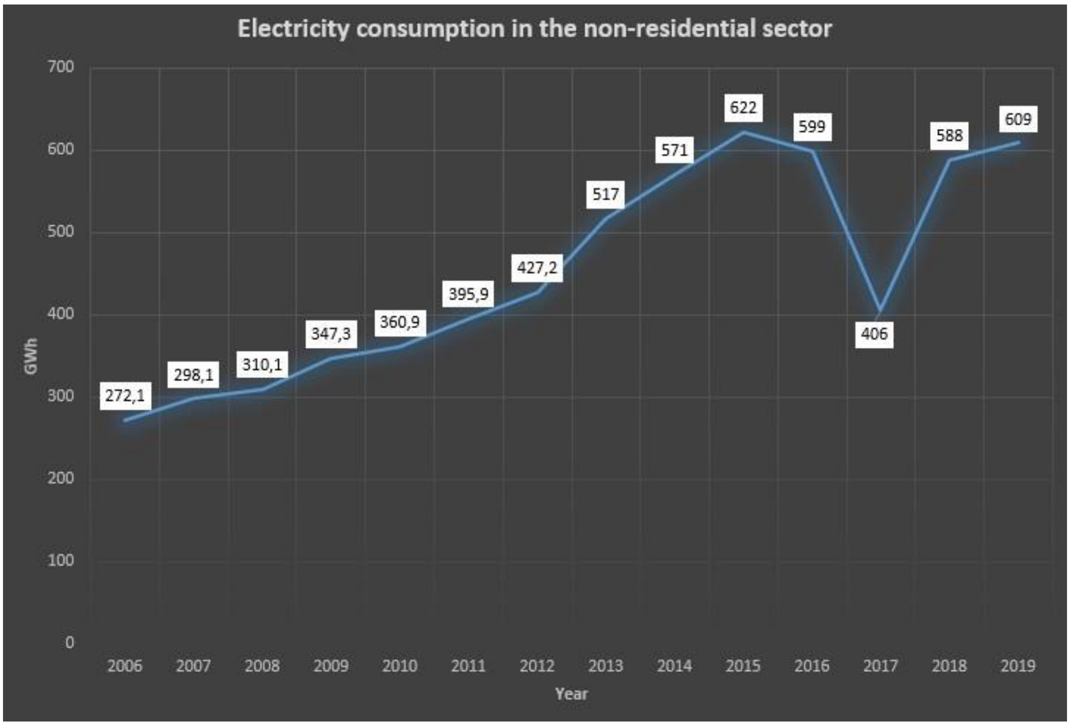


FIGURE 30- ELECTRICITY CONSUMPTION IN THE NON-RESIDENTIAL SECTOR BETWEEN 2006-2019. SOURCE: [24].

From 2006 to 2015 the electricity consumption presented a steady growing rate, with an average value of 10% per year. However, as in other economic sectors in 2017 a strong reduction in the electricity consumption took place. This reduction might have been caused by the impact of a severe tropical depressions, with heavy rains and flooding in several provinces, causing damages in the national power grid, which had a severe impact in tourism, school infrastructures and other buildings related to this economic sector. In 2018 the usual consumption level was resumed most likely due to fact that the economic activities in this sector were able to recover much faster (e.g. tourism, hotels, restaurants, healthcare facilities, etc.) than other economic sectors.

It is important to keep in mind that the electricity consumption considered in Figure 30 includes the electricity used by the public street lighting connected to the national grid. The electricity consumed by this equipment type will be analysed with more attention in section 4.5.1.2. In Mozambique there is also a part of the public street lighting that is powered by off-grid systems (by solar photovoltaic panels). These systems represent an effort made by FUNAE to provide public street lighting to people in areas where the national grid is not available or in which it would take a long time to get there.

4.2.2. Consumption Disaggregation by Equipment

It is important to note that it has been extremely challenging to arrive at these figures presented in this section. While in developed countries this information is usually available in several institutions at national or international level, in Mozambique the necessary statistics are more challenging to obtain. Even if they are, they may contain different groupings, and thus during the regrouping (the grouping or client classification used in Mozambique is presented in Table 4) new assumptions needed to be introduced. For the majority of the economic sectors, interviews with key experienced stakeholders, expert judgment and extrapolations based on sample data, was combined to derive the presented figures. Taking all this under consideration for the purpose of this report, the electricity consumption breakdown presented in Figure 31 will be considered in the non-residential sector in the other parts of the study.

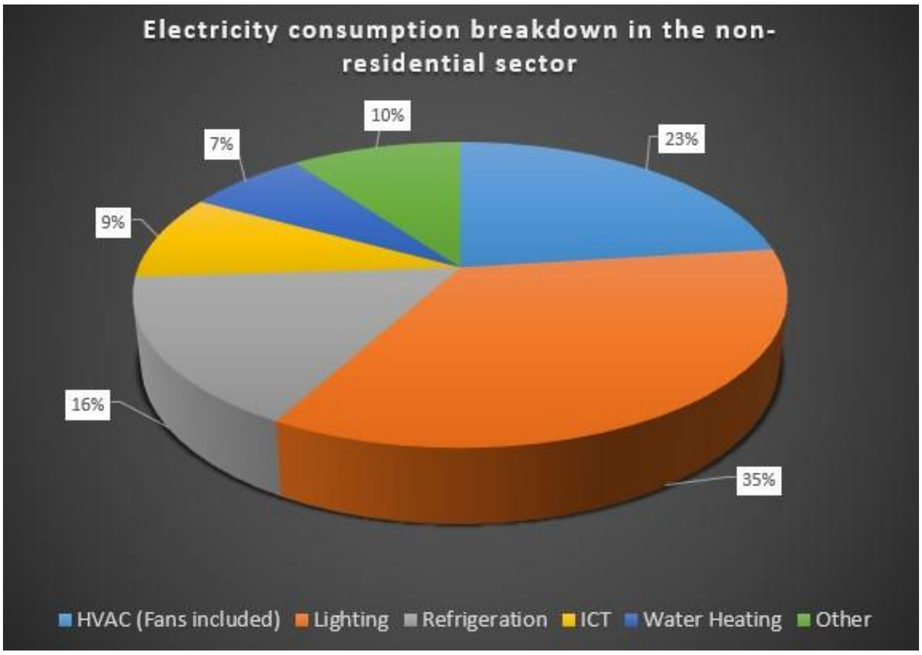


FIGURE 31- ESTIMATION ON THE NON-RESIDENTIAL ELECTRICITY BREAKDOWN CONSUMPTION.

The electricity consumption per equipment presented in Figure 31 will be used in Chapter 5 to estimate the country electricity savings potential.

4.2.3. Consumption Trends

Figure 32 presents the estimated electricity consumption in the non-residential sector between 2020-2050.

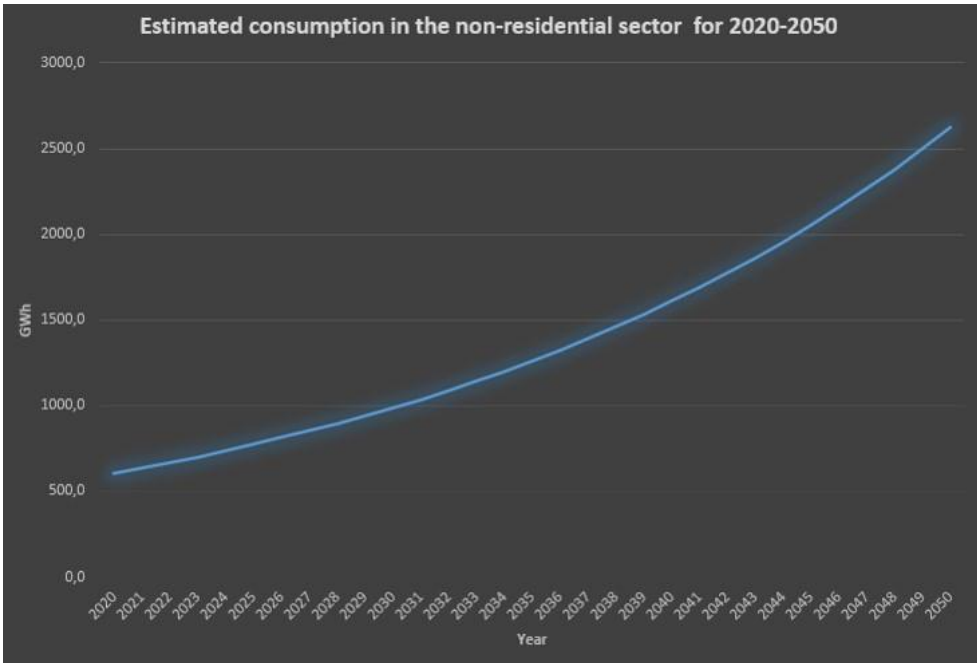


FIGURE 32 - ESTIMATED CONSUMPTION IN THE NON-RESIDENTIAL SECTOR FOR 2020-2050. SOURECE: [24].

This estimation was made in line with the World Bank economic forecast for Mozambique. Considering a favourable economic scenario in this analysis, an average growing rate of 5% per year for electricity consumption in the non-residential sector was considered.

4.2.4. Considerations

The information available about the energy consumption for this sector is scarce. Only data regarding electricity consumption has been collected. However there should be gas consumption especially in restaurants and hotels, data of gas being sold to companies/institutions working in this sector have not been collected.

One of the most important findings of this study is the importance of creating an energy information system to gather information for each economic sector. Additionally, it is important to make a clear grouping of economic activities per sector similar to the one promoted by the International Energy Agency and or AFREC to allow any possible comparison and the use of evolution scenarios similar to the ones used in other countries which economic situation is similar to Mozambique.

Naturally, as in other sectors of activity, cyclones and tropical storms had also impact in electricity consumption (specially in 2017, effect visible in Figure 30) due to damage in electrical infrastructure and also affecting tourism. If Mozambique wants to select tourism as one of its main sources of income, the country needs also to invest in electrical infrastructures to attract foreign investment in hotels, restaurants, etc. The foreseen increase in population will require additional schools, hospitals and other structures, as well as an increase of the country industrialization, will have an impact in the electricity consumption, which will influence the estimated evolution in the electricity consumption (Figure 32) over the next decades.

The non-residential sector includes a wide variety of activities and businesses, as well as public street lighting. As previously mentioned, the public lighting systems and lighting fixtures used in buildings will be analysed it more detail in section 4.5.

4.3. Characterization of the Industrial Sector

The industrial sector in Mozambique comprises a limited number of activities, which results in industrial production focusing on the following products: non-agglomerated coal (mineral coal), aluminium, natural gas, beer with alcohol, cement, other non-ferrous metal ores and their concentrates, wheat flour, sugar, soft drinks, sunflower and palm oil.

According to the most recent statistics for industry presented by INE for 2019, almost 90% [26] of the country production consists of the products presented in
Figure *33*. The remaining 10% includes products (e.g. furniture, textile, leather products, paper, paper pulp, cardboard and by-products, etc.) with very small relevance, in terms of production quantity.

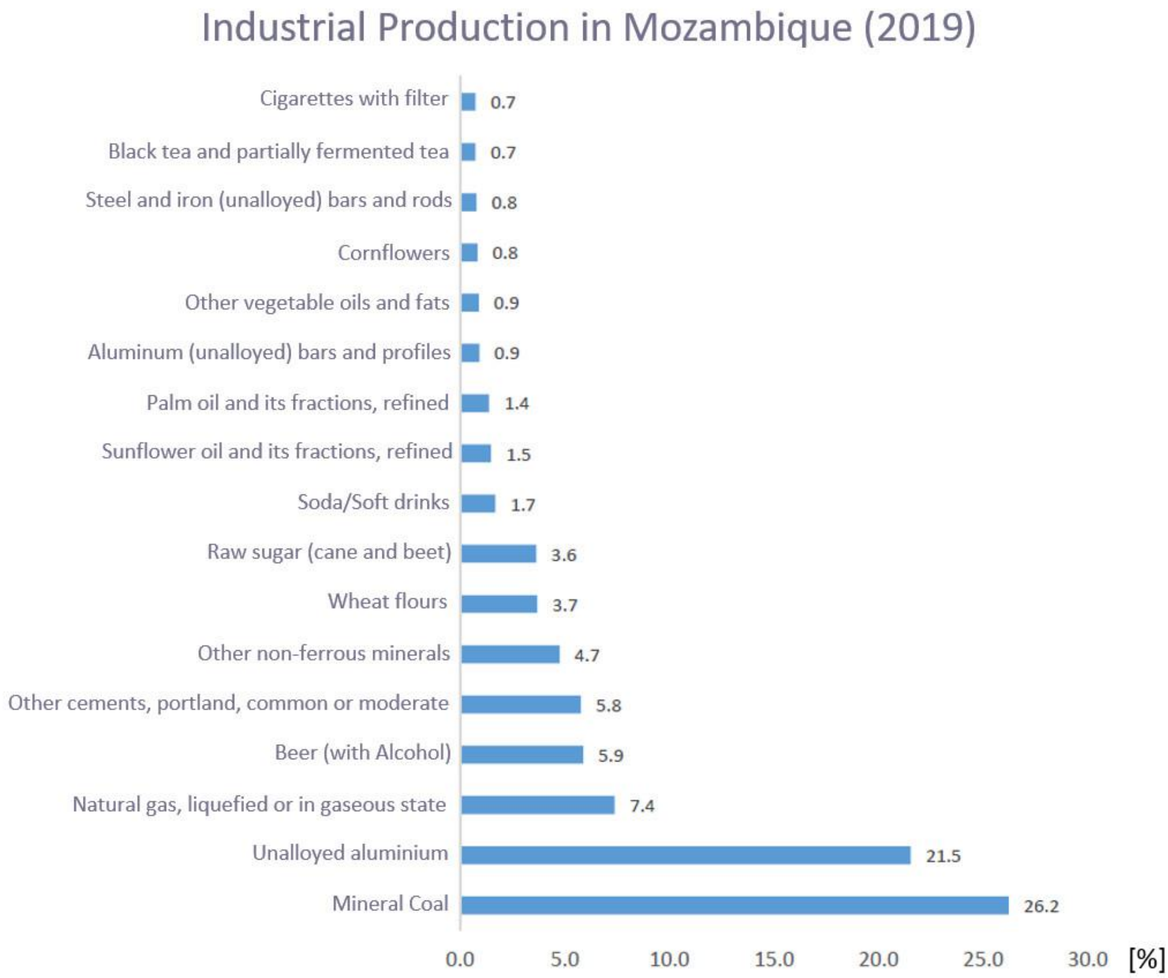


FIGURE 33- PERCENTUAL BREAKDOWN OF MAIN PRODUCTS PRODUCTS MADE IN MOZAMBIQUE. SOURCE: [26].

4.3.1. Consumption Disaggregation by Energy Source

The two main sources of energy in industry are electricity and natural gas. The industrial sector was responsible for 2007 GWh in 2019, almost 36% of the country energy consumption, as presented in Figure 34.

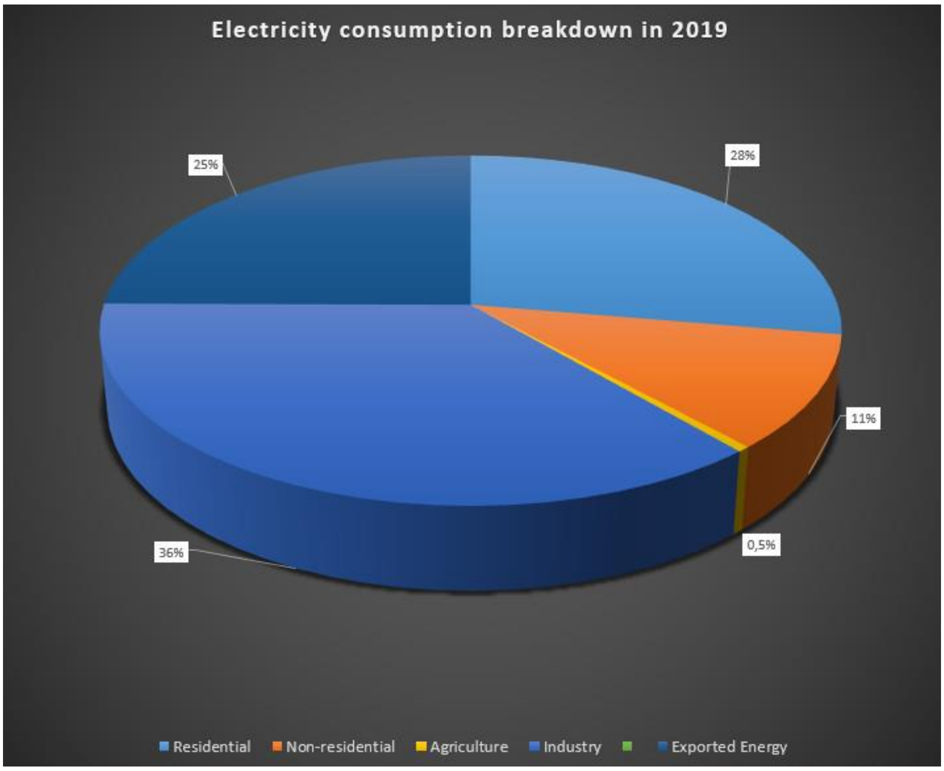


FIGURE 34 - MOZAMBIQUE ELECTRICITY CONSUMPTION BREAKDOWN (INCLUDING EXPORTED ENERGY) IN 2019. SOURCE: [24].

As previously mentioned, the other main source of energy used in industry is natural gas, whose consumption in 2019 was 993 GWh [26].

Figure 35 presents the evolution of the electricity consumption in the industrial sector between 2010 and 2019.

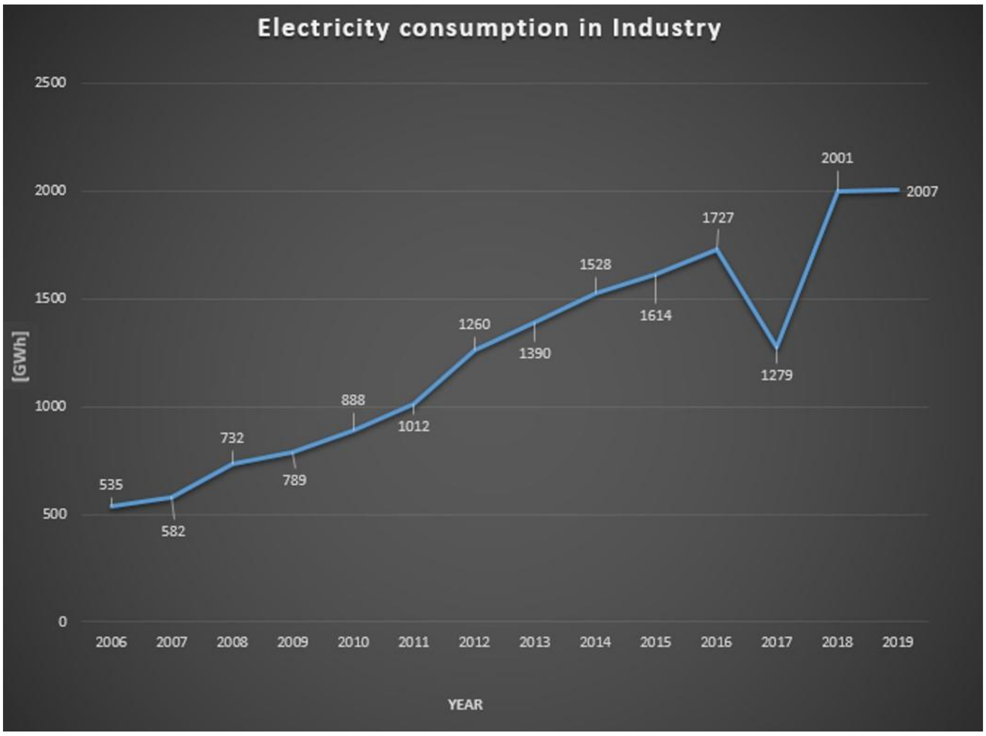


FIGURE 35 - EVOLUTION OF THE ELECTRICITY CONSUMPTION IN INDUSTRY BETWEEN 2010 AND 2019. SOURCE: [24, 26]

The electricity consumption in the industrial sector presented a strong growth between 2006 and 2016, with an average of 13% increase per year. This growth was motivated due to an increase on the number and modernization of industries mostly due to foreign investment. In 2017, as in other sectors (e.g. residential sector) the electricity consumption dropped 26%. This reduction might have been caused by the impact of a severe tropical depression, with heavy rains and flooding in the provinces of Maputo, Gaza, Inhambane and Nampula, due to the damages in the national power grid, industrial facilities and housing, as previously mentioned.
Similarly, Figure 36 presents the evolution of the natural gas consumption in industry between 2010 and 2019.

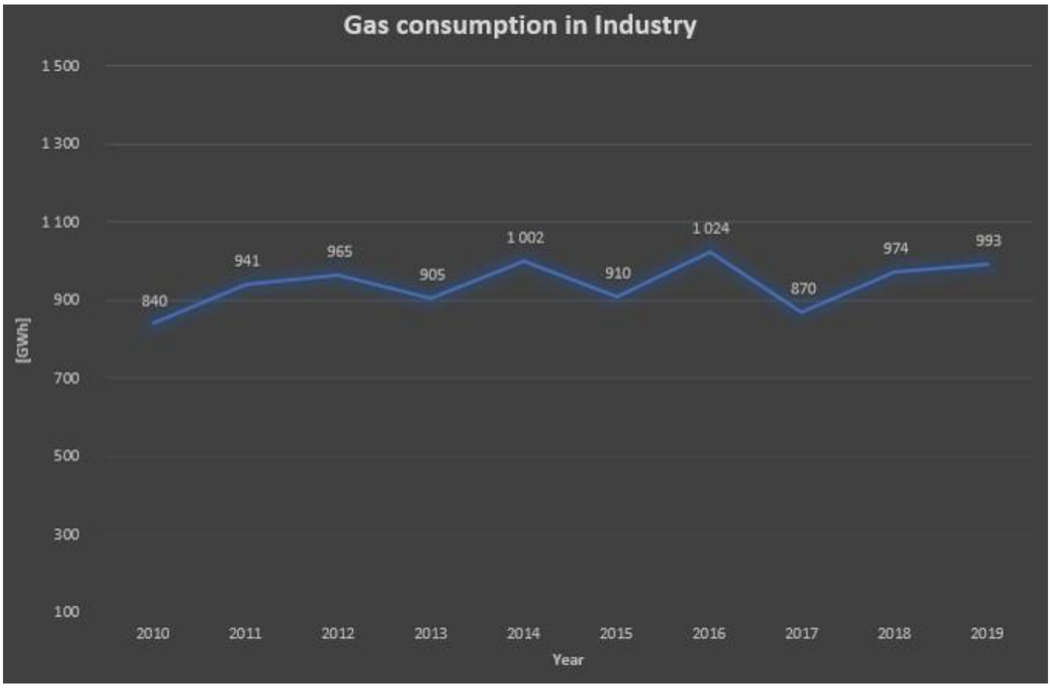


FIGURE 36- EVOLUTION OF THE NATURAL GAS CONSUMPTION IN INDUSTRY BETWEEN 2010 AND 2019. SOURCE: [26].

Unlike the electricity, natural gas consumption does not present a steady pattern of evolution, this could be explained with fluctuations of the production levels. From 2010 to 2012 the NG consumption increased 11% in 2011 and 2% in 2012. After this date the NG consumption goes up and down each year alternately. This fluctuation keeps the NG consumption between 905 GWh in 2013 to 1024 GWh in 2016. Once again in 2017 the impact of the severe tropical depression is visible in the NG reduction in consumption, likely due to a drop in the production levels and due to probable damage in industrial facilities. In 2018 the NG consumption resumed its growing trend.

4.3.2. Consumption Disaggregation by Equipment

As well as in the non-residential sector, in industry there are no available statistics regarding the breakdown on the electricity consumption per equipment type. Figure 37 presents the estimations made for the industrial sector regarding the electricity breakdown consumption.

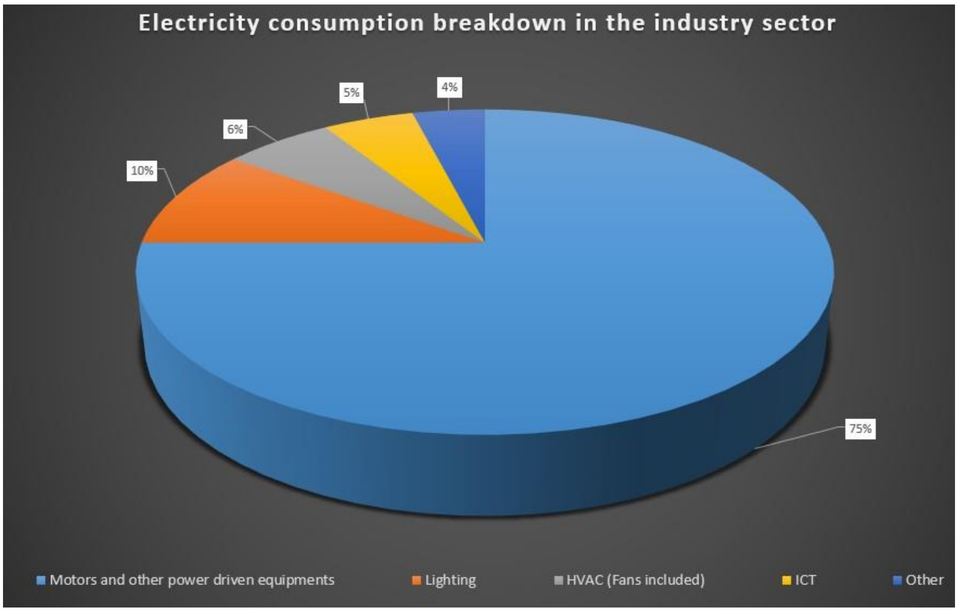


FIGURE 37- ESTIMATION ON THE INDUSTRY ELECTRICITY BREAKDOWN CONSUMPTION.

As previously mentioned, due to lack of information regarding the sector breakdown in terms of electricity consumption per equipment, the percentages in Figure 37 will be used in Chapter 5 to estimate the country electricity savings potential.

4.3.3. Consumption Disaggregation by Subsector of Activity

The industrial production of Mozambique is based in a limited number of products. Figure 38 presents the most electricity consuming subsectors of industry and its weight in the sector total electricity consumption.

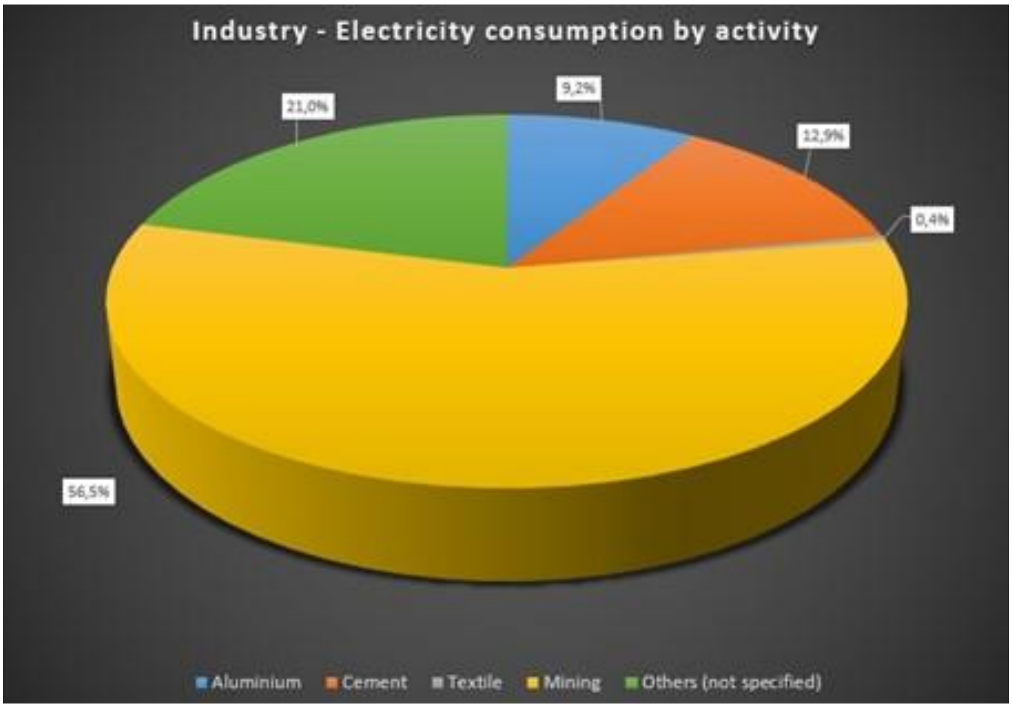


FIGURE 38- ENERGY CONSUMPTION IN INDUSTRY BY SUB-SECTOR OF ACTIVITY. SOURCE: [24, 26].

4.3.4. Consumption Trends

In 2020 the country economy suffered a contraction around 0,4% [27], mostly due to disruptions caused by Covid-19 pandemic. The economic fall-out from the pandemic has adversely affected the economy, employment and households. However, the World Bank estimates that Mozambique will resume its economic growing trend in 2021 by growing 2.8% and 4.4% in 2022 [27]. For the purpose of this analysis and assuming a favourable economic scenario it was considered an average growing rate of 5% per year for electricity consumption and 2% for NG (between 2010 and 2020 the average growth rate was 1% as presented in Figure 36) being consumed in the industrial sector in Mozambique. Figure 39 presents the estimated evolution in the energy consumption (electricity and NG) for the industrial sector between 2020 and 2050.

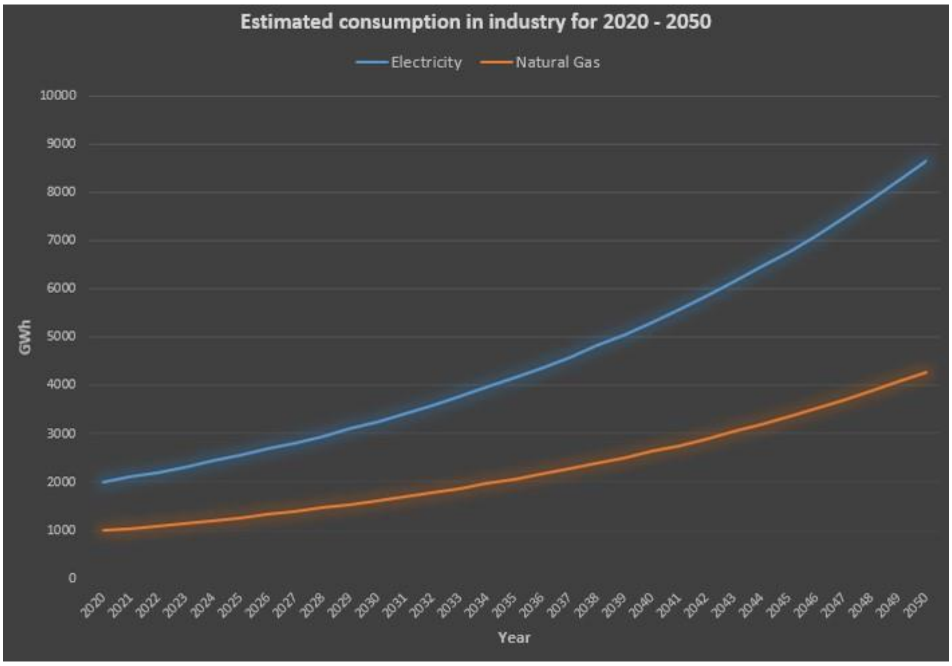


FIGURE 39- ESTIMATED EVOLUTION ON THE ENERGY CONSUMPTION OF ELECTRICITY AND NATURAL GAS IN INDUSTRY BETWEEN 2020-2050. SOURCE: [24, 26].

4.3.5. Considerations

In 2019, cyclones Idai and Kenneth caused massive damage to infrastructure and livelihoods, further lowering growth and wellbeing of the population, as well as the industrial production in the country. These cyclones caused supply disruptions, destroyed infrastructure, and took the lives of hundreds of people. The economy remains highly susceptible to climate-related shocks due to its geography and high-dependence on regular rainfall to supply water to subsistence agriculture. Furthermore, in 2020 the Covid-19 pandemic situation created an additional setback on the country's economic prospects [27].

The Covid-19 pandemic dimmed the short-term growth prospects of Mozambique, whereas in the mid and long-term the pandemic crisis will have a heavy impact on economic activity, namely industrial production, as well as in social distancing and travel restrictions (domestically and globally) affecting the demand for goods and services [27]. At the same time, the reduced demand and prices of commodities are slowing the pace of investment in gas and coal, two key industries for Mozambique.

One of the major problems that industry faces in Mozambique is the average population low skill levels which hinder employment and productivity, while the fast growing population pushes unemployment rates high, particularly among younger population. This gap reduces local companies ability to take advantage of technological breakthroughs made worldwide, as well as the access to global value chains. Additionally, the fact that only 32% of the population has access to electricity further limits economic growth [24].

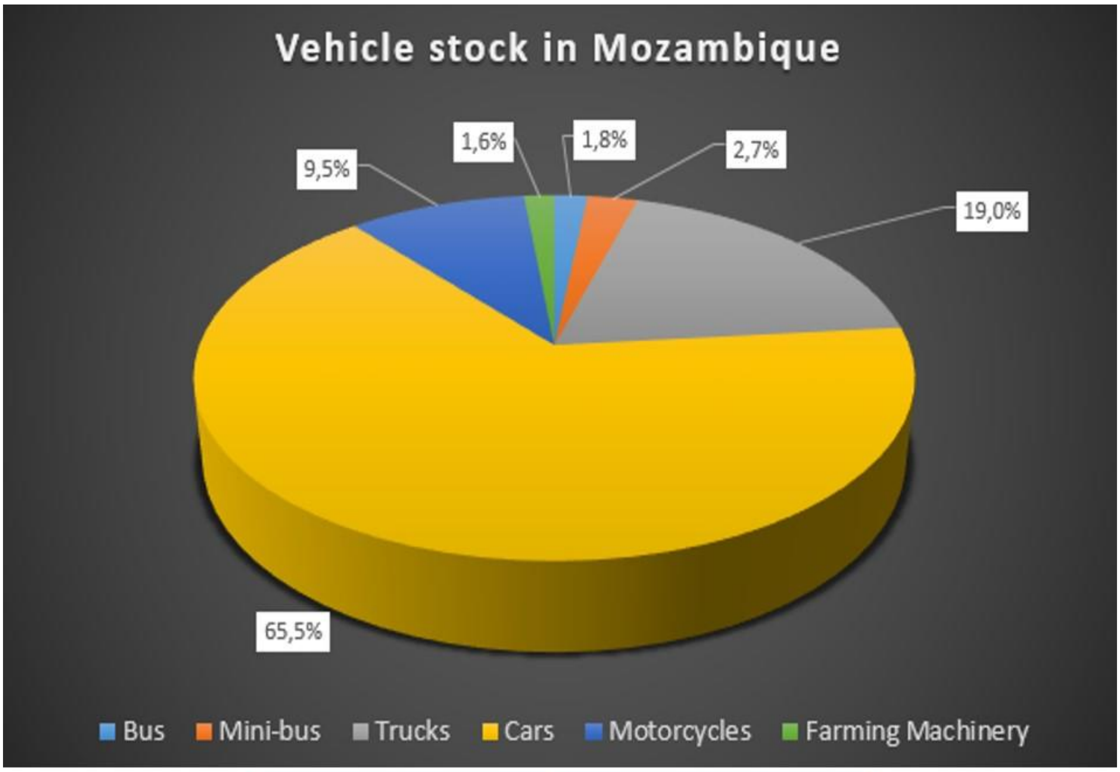
Another major challenge is diversification the economy by moving away from the current focus on capital-intensive projects and low-productivity subsistence agriculture, while strengthening the key drivers of inclusion, such as improved quality education and health service delivery, which could in turn will improve social indicators. Additionally, the industrial sector needs to open its horizons to technology and other manufacturing sectors (e.g. domestic appliances, industrial machinery and equipment, electronics, etc.) in order to strengthen the country economy as well as to balance the relation between importation and exportation of goods.

In order to achieve this transformation, Mozambique needs to overcome one major issue linked to the pressing need to increase the population levels of education and provide vocational training and technical education to enhance employability and productivity. The lack of skilled workers makes the labour market dysfunctional, limits the attraction of foreign investment, especially in technological sector, for which it is crucial to have a well prepared labour market. Industries with high potential value for local/national economy (e.g. fertilizers, pulp-paper, metal-mechanic, etc.) should play an important role in the country economy. These industries might also enhance macroeconomic stability, with higher revenues contributing to financial benefits for the whole economy.

4.4. Characterization of the Transportation Sector

4.4.1. Characterisation of the Vehicles Stock in Mozambique

The vehicle stock (existing vehicles) in Mozambique can be divided in five categories: buses, mini-buses, trucks, cars, motorcycles and farming machinery (e.g. tractors, mowers and conditioners, planting and seeding, etc.). Figure 40 presents the vehicle stock breakdown, as well a table with the number vehicles.



Type of Vehicle	Number of Vehicles
Bus	10 978
Mini-bus	16 466
Trucks	117 005
Cars	404 426
Motorcycles	58 539
Farming Machinery	9 916
Total	617 330

FIGURE 40 - VEHICLE STOCK IN MOZAMBIQUE. SOURCE: [28, 29].

Table *11* presents the Mozambique vehicle stock characterization in terms of fuel type, number of vehicles, average kilometres (Km) made per year, fuel consumption, fuel price and total fuel cost for each type of vehicle.

Table 11 - Mozambique vehicle stock characterization. Source: [28, 29].

Mozambique vehicle stock	Bus			Minibus		Trucks		Cars			Motorcycles	Farming Machinery
	Urban		Intercity	Urban	Intercity							
Fuel	**Diesel**	**NG**	**Diesel**	**Diesel**	**Diesel**	**Diesel**	**NG**	**Diesel**	**NG**	**Gasoline**	**Gasoline**	**Diesel**
Number of vehicles	9 716	164	1098	14 819	1 647	116 983	22	160 683	2 719	241 024	58 539	9 916
Average Km per year	15 000	80 000	20 000	30 000	35 000	15 000	30 000	15 000	30 000	15 000	7 000	15 000
Fuel Consumption [litre/100Km]	20	30	18	17	15	18	35	11	9	11	5	18
Total fuel consumption per year [million Litres]	29,15	3,94	3,95	75,6	8,7	315,9	0,231	265,1	7,3	397,7	20,5	26,8
Fuel price per litre[19]	$0,81	$0,42	$0,81	$0,81	$0,81	$0,81	$0,42	$0,81	$0,42	$0,88	$0,88	$0,81
Total Fuel cost per year [million USD]	23, 54	1,63	3,2	61,0	7,0	255,0	0,096	214,1	3,0	349,9	18,0	21,6

19- Fuel price in November 2020 in USD – United States Dollars. ($1= 73,0 Mozambican Metical)

4.4.2 Consumption Disaggregation by Type and Number of Vehicles

The main fuel used for vehicles in Mozambique is diesel (51,0%), very closely followed by gasoline with 48,5% and natural gas with only 0,5% of the vehicles. Figure 41 presents the vehicle breakdown by type of fuel.

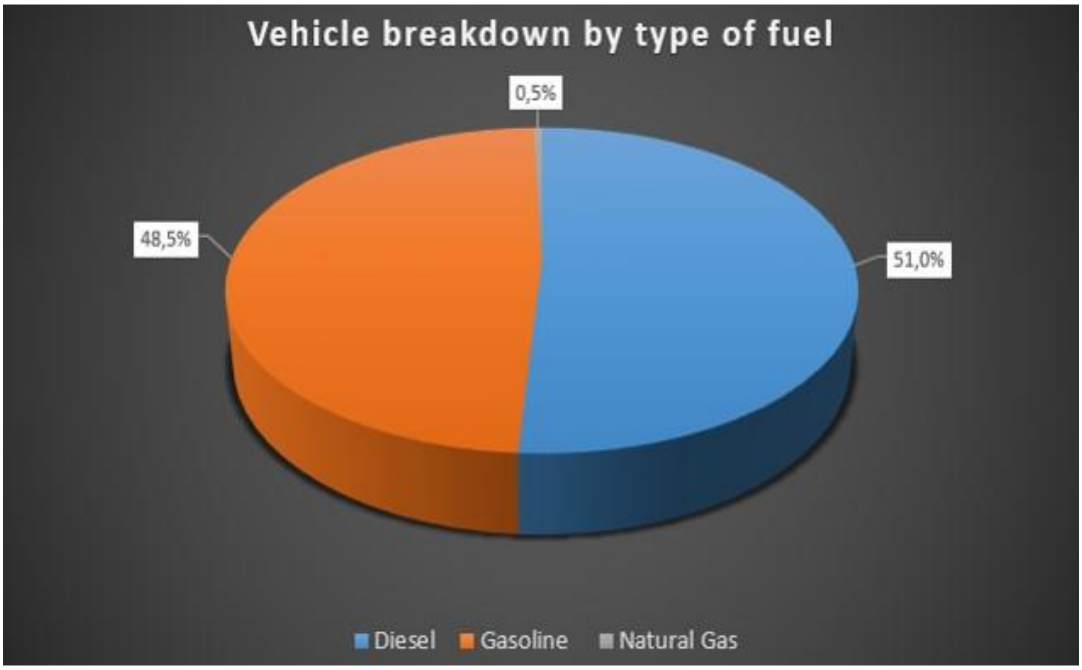


FIGURE 41- VEHICLE PERCENTUAL BREAKDOWN BY TYPE OF FUEL. SOURCE: [28, 29].

The percentage of vehicles using natural gas (NG) is still very low, despite Mozambique being a NG producer, mainly due to fact that NG is only available in the larger cities.
Regarding fuel sales for vehicles in Mozambique, Figure 42 presents the fuel mix in 2019.

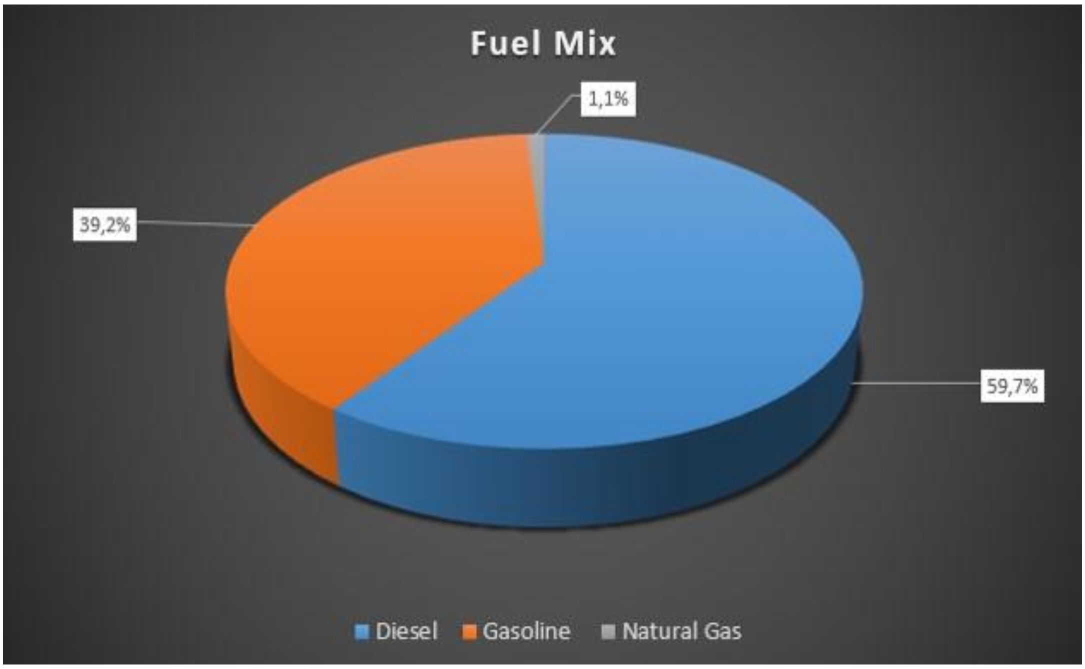


FIGURE 42- FUEL SALES IN LITRES IN MOZAMBIQUE. SOURCE: [28, 29].

Figure 43, Figure 44, Figure 45 present the vehicle disaggregation per type of fuel (diesel and gasoline).

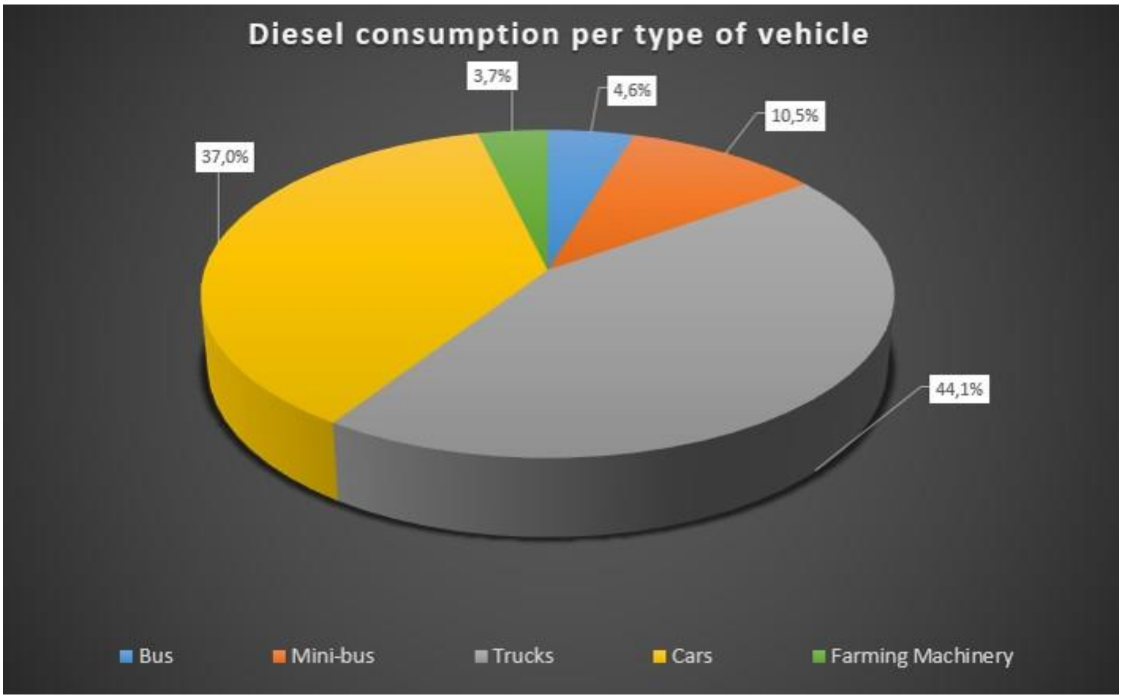


FIGURE 43- DIESEL CONSUMPTION PER TYPE OF VEHICLE. SOURCE: [28, 29].

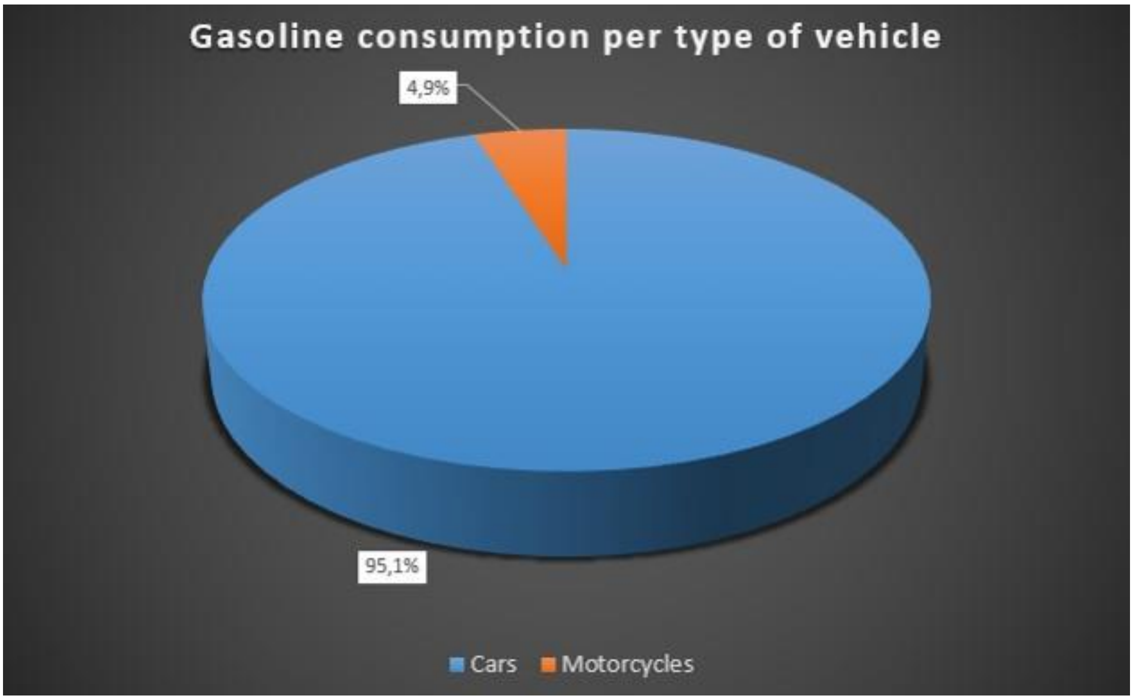


FIGURE 44- GASOLINE CONSUMPTION PER TYPE OF VEHICLE. SOURCE: [28, 29].

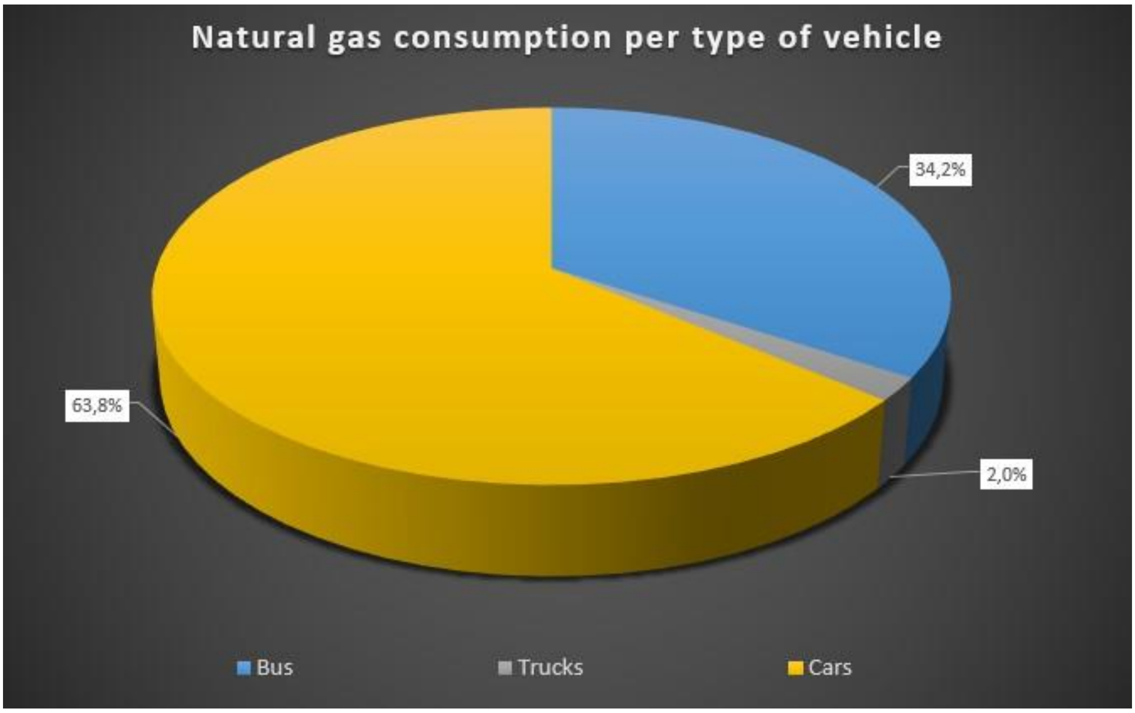


FIGURE 45- NATURAL GAS CONSUMPTION PER TYPE OF VEHICLE. SOURCE: [28,29].

Cars and buses (including minibus) represent 70% of the total number of vehicles in Mozambique. These vehicles have a huge potential for fuel switching from fossil fuels into an eco-friendlier fuel such as, electricity or natural gas. Despite natural gas being a fossil fuel, considering that Mozambique has large reserves, natural gas could be considered as an intermediate stage for decarbonisation transportation before switching into electric mobility. Even the non-urban buses depending on the distance travel may be able to move to electricity depending on the installation of a charging infrastructure. The potential of this fuel switching transformation will be analysed with more detail in Chapter 5.

4.4.3. Consumption Trends

In the transportation sector, it is likely that the fuel consumption will keep increasing, namely due to an increase on the country vehicle stock (number of existing vehicles). This stock is likely to increase, considering the foreseen population growth (2,6% per year according to INE - Mozambique National Institute of Statistics). This growth rate was considered in our analysis into the vehicle stock evolution. Figure 46 presents the vehicle stock evolution between 2009 to 2019 and Figure 47 presents an evolution scenario that includes the mentioned population growth rate and its impact in the vehicle stock evolution from 2020 to 2050.

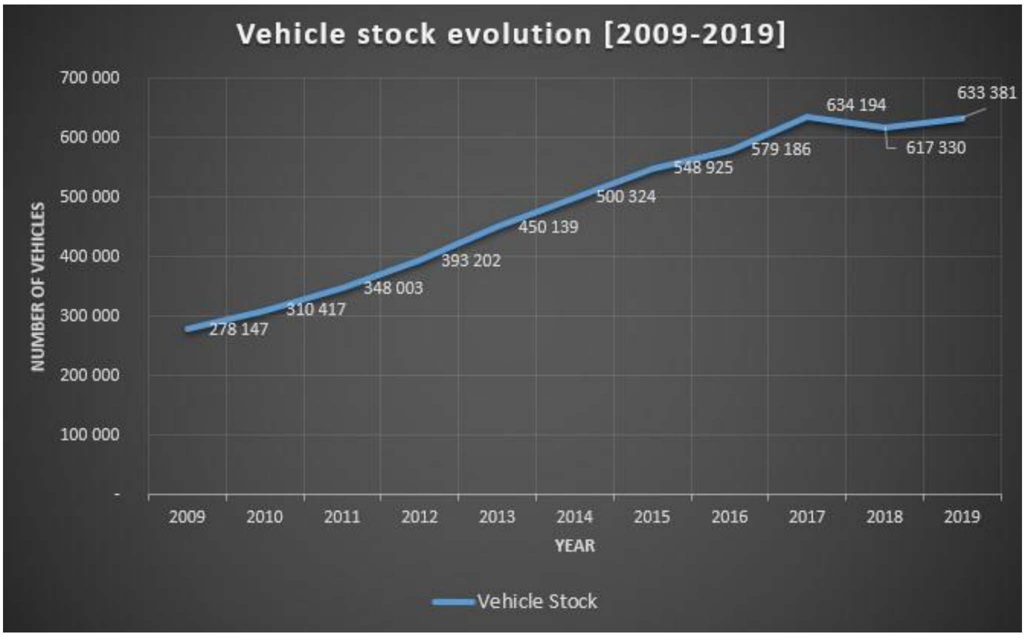


FIGURE 46- VEHICLE STOCK EVOLUTION IN THE 2009-2019 PERIOD. SOURCE: [28, 29].

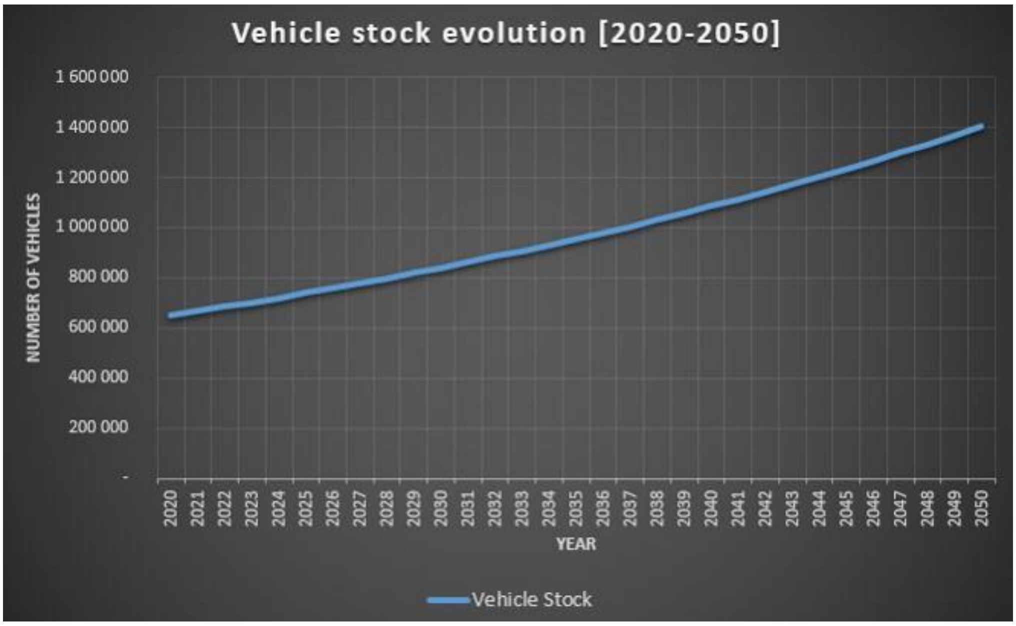


FIGURE 47 – ESTIMATION ON THE VEHICLE STOCK EVOLUTION BETWEEN 2020-2050.

In 2020 Mozambique population is close to 27,9 Million people and in 2050 it is expected, according to INE projections, to reach 60 Million people. Even if the economy does not behave in a positive direction, a growth in vehicle stock similar to the population growth rate, is still likely to occur. However, if the economic growth between 2020-2050 is favourable to the country development [30], the vehicle stock evolution could be larger. For the purpose of this analysis a 2,6% rate of growth was considered in the vehicle stock evolution.

4.4.4. Considerations

The transition to electric vehicles (EV) is underway in most developed countries. However, in most developing countries due to economic reasons (especially the EV acquisition cost that still is too high for people in those countries) might change in short-medium term. Conventional automakers have now announced ambitious plans for electrification of their respective fleets, which will drastically reduce the production costs, allowing the introduction of EVs in the market at lower costs. Electric vehicles are now perceived as technology not only to address climate change, but also to improve urban air quality. Decarbonisation strategies typically include the transition to electric transportation as a key element in long-term plans. While the transformation from conventional passenger vehicles (with internal combustion engines, powered by oil-based fuels) to EV (vehicles propelled totally, or in part, by electricity), is very likely, the trajectory of this transition is considerably different in each country.

The fundamental case for EV rests on the fact the transportation sector CO_2 emissions are large and are growing faster than emissions from any other sector. Combustion vehicles are directly responsible for these emissions due to the use of oil based fuels (e.g. diesel and gasoline).

In 2018, the transportation sector was responsible for approximately 14% of all greenhouse gas emissions worldwide and a quarter of the emissions derived from burning fossil fuels [31]. Passenger vehicles are responsible for the larger part (72%) of emission in the transportation sector emissions and are the primary reason for emissions continuous growth [31]. Fuel substitution, therefore, is a critical element in reducing the climate impact caused by the transportation sector. The impact of fuel substitution can also be complemented by increasing fuel efficiency, car sharing, public transportation, etc. However, in some countries the personal ownership of a vehicle is a cultural issue, people have cars not only to improve the quality of life (e.g. using it to go to work, take children to schools, etc.) but also as a social status. And, in these countries, it seems unlikely that this type of ownership will diminish any time soon.

Mozambique has a significant number of passenger vehicles (as presented in Figure 40, cars are 404426 and buses 27444), mostly using diesel and gasoline. The transition to EV might seem to be far away, but the introduction of VE in the major cities for example by creating an urban network of electric buses will help reducing the municipality diesel bill and at the same time help reducing the country oil dependence. Urban buses can represent 30-40% of the air pollution in large urban centers, with negative impacts in the population health. In early 2021, the city Bogota in Colombia, placed an order of over 1000 electric buses. However, considering that Mozambique is a Natural Gas (NG) producer, it might be wise to consider Natural Gas Vehicles (NGV) as an intermediate step into the EV transition. NGV can offer an array of economic and environmental benefits, which may include the economic benefits of having a lower cost fuel, improvement of regional air quality, reduction of greenhouse gas emissions, reduction of the country dependence on petroleum and providing a pathway into fuel switching to EV.

NGV are a better solution comparing to diesel/gasoline vehicles, offering up to 30% reduction in greenhouse gas (GHG) emissions for light-duty vehicles, and as much as 23% reduction for medium- to heavy-duty vehicles, when compared with gasoline and diesel [31].

Additionally, EV may help reducing families (and companies) monthly expenditure in fuel (e.g. gasoline or diesel) for the family cars or on companies car fleets. The introduction of EV in Mozambique can have a significant impact economy, by reducing the oil importation and replacing it with electricity produced by renewable energy sources such as hydroelectric, solar, wind, etc. In conclusion the transport sector, is facing a challenging time, the EV are already a success story in most developing countries. European car manufacturers are already considering stopping production of diesel vehicles in 2030. In Mozambique, as well as in other African countries, this transition is likely to take more time, but it will certainly take place. NGV will have an important role in this transition and climate change policies might speed it up.

4.5. Cross Sectoral Information

4.5.1 Lighting

This section presents an overview on the main types of systems and its characteristics used for lighting in non-residential buildings, residential households and also in public street lighting systems.

4.5.1.1 - Lighting Used in Buildings/Households

The lighting systems used in Mozambique are quite similar in all economic sectors, with the exception of specific equipment types such as, large industrial lighting systems used in factories and warehouses. This section resumes the main characteristics of these systems.

Lighting is still an area with a large potential of improvement, since it represents a large part of the energy consumption (13,6% in the residential sector, 35% in the non-residential sector which includes public street lighting and 10% in industry) in the country. In Mozambique either in households and in non-residential buildings incandescent lamps are still often used due to its low price and availability. It is important to raise awareness of the population and of the decision makers about the benefits of moving forward to more efficient lighting technologies such as LEDs. Additionally, it is important to create the necessary conditions to allow that these energy efficient technologies are available for the population at a moderate cost.

LEDs allow residential, commercial and government buildings to achieve significant energy savings, by reducing the energy bills which allows to channel the economic savings into other areas where they are most needed. Despite LEDs higher acquisition costs, the savings obtained during their lifetime allow to achieve significant economic savings, however it is important to assure that the available products in market comply with high quality and energy efficiency standards. For this, it is important to create regulation to protect the market from low quality and inefficient products. This is valid for lighting as well as, for home appliances and any other electric equipment with relevant electricity consumption (e.g. industrial electric motors).

In developed countries LEDs are shaping the market, as the momentum created by the phase-out of incandescent and halogen lamps as well as the declining shares of fluorescent technologies is increasing the lighting fixture efficiency. The LEDs available in the market have considerable improvements relatively to the ones available in the early 2000s when incandescent lamps were being partially replaced by equally low-efficiency halogens and Compact Fluorescent Lamps (CFL) in many parts of the world, including Europe.

Between 2005-2015 consumers considered that the available alternatives to halogen and incandescent lamps where inadequate (due to price, quality, light colour, etc.) LED did not have the sufficient light quality to convince consumers. After this, manufacturers introduced higher quality products (higher efficiency, better colour rendition, longer lifetime) new design, new functionality improvements and reduced the prices. In the last five years LEDs have exponentially increased their market share leading to lower prices.

Worldwide LEDs have passed from a market share of 5% in 2013 to nearly half of global lighting sales in 2019, with integrated LED luminaires making up an increasing share. LED sales are starting to overtake the fluorescent lamp sales for both residential and commercial applications, and it is likely that LED market share will continue to increase.

LED penetration remains uneven across many markets, especially in developing countries such as Mozambique, and sales are typically lower in relative terms for lamp replacements than for

newly built buildings. The government authorities play an important role in raising population awareness into the importance of using high quality and high efficiency lighting systems. The creation of lamp exchange programmes or other types of initiatives/actions to disseminate the benefits of LED are extremely important and should be considered in a short term.
To create the mentioned initiatives/actions it is essential that the authorities and experts have an overview on existing lamp stock (number of lamps being used in the country by type of lamp). However, that information is not yet available - It was possible to find some information (only the estimated quantity of lamp per type, but no technical information could be found) related to lamp stock in 2014, please look at Table 12 [32]. It is likely that the actual situation might be different in a significant way due to the fast rotation of these products. This highlights once again the necessity of having an energy information system that gathers all the information related to energy consumption and any energy related products/equipment types.

TABLE 12 - LAMP STOCK IN MOZAMBIQUE IN 2014. SOURCE: [32]

Lamp Type	Number of lamps (Million Units)
Compact Fluorescent Lamp – CFL	164
LEDs	0,36
Incandescent	9,64
Halogen	0,73
Linear Fluorescent	13,63

Considering the lack of recent information regarding lamp stock, a local survey was conducted in some of the major stores in Maputo to determine which are the types of lamps being sold by the end of 2020. Table 13 present this information.

TABLE 13- SOME TYPES OF LAMPS AVAILABLE IN STORES IN DECEMBER 2020 IN MAPUTO[20]

Lamp Type	Description	Brand	Power	Average Cost [$USD[21]]
Compact Fluorescent Lamp - CFL	Energy Class A Lighting efficiency 58 lm/W Lifetime 8 years	N/A	14 W	$ 2,72
	Energy Class A Lighting efficiency 58 lm/W Lifetime 8000 hours	N/A	15 W	$ 3,55
LEDs	Energy Class A Lighting efficiency 71 lm/W Lifetime 25000 hours	N/A	10 W	$ 2,06
	Energy Class A Lighting efficiency 90 lm/W Lifetime 15000 hours	N/A	14W	$ 2,53
Incandescent	Energy Class E Lighting efficiency 11 lm/W Lifetime 1000 hours	N/A	60 W	$ 0,62
Linear Fluorescent[22]	60 cm 120 cm 150 cm	Osram, Philips and Radiant	23,4 Wh 46,8 Wh 75,4 Wh	$2,04 $1,08 $1,08
N/A – Not Available				

4.5.1.2 - Public Street Lighting

[20] The average cost was obtained in January 2021.
21- USD- United States Dollars. ($1= 73,0 Mozambican Metical)
22- The energy consumption considered in these lamps include the ballast consumption.

Regarding public lighting, EDM was able to provide quality information regarding the number of lamps, power, lumen output and working hours. But average cost was not possible to obtain. Table 14 presents this information.

TABLE 14 - PUBLIC STREET LIGHTING CONNECTED TO THE NATIONAL POWER GRID IN 2020. SOURCE: EDM[23]

Lamp Type	Number of lamps	Power [W]	Efficiency [Lm/W]	Number of working Hours	Total Consumption per year [GWh]	Average Cost [$USD[24]]
Mercury Vapor	8 762	70W	100 Lm/W	12 Hours per day	223,9	N/A
Low Pressure Sodium	7 314[25]	80W	90 Lm/W		0,66	N/A
		100W				N/A
High Pressure Sodium	86 807[26]	125W	100 Lm/W		87 925,2	N/A
		150W				N/A
		250W				N/A
		400W				N/A
LED	7 000[27]	60W	120 Lm/W		2 684,9	N/A
		100W				N/A
		150W				N/A

N/A – Not Available

Public street lighting represents almost 15% of the total consumption in the non-residential sector (609 GWh per year in 2019). Non-efficient lamps are still the most used type, considering this the energy savings potential in this case is substantial. The transition into energy efficient lamps (LEDs) should be made at a steady rate and it will allow very significant savings at a short-medium term. It is important to plan this transition and programme the necessary investment, which is considerable.

TABLE 15- PUBLIC STREET LIGHTING POWERED FROM SOLAR ENERGY IN 2020. SOURCE: FUNAE[28]

Lamp Type	Number of lamps	Power [Watt]	Efficiency [Lm/W]	Number of working Hours	Total consumption per year [MWh]	Average Cost [$USD[29]]
Mercury Vapor	122	80W	48 Lm/W	12 Hours per day	42,8	N/A
High Pressure Sodium	147	400W	140 Lm/W		257,6	N/A
LED	89 913	2X24W	100 Lm/W		9 451,66	N/A

N/A – Not Available

Please note that any procurement procedures made by either EDM and/or Mozambican authorities regarding lamps and lighting fixtures should be based in well-defined quality and

[23] The information was obtained during a bilateral meeting with EDM representatives
[24] USD- United States Dollars. ($1= 73,0 Mozambican Metical)
[25] Estimating that 50% of lamps are from each power.
[26] Estimating that 25% of lamps are from each power.
[27] Estimated quantity 60W-2800 Units, 100W-3700 Units and 150W-500 Units.
[28] The information was obtained during a bilateral meeting with FUNAE representatives
[29] USD- United States Dollars. ($1= 73,0 Mozambican Metical)

technical criteria to assure the overall performance of these equipment types. As a support to these procurement procedures the guidelines and best practice guides produced in the Premium LightPro project [33] could be used as guidance.

The international consortium responsible for developing the Premium Light Pro project had its main focus on the implementation of next-level energy efficient LED lighting systems (indoor & outdoor lighting) in the private and public service sector. The main target of this project was to support the implementation of high quality and efficient LED solutions by appropriate instruments and services. The successful implementation was facilitated by the development of effective policy instruments which will be designed in cooperation with experts from the supply and demand side market. One of the project outcomes was the creation of technical guides, guidelines and other support documents for indoor and outdoor lighting (public street lighting included). These guides may provide important information (e.g. quality criteria, lighting and component design, procurement criteria, technical requirements and regulation) for Mozambican decision/policy makers in the creation of regulation for efficient lighting systems in the country.

4.6. Off-Grid Market Characterization

The limited access to electricity is one of the major challenges that the Mozambican energy sector is currently facing. The Government of Mozambique is committed to achieve the Sustainable Development Goal 7 – SDG7, ensuring access to affordable, reliable, sustainable and modern energy for all by 2030. However, only with a more diversified approach including the expansion of the grid and off-grid solutions, where households are not solely dependent on the national gird, ensures the fulfilment of SDG7.

Approximately 68% of the 29,7 million Mozambique inhabitants do not have access to the national power grid. In rural areas only 5% of the population enjoys the benefits of grid connected electricity [10, 34, 35, 36, 37, 38]. At the moment, off-grid households rely on technologies such as battery powered flashlights and kerosene lamps to meet their lighting needs. These equipments provide lower-quality light, unsafe (e.g. equipments using kerosene), causing health problems and usually are more expensive compared to household clean energy products (e.g. solar home systems) that are used only by approximately 10% of households that use off-grid electricity.

According to the current projections, in 2030 only around 50% of the population will have access to the national power electricity grid. Providing 100% of electricity access (grid connected and off-grid) to the population is a long-term ambition of the Mozambican Government. However, considering the country dimension and the low population density, the national grid expansion might not be a cost-effective option in remote areas. In these cases, off-grid systems (solar home systems, microgrids and minigrids) will allow communities to enjoy the same quality of electricity as in grid connected systems, Therefore, off-grid rural electrification can play a crucial role in the efforts of making electricity available for all by 2030. Additionally, while grid connections are highly subsidized and take very long time to get into service, solar home systems (SHS) have small cost and are very quick to install (one or two days). Due to these facts off-grid systems can leverage a much faster electrification development in Mozambique.

The solar systems value chain remains underdeveloped in Mozambique and divided between different entities formal companies (registered businesses), informal vendors (unregistered sellers), and public entities. The formal distributors import the products in most cases from Chinese manufacturers. Units are shipped by sea and arrive in the several ports along the coastline (the largest being Maputo, Beira, Nacala, and Pemba) within an average time of two months. The entrance of this products in Mozambique implies the payment of custom fees (pay between 7.5% and 20% import duties related to the cost of goods imported and an upfront 17% Value Added Tax (VAT) on the cost of the systems). The informal vendors of solar systems are found in the larger urban markets across the country and increasingly present in rural areas. Systems are acquired either directly from electronic shops in the major cities (Mozambique), or in South Africa, Zimbabwe, Zambia, Tanzania, and even brought from Kenya. These vendors typically make a 20-30% profit margin. It is not clear if any taxes are paid considering the low prices of these systems. The sales model used by these vendors is direct (cash only) and payment modalities and product warranty are not offered to the end-users.

As previously mentioned, the off-grid solar market in Mozambique can be divided into three main supplier groups:

- **Registered businesses dedicated to the sale of SHS and associated products, providing services or commercialising solar systems/services in addition to multiple other products and services offered.**

In recent years, a small number of companies have either been established to sell solar systems or to have included these products as part of their product portfolio. Although, this sector is still in its early stage, several reliable brands in SHS are currently being sold by these companies. The establishment of these companies was in most cases, driven by donor programmes that gave incentives to the off-grid solar market development. In 2018 the World Bank Mozambique off-grid assessment report [10] identified 21 companies either being active in the Mozambican off-grid market or with interest to enter soon, mainly through SHS. Only a handful of these companies are currently operating at a large scale (micro and minigrids). The most advanced company is offering a Pay as You Go (PAYG) service to its customers in the southern part of Mozambique and currently has just over 5,000 users and is expanding to the central and northern provinces [10]. Figure 48 presents some examples of the products available for SHS in Mozambique.

Figure 48- Low price solar products from established companies in Mozambique. Source: [10].

Please note that the products display in the bottom of Figure 48 are available in Mozambique with a price under $50 USD.

Households can purchase solar energy components for their basic energy needs (lighting, radio, phone charging, etc.) at a starting price of $50 USD. The cost of SHS in these shops is also set at around the same price. Buyers have the option to scale-up their SHS according to their energy requirements. It should be noted that charge regulators are not easily sold at these shops and correct installation guidance is not given by shop attendants. Additionally, it is important to mention that some equipment suppliers (e.g. Chinese-owned shops in Chimoio) offer a guarantee of up to six months for systems sold [10].

- **Informal (unregistered) traders offering solar products/services.**

The informal trade in Mozambique is prospering and largely out-numbers the traditional commercial activity (in stores). Most of the products available in the informal market are imported through cross border traders or supplied by wholesale agents. It is becoming progressively more usual to find SHS sold through this type of traders. The products available through these channels range from complete solar kits (lights, phone charging, radio, etc.) to individual components (PV panels, batteries, inverters, charge regulators and other accessories). The quality of these systems is sometimes questionable and usually buyers do not have access to any sort of warranty or installations guides. The common perception regarding these systems is that they break down easily and are considered a risky investment.

A combination of these system components with associated accessories can cost the buyer just under $50 USD for a functional basic solar kit being able to run two or three lights, a phone charger and a radio. The systems are brought from South Africa or China. The vendors either acquire the systems directly from shops (in larger cities of Mozambique and/or South Africa) or through traders which import the systems and distribute across several African markets (traditional and informal). In most cases, the population from rural remote areas purchases these systems in the informal markets in the cities. Large municipal (informal) markets are a common source for manufactured goods, despite the fact, that most often the price of these goods is higher in the informal markets than in the formal shops. It is a common practice for households to purchase from informal markets due to market proximity, the perception that products are cheaper and that it possible to bargain for them. Figure 49 presents some examples of the products sold in informal markets in Mozambique.

FIGURE 49- SOLAR ENERGY COMPONENTS SOLD IN AN INFORMAL MARKETS IN MOZAMBIQUE. SOURCE: [10]

- **Suppliers of solar systems as a result of subsidised initiatives (NGO, Governmental, or CSR initiative)**

To date, the main drivers of off-grid solar projects have been donors, NGOs and the Mozambique Energy Fund (FUNAE). FUNAE possesses a solar PV manufacturing plant in Boane (Maputo province), which FUNAE uses to supply households and institutional users in rural areas with solar systems. Other system components are supplied by third party suppliers. To date, FUNAE has been involved in more than 1260 projects, including the electrification of small towns, schools and health centres [10].

In the absence of a developed market for quality solar systems, NGOs such as ADPP (Ajuda de Desenvolvimento de Povo para Povo - People to People Development Assistance), ADEL Sofala (Agência de Desenvolvimento Económico Local de Sofala - Local Economic Development Agency of Sofala) and Kulima have bridged this gap by distributing solar systems as part of their activities. The NGOs have formed an association called FEDESMO (Fórum de Energias e Desenvolvimento Sustentável de Mozambique - Mozambican Forum for Energy and Sustainable Development). These non-commercial players hold valuable experience and understanding of the off-grid sector and specially of the household and people dynamics. These NGOs can play an important role in stimulating demand for solar systems, in the dissemination of information regarding solar systems and technologies and in the engagement of the population in awareness raising campaigns for solar products with high quality standards.

The use of renewable energy as a vehicle for the development of local businesses and economic activities should be considered as a priority by the local authorities. The development of regulation to increase the overall quality standards of off-grid equipment will be an important step to assure consumer confidence. The number of people who may be potential clients for these equipment types is enormous, and a regulated market will raise awareness in those people for the benefits (financial, related to health and environmental) of having access to clean electricity, electricity services and clean cooking. This increase on the number of people acquiring solar products will most certainly have a positive impact in local economies by creating jobs, increasing sales in stores and especially will increase the population living standards. A quality market that captures consumers attention and trust by guaranteeing that the purchased products have quality and are sold at a fair price will boost the off-grid market.

Regarding the available products for solar off-grid systems, considering the large dissemination of unofficial vendors, it is not easy to fully characterize the available products and its cost due to fact that product prices show large differences depending on the type of vendors and on the equipment quality. Figure 50 presents this differences.

Sales price comparison between different type of SHS distributors

Distributor type	Average price of SHS (MZN)	Average price of SHS ($)
Official distributors of quality-verified systems	7,567	$126
Electronic shops (non-certified systems)	2,867	$48
Informal vendors (non-certified systems)	3,000	$50

FIGURE 50- SALES PRICE COMPARISON BETWEEN DIFFERENT TYPE OF DISTRIBUTORS. SOURCE: [10].

In order to give a general overview on the off-grid market Figure 51 presents the products available in four different types of stores in Mozambique.

Price list of solar energy equipment sold at electronic stores

	Shop			
Component	Metalex (Maputo)	Casa Asa (Maputo)	Chinese shop (Chimoio)	Electric Shop (Quelimane)
10 Wp solar panel	1,180 MZN ($20)	1,050 MZN ($18)	700 MZN ($12)	600 MZN ($10)
20 Wp solar panel	1,890 MZN ($32)	1,350 MZN ($23)	1,200 MZN ($20)	1,200 MZN ($20)
50 Wp solar panel	3,780 MZN ($63)	3,000 MZN ($50)	3,200 MZN ($53)	N/A
100 Wp solar panel	6,980 MZN ($116)	5,500 MZN ($92)	N/A	N/A
12v 7 AH battery	1,250 MZN ($21)	700 MZN ($12)	700 MZN ($12)	800 MZN ($13)
12v 12 AH battery	2,510 MZN ($42)	1,200 MZN ($20)	N/A	N/A
DC to AC inverter (159 W Max)	1,600 MZN ($27)	N/A	700 MZN ($12)	900 MZN ($15)
DC to AC inverter (300 W Max)	3,150 MZN ($53)	N/A	1,800 MZN ($30)	N/A
DC to AC inverter (800 W Max)	6,050 MZN ($101)	N/A	N/A	N/A
Solar home system 3 lights/phone charging/lantern	3,100 MZN ($52)	3,000 MZN ($50)	2,500 MZN ($42)	N/A

FIGURE 51- PRICE LIST ON SOLAR ENERGY EQUIPMENT AT ELECTRONIC STORES IN MOZAMBIQUE. SOURCE: [10]

From the consumer point of view, the most important issues in a solar off-grid system are affordability (ability of people to purchase goods or a service), accessibility (level of difficulty to obtain a good or a service at a specific time or place where it is needed) and quality (how the good or service meets the consumer expectations, including reliability). If all these points are addressed the number of people using solar off-grid systems will most certainly increase. In order to achieve this goal it is crucial to raise awareness on the population through information campaigns and other methods of information dissemination, explaining them the potential benefits of off-grid systems in terms of access to goods and services. By doing this, a giant step in the speeding up of the rural electrification rate of Mozambique will be achieved.

Regarding off-grid equipment/appliances sales, the information is not easy to obtain considering that a large percentage of this equipment is sold by unregistered vendors in street markets. Traditionally people, namely that live in rural areas, prefer to buy in the street markets due to the perception that in those places they can negotiate prices, however often in those places the prices are higher, and no warranty or installation guidance is provide as previously mentioned. A study conducted by the Green light for the World Bank [10] presented the results listed in Table 16 regarding the solar off-grid appliances/ equipment sold in Mozambique.

TABLE 16- AVAILABLE OFF-GRID EQUIPMENT IN STREET MARKETS AND LOCAL STORES IN MOZAMBIQUE. SOURCE: [10].

Off-grid Equipment	Brand	Main characteristics	Country of origin	Average cost[30]
Solar panels	Sunshine solar	5Wp	China	$6,9 - $9,6
	Sunshine solar	10Wp	China	$9,6 - $16,44
	Juta	10Wp	South Africa	$20,5
	Sunshine solar	15Wp	China	$13,7 - $16,4
	Solar Module China	15Wp	China	$12,3
	Sunshine solar	20Wp	China	$16,5 - $23,3
	Juta	20Wp	South Africa	$34,2
	Sunshine solar	25Wp	China	$26,0
	Solar Module China	25Wp	China	$19,2
	Several brands	25Wp	Unknown	$13,7
	Sunshine solar	30Wp	China	$21,9 - $34,2
	Sunshine solar	35Wp	China	$41,1
	Sunshine solar	40Wp	China	$34,2 - $39,7
	Solar Africa	40Wp	South Africa	$41,1 - $45,2
	Sunshine solar	50Wp	China	$43,8 - $47,9
	Several brands	50Wp	Unknown	$27,4
	Juta	50Wp	South Africa	$68,5
	Sunshine solar	60Wp	China	$52,0
	Several brands	80Wp	Unknown	$54,8
	Several brands	100Wp	Unknown	$82,2
	Sunshine solar	100Wp	China	$95,9
	Several brands	180Wp	Unknown	$102,7
Batteries	Yuasa	Lead-acid 12V 7,2 Ah	Japan	$11,0
	CBS	Lead-acid 12V 7,2 Ah	Vietnam	$9,6
	Ritar	Lead-acid 12V 7,2 Ah	China	$6,2
	Sensys	Lead-acid 12V 7,2 Ah	China	$6,2
	Ecobrand	Lead-acid 12V 7,2 Ah	China	$6,2
	Portalac	Lead-acid 12V 9 Ah	Taiwan	$13,7
	Unknown	Lead-acid 12V 9 Ah	Unknown	$7,53
	CBS	Lead-acid 12V 17 Ah	Vietnam	$20,6
	CBS	Lead-acid 12V 26 Ah	Vietnam	$24,7
	Voltron	Lead-acid 12V 45 Ah	Unknown	$20,5
	Osaka	Lead-acid 12V 45 Ah	India	$20,5
Solar Inverters	Unknown	Small (no power available)	Unknown	$11,0
	Solar Africa	Large (no power available)	South Africa	$24,7
	Unknown	130W max.	Unknown	$13,7
	Unknown	150W max.	Unknown	$20,55
	Unknown	180W max.	Unknown	$24,7
	Solar Africa	300W max.	South Africa	$12,3
Other equipment	Yuegan	Solar radio with lantern and phone charger	China	$12,3
	BY	Small solar lantern	China	$2,47
	BY	Large solar lantern with phone charger	China	$4,8
	Unknown	Solar phone charger adaptor for battery	Unknown	$2,74
	Several brands	SHS with one light and phone charger	Unknown	$34,24
	Unknown	Solar light	Unknown	$3,43

30- USD – United States Dollars. ($1= 73,0 Mozambican Metical)

Concerning off-grid appliances there is no information available, in the same as in grid connected appliances. A local survey was made in specialized stores in Maputo to gather information regarding this type of appliances. Table 17 summarizes the characteristics obtained in the survey carried out for this study.

TABLE 17- OFF-GRID APPLIANCES IN DISPLAY IN SPECIALIZED STORES IN MAPUTO-MOZAMBIQUE[31]

Off-grid Appliances	Equipment	Power (W)	Maximum Number of Working Hours/day[32]	Average price[33]
Lighting - LED	Lamp A100	0,83 W	12	$5,48
	Lamp A200	1,94 W	5	$8,51
	Lamp A400	3,61 W	6	$19,30
	Lamp DC	2,0 W	12	$13,01
TV - Television	24'' inch – LCD	12,50 W	10	$82,19
	32'' inch – LCD	16,60 W	10	$315,07
Fan	500 mm	8,33 Wh	5	$15,75
Solar Water Heater	100 Litre capacity	-	-	$410,96
	150 Litre capacity	-	-	$643,84

The number of equipment types sold was not disclosed by the stores, street vendors mentioned average sales but cannot specify the amount of systems/equipment types sold. Table 16 presented the individual cost and characteristics of individual solar equipment types, but in Mozambique people also buy complete kits (Solar Home Systems – SHS). Figure 52 presents an example on several types of SHS, including its costs, in Mozambique.

31- The average cost was obtained in January 2021.
32- The maximum number of working is determined by the solar panel sizing
33- USD – United States Dollars. ($1= 73,0 Mozambican Metical)

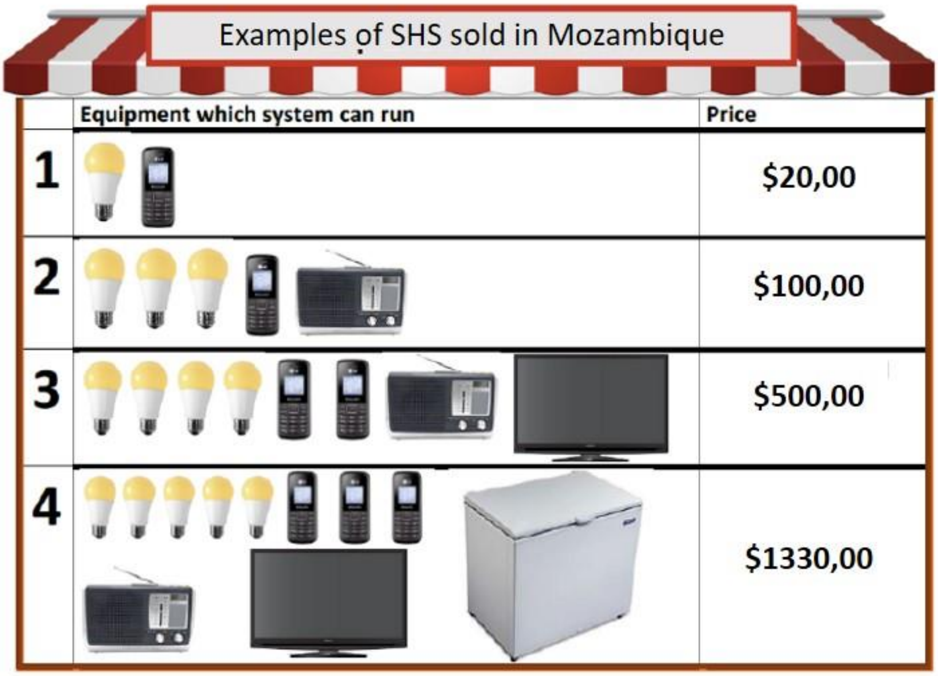


FIGURE 52- EXAMPLES OF SHS SOLD IN MOZAMBIQUE. SOURCE: [10].

In our survey we have also contacted a private company with significant presence in the Mozambican off-grid market with more than 42000 SHS installed in the end of 2020, 13 stores in Mozambique and over 200 people work in this company. As presented in Figure 53 the company expects to reach 65000 SHS installed by the end of 2021.

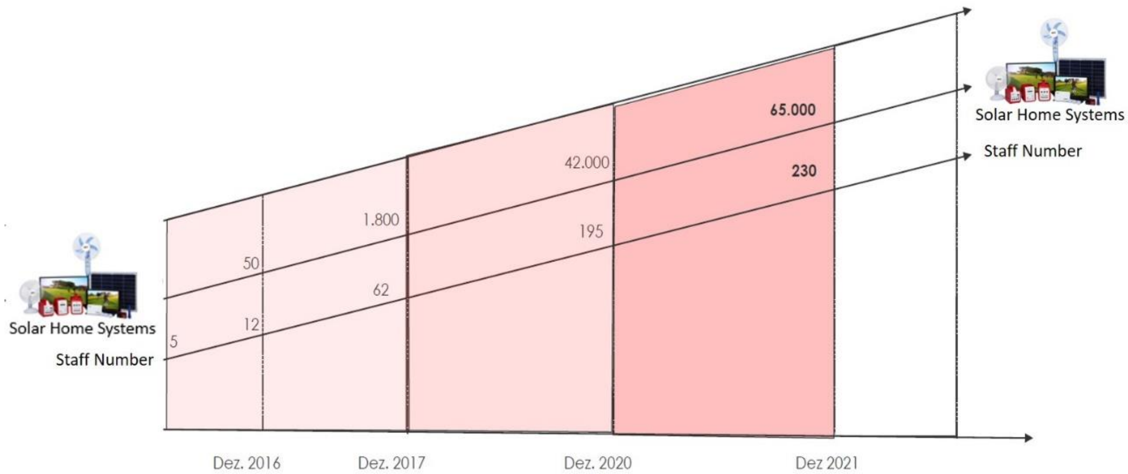


FIGURE 53- SHS SALES AND STAFF NUMBER BETWEEN OCTOBER 2016 AND DECEMBER 2021. SOURCE: [39].

The next two figures presented the company portfolio concerning SHS, which includes price and the available payment options (full payment and a monthly payment plan).

Solar Home Systems for Lighting

	SW 20	SWLite	SW40 Recond.	SW 80Lite
Monthly payment plan	$8,15 + 30 X $4,04	$12,33 + 30 X $6,16	$12,33 + 30 X $6,16	$17,12 + 30 X $9,52
Full payment	$ 89,05	$ 171,23	$ 164,38	$ 239,72
Battery	19 Wh	22 Wh	38 Wh	77 Wh
Solar Panel	6 Wp	6 Wp	10 Wp	22 Wp (12+10)
Lamps	3 lamps for 5,5 hours	4 lamps for 4,5 hours	3 lamps for 6 hours	4 lamps for 8 hours
Phone Charging	5 phone charges	6 phone charges	10 phone charges	----
System Extras	Radio - $17,12	----	Radio - $17,12	Radio - $17,12

FIGURE 54- SOLAR HOME SYSTEMS FOR LIGHTING AND PHONE CHARGING. SOURCE: [39].

Solar Home Systems for Lighting and/or TV

	SW 80 + 24" TV	SW 155 + 24" TV	SW 155 + 32" TV
Monthly payment plan	$68,35 + 30 X $21,85	$78,49 + 30 X $27,26	$95,62 + 30 X $39,45
Full payment	$530,14	$588,90	$657,40
Battery	77 Wh	154 Wh	154 Wh
Solar Panel	35 Wp	55 Wp	55 Wp
Lamps	3 lamps for 9 hours	4 lamps for 19 hours	4 lamps for 19 hours
TV	24" TV for 6 hours	24" TV for 11 hours	32" TV for 9 hours
Lamps + TV	For 4 hours	For 7 hours	For 6 hours

FIGURE 55- SOLAR HOME SYSTEMS FOR LIGHTING AND TELEVISION. SOURCE: [39].

Figure 54 and Figure 55 present the main technical characteristics of the equipment in the SHS, average autonomy and the available payment options. The choice of including this particular company was made due to the fact that it has a very high number of SHS installed which have direct impact in terms of improving the electricity access rate in rural and remote areas.

Another important issue that needs to be addressed is the use of off-grid systems for supporting the productive use of energy, considering that a significant part of the population lives in rural areas and produces their own food it is important to consider the use of these systems in the small subsistence agriculture, even for small community farms and small industry.

These systems could be used to improve agriculture, water supply for crops or for people, cereal milling, small industry, etc. The number of companies providing solar systems related to productive use of energy is even smaller and only a handful of companies has these products in their portfolio.

However, some NGOs and other development organization are investing time and resources in this type of end-use for off-grid systems. The study made by the World Bank [10] in 2018 points that the focus of companies should be on the most relevant opportunities for commercial and productive use of energy in rural areas. Some of these opportunities are presented in Figure 56.

FIGURE 56- MOZAMBIQUE OFF-GRID MARKET OPPORTUNITIES. SOURCE: ADAPTED FROM [10].

5. Assessment of the Country Savings Potential

The methodology used in the estimation of the country savings potential is similar to the one used in other countries. Figure 57 presents the scheme of the methodology used in the assessment of the country savings potential.

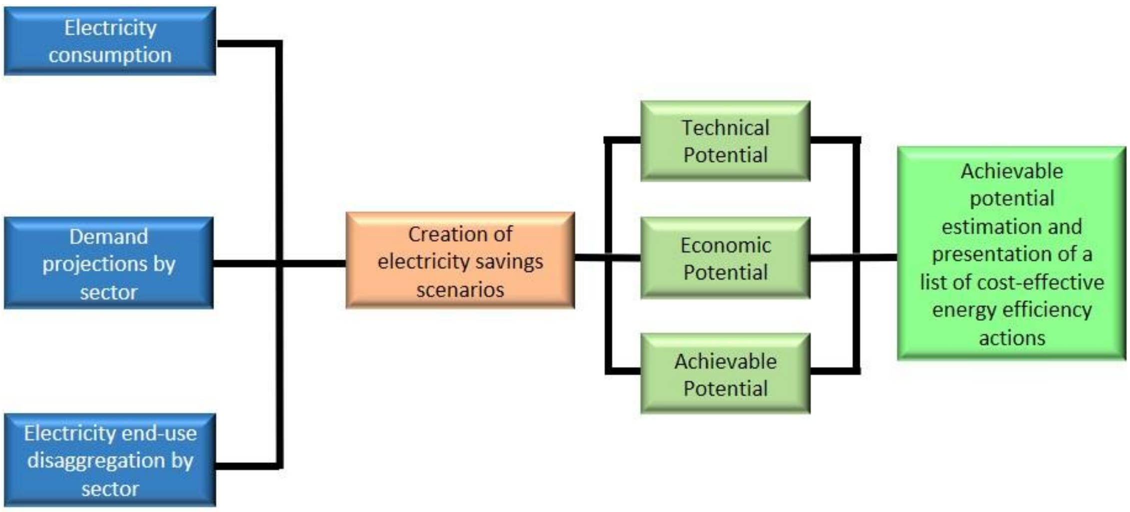


FIGURE 57- FRAMEWORK FOR THE METHODOLOGY USED IN THE ESTIMATION OF MOZAMBIQUE SAVINGS POTENTIALS.

The assessment of the country savings potential began with the collection of the most relevant information, such as electricity consumption since 2009, demand forecast and the electricity end-use disaggregation for each economic sector. This information allowed to determine the amount of electricity used in each sector for each end-use which resulted in a detailed characterization of each sector. All this information resulted in a well-defined set of assumptions that allowed to define the electricity savings scenarios. These scenarios allowed to calculate the impact of moving forward to more energy-efficient equipment (e.g. house appliances, lighting, electric motors, etc.). With these scenarios the country potentials (technical, economic and achievable) were calculated which allowed, to determine in Chapter 6 the impact (in terms of energy savings) and the cost effectiveness of the proposed actions/measures per economic sector.

5.1. Technical Savings Potential

This section will present the technical savings potential for each economic sector including the electrification of the transportation sector. For each sector, a set of assumptions is made to establish different savings scenarios according to the electricity consumption and the end-use disaggregation made in Chapter 4. Regarding the transportation sector, a set of conditions is drawn for moving vehicles away from fossil fuels and into electric mobility. These conditions were defined considering the country economic limitations, which are a considerable barrier for energy efficiency, fuel switching and for the large dissemination of electric vehicles.

In this report four scenarios were considered to estimate the technical savings potential for the residential, non-residential, industrial and transportation sectors. These scenarios are:

- **BAUS – Business As Usual Scenario** – In this scenario no energy efficiency measures are implemented, and no significant transition is made to more efficient equipment models. Due to these constraints no relevant savings take place in this scenario;

- **LESS – Low Electricity Savings Scenario** – This is a conservative scenario where the electricity savings are smaller, due to a transition to equipment models that have the average efficiency of the models available in the market. Due to this fact, the energy savings are modest in this scenario;

- **MESS – Medium Electricity Savings Scenario** – In this scenario the electricity savings are higher due to the transition to equipment models that are half away between the ones being sold on average and the most efficient types;

- **HESS – High Electricity Savings Scenario** – This scenario considers the transition to equipment models that are the most energy efficient available in the market. Therefore the energy savings in this scenario are largest.

5.1.1 Residential Sector Technical Potential

As previously mentioned in order to estimate the technical savings potentials, a set of assumptions, regarding appliances energy efficiency was made taking into account the available information (energy efficiency plans from other countries, reports from energy efficiency experts, market information, manufacturers, scientific articles, technical reports and the authors experience in the field).

Table 18 summarizes the assumptions made for electricity savings in the residential sector considering the four scenarios mentioned above. This table defines savings percentages for appliances in grid connected systems (in urban and rural areas) by switching the existing equipment models by others that are more energy efficient, considering the end-uses identified in section 4.1.

TABLE 18- ASSUMPTIONS MADE FOR ELECTRICITY SAVINGS IN THE RESIDENTIAL SECTOR. SOURCE: [40, 41, 42, 43]

Assumptions made for savings in the residential sector (urban and rural areas)					
	Equipment/Appliance	**End-use**	**Savings Scenarios**		
			LESS	**MESS**	**HESS**
Grid Connected Systems	LED lighting	Lighting	50%	58%	70%
	High Efficiency AC units	Cooling	36%	45%	53%
	High Efficiency fans	Cooling	15%	30%	45%
	High Efficiency refrigerators/freezers	Refrigeration	40%	45%	60%
	Washing Machines	Cloths washing	30%	55%	60%
	LCD TVs	Entertainment	25%	35%	45%
	Other appliances / Other uses	Unknown	30%	55%	60%

Considering the savings percentage per appliance in each scenario, an analysis was made for the residential sector electricity consumption between 2020 and 2050. In this period the savings percentages presented in Table 18 were used to calculate the impact of replacing the existing appliances by others that are more energy-efficient.

Figure 58 presents the country electricity consumption evolution in each scenario.

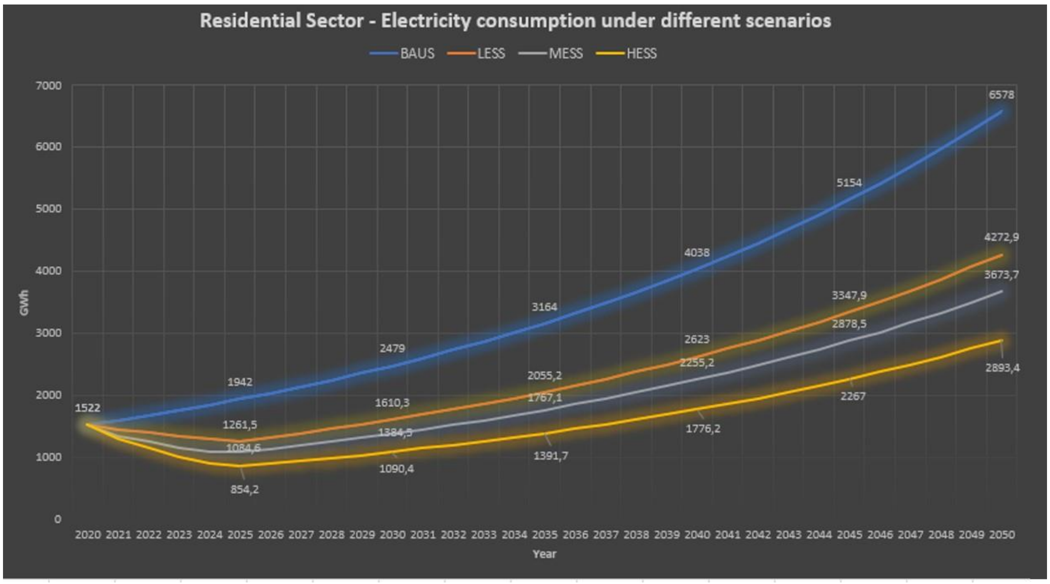


FIGURE 58- RESIDENTIAL SECTOR ELECTRICITY CONSUMPTION UNDER DIFFERENT SCENARIOS

Figure 58 presents four scenarios, BAUS (blue line) represents electricity consumption without the implementation of any energy efficiency measures. The LESS (orange line) is a scenario where electricity consumption is higher (than in MESS or HESS) due to the use of average efficiency appliances. However, these average efficiency appliances are considerably more efficient than the ones used at the moment, which are mostly old and inefficient. The MESS (grey line) considers the use of appliances that have a moderate efficiency (half way between LESS and HESS scenarios), ranged in the market average which leads to a lower electricity consumption than in LESS. The HESS (yellow line) is a scenario that considers that the existing appliances are progressively replaced by the most energy efficient appliances in the market which leads to lower electricity consumption as displayed in Figure 58.

Figure 59 presents the cumulative electricity savings for each decade and also for the 2020-2050 period.

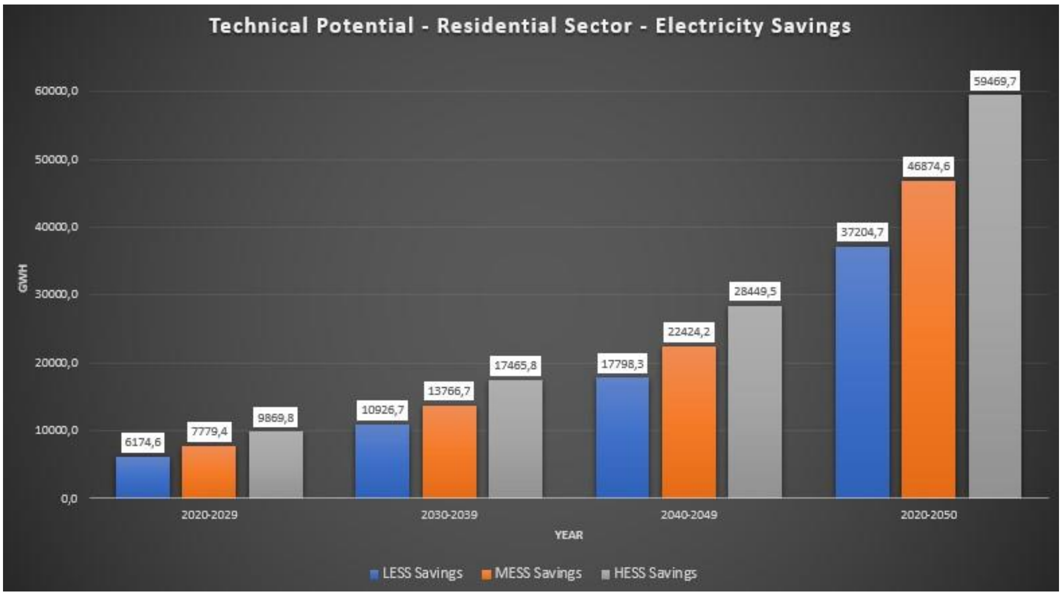


FIGURE 59- RESIDENTIAL SECTOR CUMULATIVE ELECTRICITY SAVINGS POTENTIAL BY DECADE AND IN THE 2020-2050 PERIOD

From Figure 59 it is possible to observe that the implementation of energy efficient measures can have a significant impact in the reduction of the energy demand over the next decades.

Considering the expected increase in demand caused by several factors (e.g. population growth rate, increase in the economic activity, etc.) the implementation of actions to reduce the demand, namely through the implementation of energy efficiency measures, will allow the national grid to maintain its flexibility, performance indexes and quality of service. As well as in other emerging economies, the electricity demand grows much faster than the national grid capacity. If this situation is not properly addressed it can have, a significant impact at medium/long term in the country electric system capacity to provide reliable energy services.

In the 2020-2050 period Mozambique residential sector has the technical potential to reach electricity savings between 37,2 TWh and 59,5 TWh. This large electricity savings potential, reduce the investment costs, allowing to improve the system reliability, reducing the energy off-time and providing precious time for the country to implement the grid expansion plan. With the implementation of suitable energy-efficiency measures, in 2050 the savings will represent 35% in the LESS, 44% in MESS or 56% in HESS scenarios of the total energy consumption in the residential sector.

5.1.2. Non-residential Sector Technical Potential

Table 19 summarizes the assumptions made for the estimation of the technical potential in the non-residential sector considering the same four scenarios mentioned in section 5.1. This table defines the savings percentages for grid connected systems (in urban and rural areas) when the existing equipment models are replaced by others that are more energy efficient, considering the end-uses identified in section 4.2.

TABLE 19- ASSUMPTIONS MADE FOR ELECTRICITY SAVINGS IN THE NON-RESIDENTIAL SECTOR. SOURCE: [40, 41, 42, 43]

Assumptions made for savings for non-residential sector					
	Equipment/Appliance	**End-use**	**LESS**	**MESS**	**HESS**
Grid Connected Systems	LED lighting	Lighting	50%	58%	65%
	HVAC(Air Cond. + Fans)	Cooling	15%	30%	45%
	High Efficiency refrigerators	Refrigeration	40%	45%	60%
	High Efficiency freezers	Refrigeration	45%	56%	65%
	Other	Unknown	30%	55%	60%
	ICT- Information and Communications Technology	ICT	13%	17%	20%
	Water Heating (electric)	Cooking/Sanitary use	30%	55%	60%
	Solar Water Heating	Sanitary use	60%	75%	90%

An additional assumption was made in the non-residential sector. In this sector water heating made with electricity represents 7% of the non-residential sector total consumption (see Figure 31). Taking this fact under consideration this report considers moving 50% of this consumption into solar water heaters which will lead to significant electricity savings.

Similarly to the analysis made for the residential sector, the four scenarios mentioned above were considered to estimate the technical potential of the sector for 2020-2050. For this period the savings percentages presented in Table 19 were used to estimate the impact of replacing the existing appliances by others that are more energy efficient. Figure 60 presents the non-residential sector electricity consumption for each scenario.

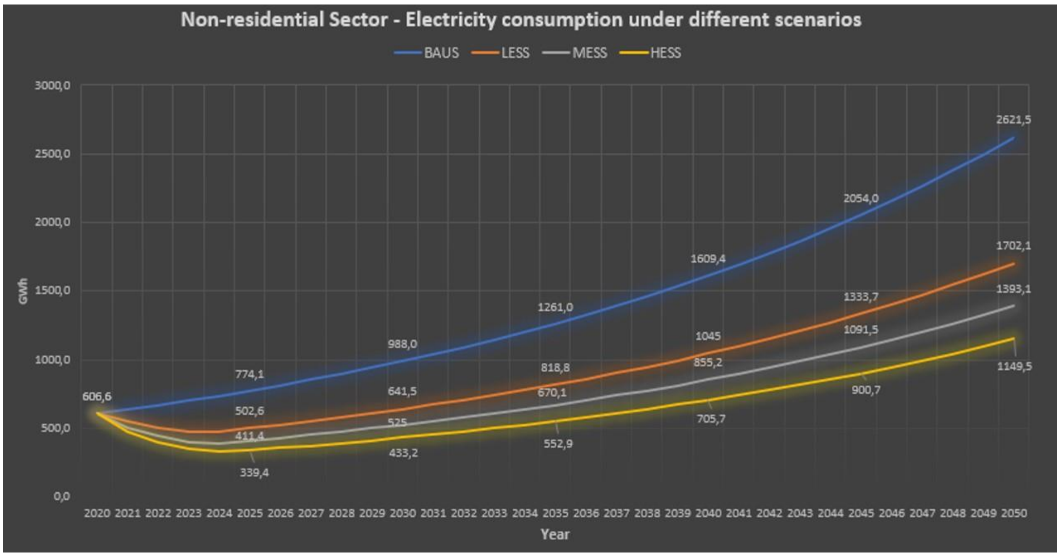


FIGURE 60 – NON-RESIDENTIAL SECTOR ELECTRICITY CONSUMPTION UNDER DIFFERENT SCENARIOS

As in the residential sector, the implementation of energy efficiency measures in the non-residential can have a significant impact in reducing the energy demand of this sector over the next decades. The four scenarios presented represent the different energy consumption scenarios according to the efficiency level of the appliances sold in the country over the next decades.

Figure 61 presents the non-residential sector cumulative electricity savings for each decade and also for the 2020-2050 period.

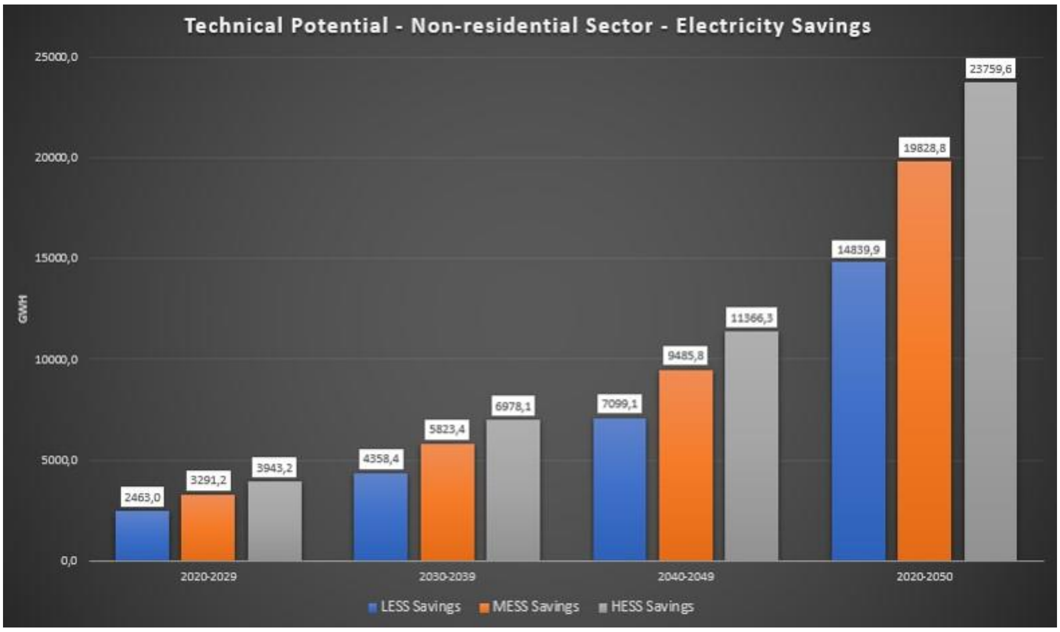


FIGURE 61- NON-RESIDENTIAL SECTOR CUMULATIVE ELECTRICITY SAVINGS BY DECADE AND IN THE 2020-2050 PERIOD

From Figure 60 and 61 it is possible to observe that the implementation of energy efficiency measures can play an important role in a sector that is expected to substantially grow over the next years, due to economic growth and large investments in tourism. Between 2020-2050 Mozambique non-residential sector has the technical potential to reach electricity savings between 14,8 TWh and 23,8 TWh. In 2050 these savings will represent 35% in the LESS, 46,9% in MESS or 56,1% in HESS scenarios of the total energy consumption in the non-residential.

5.1.3. Industrial Sector Technical Potential

Table 20 summarizes the assumptions made for the estimation of the technical potential in the industrial sector considering the same four scenarios described in section 5.1. This table defines the savings percentages for grid connected systems (in urban and rural areas) by replacing the existing equipment models by others that are more energy efficient, considering the end-uses identified in section 4.3.

TABLE 20- ASSUMPTIONS MADE FOR ELECTRICITY SAVINGS IN THE INDUSTRIAL SECTOR. SOURCE: [40, 41, 42, 43]

Assumptions made for savings in Industrial sector					
	Equipment/Appliance	**End-use**	**LESS**	**MESS**	**HESS**
Grid Connected Systems	LED lighting	Lighting	40%	50%	55%
	HVAC[34] (Air Cond. + Fans)	Cooling	15%	30%	45%
	ICT Equipment	ICT	13%	17%	20%
	Other equipment/Other uses	Unknown	30%	55%	60%
	Variable Speed Drives (VSD)	Drive power	20%	25%	30%
	High-efficiency Small Motors	Drive power	14%	18%	20%
	High-efficiency Large Motors	Drive power	5%	6%	7%

Additional assumptions were made for electric motors (including pumps, industrial fans and other power driven equipments). These equipment types represent 75% of the sector electricity consumption (see Figure 37). Taking all these facts under consideration, the following assumptions, concerning the electricity consumption related to motors and other power driven equipments, were made:

- 50% of the electricity consumed in the industrial sector in motor driven equipment is related to loads in which the installation of variable speed drives (VSD) is a possible/viable solution;
- 15% of the electricity consumed in the industrial sector is related to large motors where motor replacement (by others that are more energy-efficient) is a possible/viable solution;
- 10% of the electricity consumed in the industrial sector is related to small motors where motor replacement (by other that are more energy-efficient) is a possible/viable solution;

As in the previous presented sectors, four scenarios were estimated for the industrial sector for the 2020-2050 period. For this period the savings percentages presented in Table 20 and the additional set of assumptions above, were used to estimate the impact of replacing the existing equipment models by others that are more energy efficient. Figure 62 presents the industrial sector electricity consumption for each scenario in the 2020-2050 period.

[34] HVAC- Heating, Ventilation and Air Conditioning

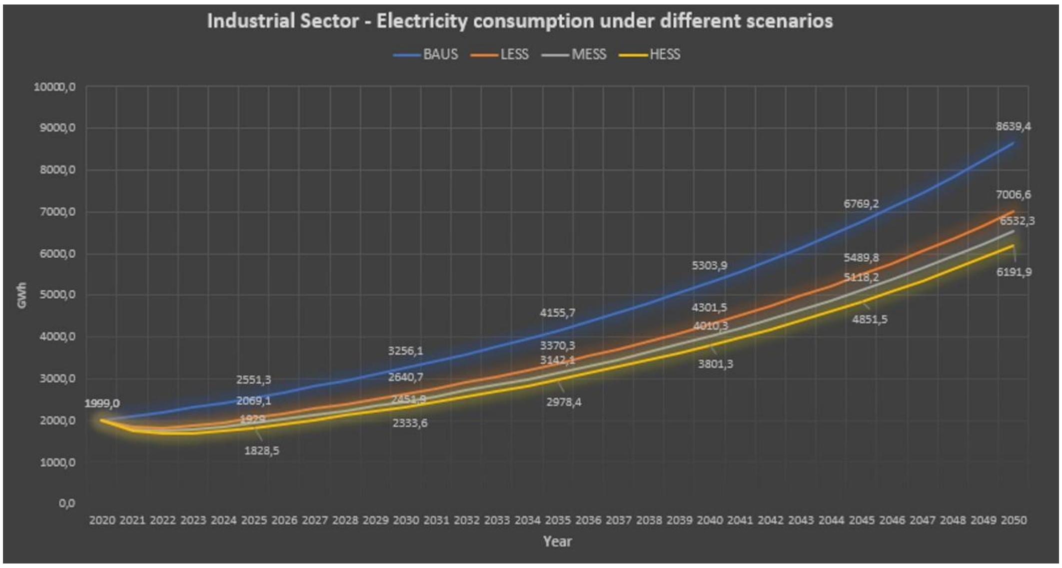


FIGURE 62- INDUSTRIAL SECTOR ELECTRICITY CONSUMPTION UNDER DIFFERENT SCENARIOS

Figure 62 presents an overview on the possible scenarios for the implementation of energy efficiency measures in the industrial sector. It is possible to observe that in this sector these measures can also have an important role not only regarding electricity consumption but can also be used to modernize and expand the industrial sector.

Figure 63 presents the industrial sector cumulative electricity savings for each decade and also for the 2020-2050 period.

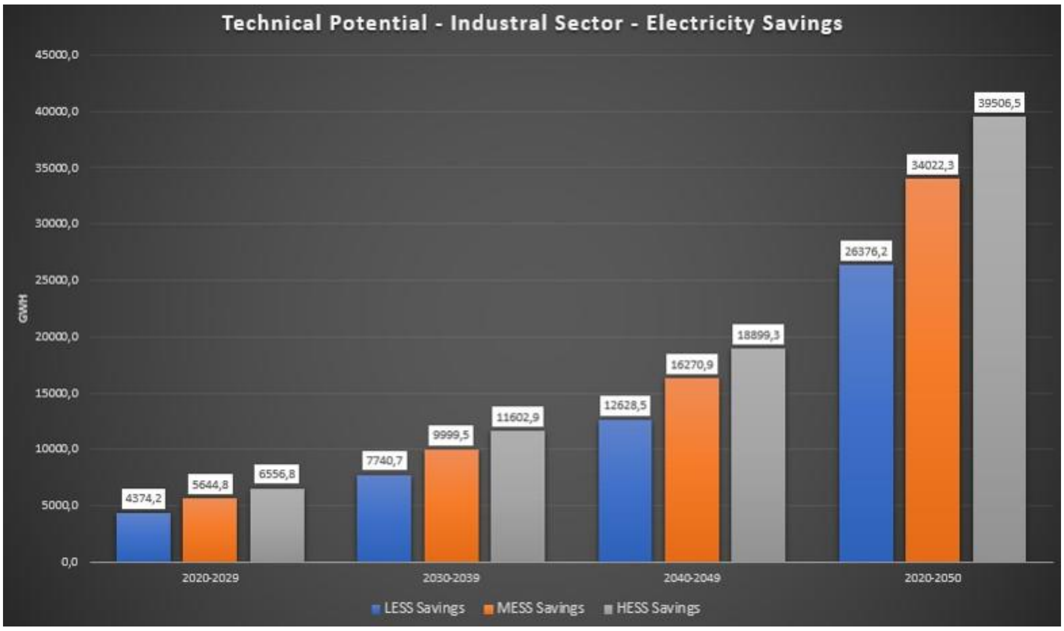


FIGURE 63- INDUSTRIAL SECTOR CUMULATIVE ELECTRICITY SAVINGS BY DECADE AND IN THE 2020-2050 PERIOD.

From Figure 63 is possible to observe that between 2020-2050 Mozambique industrial sector has the technical potential to reach electricity savings between 26,4 TWh and 39,5 TWh. In 2050 the savings will represent 18,9% in the LESS, 24,4% in MESS and 28,3% in HESS scenarios of the total energy consumption in the industrial sector.

5.1.4. Transportation Sector Technical Potential

This sector was considered in the estimation of the country technical potential due to its high levels of fossil consumption (670 135 284 litres of fossil fuels in 2020) and the possibility of decarbonization of the country economy through fuel switching to electricity generated with renewable energies. Moving from fossil fuels, namely diesel and gasoline, into electric mobility will help Mozambique to reduce it oil dependence and reduce CO_2 emissions. In Mozambique 51% of vehicles run on diesel, 48,5% on gasoline and 0,5% on natural gas. Considering these numbers, four scenarios for the penetration rate of EVs will be considered. The scenarios are:

- **BAUS** – No electric vehicles are sold in the country;
- **LESS** – The stock of EV increase 1% per year (from 1% in 2021 to 30% in 2050);
- **MESS** - The stock of EV increase 2% per year (from 2% in 2021 to 60% in 2050);
- **HESS** - The stock of EV increase 3% per year (from 3% in 2021 to 90% in 2050);

It is important to keep in mind that Mozambique has a significant number of two and three wheel vehicles (motorcycles). Replacing these vehicles by electric models, especially for those people that mainly use them in cities for short/medium distances is an attractive option. To make this fuel switching a reality, the power grid needs to create charging infrastructures to allow battery charging. Another option is to power these infrastructures with solar energy which avoids any issues concerning the interconnection of these charging stations with the national power grid. At the same time solar power allows to have these charging station in locations were the grid is not available. In some cases, like three-wheel vehicles solar power charger can be incorporated in the vehicle roof. Additionally, this solar charging stations can be used to raise the population awareness, for the cost-effectiveness of solar systems.

As a result of the scenarios above described, Figure 64 presents the evolution on the energy consumption in the transport sector according to the assumption made for each scenario.

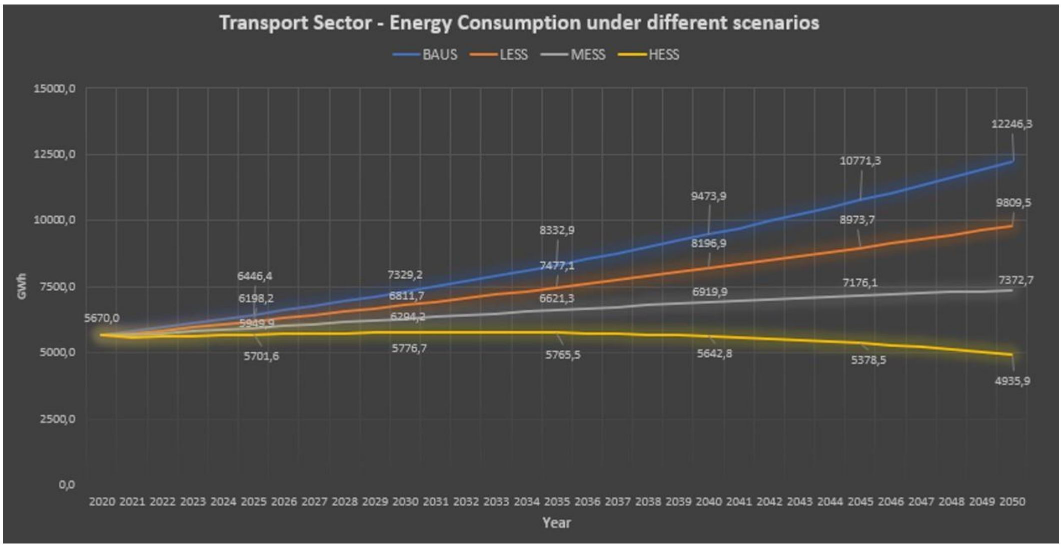


FIGURE 64- TRANSPORTATION SECTOR ENERGY CONSUMPTION UNDER DIFFERENT SCENARIOS

To estimate the energy savings, each scenario considers a percentage of Electric Vehicles (EV) sales per year. Figure 65 presents the transportation sector cumulative energy savings for each decade and also for the 2020-2050 period.

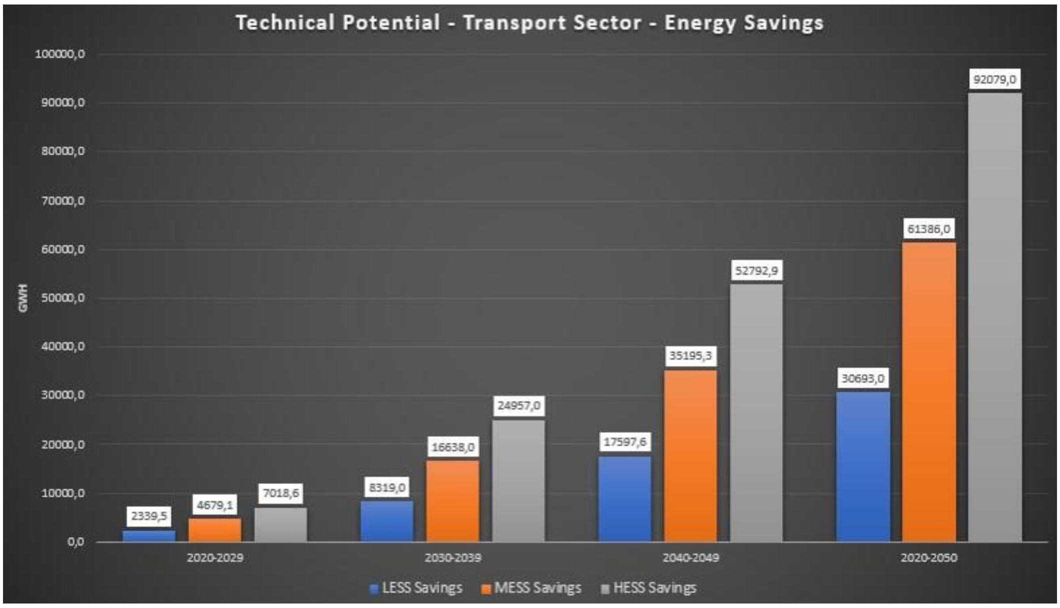


FIGURE 65- TRANSPORTATION CUMULATIVE ENERGY SAVINGS BY DECADE AND IN THE 2020-2050 PERIOD.

Figure 65 presents an overview on the possible scenarios for the integration of EV in the transportation sector. It is possible to observe that even considering moderate integration rates (between 1 and 3%) the cumulative savings in the 2020-2050 period can be between 26,4 TWh and 39,5 TWh. These savings will represent in 2050, 18,9% in the LESS, 24,4% in MESS and 28,3% in HESS scenario of the total energy consumption in the transportation. This analysis already includes the impact in terms of electricity consumption due to the increase of EV stock over the years.

The introduction of EV can also be supported by public entities by replacing urban public transports by EV such as electric bus. In large cities such as Maputo this should be considered since EV are an excellent solution to reduce air pollution. This will be further developed in Chapter 6.

5.1.5. Country Overall Technical Potential

Table 21 presents the country overall technical potential in the four selected scenarios for the 2020-2050 period.

TABLE 21- MOZAMBIQUE TECHNICAL SAVINGS POTENTIAL

Overall technical savings potential [2020-2050]					
	Sector	**BAUS[35] [TWh]**	**LESS [TWh]**	**MESS [TWh]**	**HESS [TWh]**
Grid Connected Systems	Residential Sector	107,69	37,74	47,55	60,32
	Non-residential Sector	42,92	15,05	20,11	24,10
	Industrial Sector	141,45	26,75	34,51	40,07
	Transportation Sector[36]	265,18	2,61	5,23	7,84
	Total	557,24	82,4	107,37	132,23

35 Without the implementation of any energy efficiency measures. In this scenario there are no energy savings.
36 The obtained savings are related with the benefits of moving from vehicles powered by fossil fuels (diesel e gasoline) into electric vehicles.

Summarizing, the overall technical savings estimation are 14,8% in LESS, 19,3% in MESS and 23,7% in HESS in comparison with the BAUS scenario.

5.2. Economic Savings Potential

The cost-effectiveness of any energy efficiency measure strongly depends on the electricity price. Therefore, tariffs play a very important role in determining the economic potential. EDM is responsible for the electricity supply for all customers and due to this fact EDM tariff structure is used in this analysis. The EDM clients rate structure presented in Table 22 and Table 23 is in line with EDM client classification previously presented in Table 4.
According to the information available at the EDM website[37], the electricity tariffs in Mozambique (in March 2021) are presented in Table 22.

TABLE 22- ELECTRICITY TARIFFS IN MOZAMBIQUE IN MARCH 2021. SOURCE: [39]

<table>
<tr><th rowspan="2">Recorded consumption [kWh]</th><th colspan="5">Type of Client</th></tr>
<tr><th>Domestic Households USD/kWh</th><th>General Commercial and Low Voltage Large Consumers</th><th>Agriculture MV</th><th>MV/HV</th><th>Special Clients (HV)</th></tr>
<tr><td>[0-200]</td><td>$0,09</td><td rowspan="3">$0,06</td><td rowspan="3">$0,03</td><td rowspan="3">$0,06</td><td rowspan="3">$0,05</td></tr>
<tr><td>[201-500]</td><td>$0,13</td></tr>
<tr><td>Above 501</td><td>$0,14</td></tr>
<tr><td>Prepaid</td><td>$0,12</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
</table>

Table 23 presents the electricity tariffs [44]used in the analysis made in this report to estimate the economic potential for each economic sector in Mozambique.

TABLE 23- ELECTRICITY TARIFF CONSIDERED IN THE ECONOMIC POTENTIAL ESTIMATION. SOURCE: [44]

<table>
<tr><th>Type of Client</th><th>EDM Client Category</th><th>Sector</th><th>Tariff considered in the economic potential estimation</th></tr>
<tr><td rowspan="5">Regulated Clients</td><td>Domestic</td><td>Residential</td><td>$0,12/kWh</td></tr>
<tr><td>General-Commercial</td><td rowspan="2">Non-residential</td><td rowspan="2">$0,06/kWh</td></tr>
<tr><td>Low Voltage – Large Consumers</td></tr>
<tr><td>Agriculture</td><td>Agriculture</td><td>$0,03/kWh</td></tr>
<tr><td>MV/HV (medium Voltage/High Voltage)</td><td rowspan="2">Industrial</td><td rowspan="2">$0,05/kWh</td></tr>
<tr><td>Non-regulated Clients</td><td>Special Clients</td></tr>
</table>

5.2.1 Residential Sector Economic Potential

In the residential sector there are multiple tariffs according to the household consumption. For the estimation of the economic potential an average of these multiple tariffs is used. Table 24 presents the economic potential for the residential sector in each decade and also the cumulative potential for the 2020-2050 period.

37 https://www.edm.co.mz/en/website/page/electricity-tariffs

TABLE 24- TECHNICAL AND ECONOMIC POTENTIAL IN EACH SCENARIO BY DECADE AND FOR 2020-2050.

Residential Sector	LESS		MESS		HESS	
	Technical potential [GWh]	Economic Potential in Millions $USD	Technical potential [GWh]	Economic Potential in Millions $USD	Technical potential [GWh]	Economic Potential in Millions $USD
[2020-2029]	6 174,6	$740,9	7 779,4	$933,5	9 869,8	$1 184,4
[2030-2039]	10 926,7	$1 311,2	13 766,7	$1 652,0	17 465,8	$2 095,9
[2040-2049]	17 798,3	$2 135,8	22 424,2	$2 690,9	28 449,5	$3 413,9
[2020-2050]	37 204,7	$4 464,6	46 874,6	$5 624,9	59 469,7	$7 136,4

In the residential sector the economic potential regarding ranges from $4 464,6 million USD to $7 136,4 million USD in the 2020-2050 period. The economic potential for 2020-2050 is equivalent to save between 1,1% to 1,7% of the country GDP[38] per year.

5.2.2. Non-residential Sector Economic Potential

The non-residential sector includes different types of clients, general commercial, low voltage large consumers and agriculture. Due to the fact the agriculture only represents 0,5% of the non-residential sector consumption the tariff used was $0,06/kWh for all types of clients. Table 25 presents the economic potential for the non-residential sector in each decade and also the cumulative potential for the 2020-2050 period.

TABLE 25- TECHNICAL AND ECONOMIC POTENTIAL IN EACH SCENARIO BY DECADE AND FOR 2020-2050.

Non-residential Sector	LESS		MESS		HESS	
	Technical potential [GWh]	Economic Potential in Millions $USD	Technical potential [GWh]	Economic Potential in Millions $USD	Technical potential [GWh]	Economic Potential in Millions $USD
[2020-2029]	2 463,0	$147,8	3 291,2	$197,5	3 943,2	$236,6
[2030-2039]	4 358,4	$261,5	5 823,4	$349,4	6 978,1	$418,7
[2040-2049]	7 099,1	$425,9	9 485,8	$569,1	11 366,3	$682,0
[2020-2050]	14 839,9	$890,4	19 828,8	$1 189,7	23 759,6	$1 425,6

In the non-residential sector the economic potential ranges from $890,4 million USD to $1 425,6 million USD in the 2020-2050 period. The economic potential for 2020-2050 is equivalent to save between 0,22% to 0,34% of the country GDP[28] per year.

5.2.3. Industrial Sector Economic Potential

The industrial sector includes clients classified as MV/HV (medium Voltage/High Voltage) and specials clients, in both types of clients the electricity tariff is $0,05/kWh. Table 26 presents the economic potential for the industrial sector in each decade and also the cumulative potential for the 2020-2050 period.

38 Considering Mozambique GDP in 2020 at around $14 billion USD.

TABLE 26- TECHNICAL AND ECONOMIC POTENTIAL IN EACH SCENARIO BY DECADE AND FOR 2020-2050.

Industrial Sector	LESS		MESS		HESS	
	Technical potential [GWh]	Economic Potential in Millions $USD	Technical potential [GWh]	Economic Potential in Millions $USD	Technical potential [GWh]	Economic Potential in Millions $USD
[2020-2029]	4 374,2	$218,7	5 644,8	$282,2	6 556,8	$327,8
[2030-2039]	7 740,7	$387,0	9 999,5	$500,0	11 602,9	$580,1
[2040-2049]	12 628,5	$631,4	16 270,9	$813,5	18 899,3	$945,0
[2020-2050]	26 376,2	$1 318,8	34 022,3	$1 701,1	39 506,5	$1 975,3

The economic potential in the industrial sector ranges from $1 318,8 million USD to $1 975,3 million USD in the 2020-2050 period. The economic potential for 2020-2050 is equivalent to save between 0,31% to 0,47% of the country GDP[39] per year.

5.2.4. Transportation Sector Economic Potential

This analysis was made by considering the cost of the fossil fuel (diesel and gasoline) avoided with the introduction of electric vehicles, the scenarios for the evolution of the EV stock was defined in section 5.1.4.

Considering the scenarios established in section 4.4 (this scenarios consider a percentage LESS 1%, MESS 2% and HESS 3%) of the new vehicles sold per year being powered by electricity.

According to the evolution scenarios for internal combustion vehicles, in terms of estimated consumption and average kilometers made per year (section 4.4.2), it is possible to estimate the average savings. As previously mentioned, this savings are directly related to the avoided fossil fuel consumption and also include the EV electricity consumption. Considering the fuel prices used in section 4.4 the economic potential of switching to electric vehicles is presented in Table 27.

TABLE 27- ELECTRIC VEHICLES ECONONOMIC POTENTIAL IN EACH SCENARIO BY DECADE AND 2020-2050.

Transportation Sector	LESS		MESS		HESS	
	Technical potential [GWh]	Economic Potential in Millions $USD	Technical potential [GWh]	Economic Potential in Millions $USD	Technical potential [GWh]	Economic Potential in Millions $USD
[2020-2029]	2 339,5	$662,0	4 679,1	$1 324,0	7 018,6	$1 985,9
[2030-2039]	8319,0	$2 353,8	16 638,0	$4 707,6	24 957,7	$7 061,3
[2040-2049]	17 597,6	$4 979,1	35 195,3	$9 958,2	52 792,9	$14 937,3
[2020-2050]	30 693,0	$8 684,3	61 386,0	$17 368,6	92 079,0	$26 052,9

The economic potential in the transportation sector ranges from $8 684,3 million USD to $26 052,9 million USD in the 2020-2050 period. The economic potential for 2020-2050 is equivalent to save between 2,06% to 6,2% of the country GDP[40] per year.

5.2.5. Country Overall Economic Potential

39 Considering Mozambique GDP in 2020 at around $14 billion USD.
40 Considering Mozambique GDP in 2020 at around $14 billion USD.

Table 28 presents the country overall economic potential in all economic sectors and taking in consideration the three evolution scenarios by decade and in the 2020-2050 period.

TABLE 28- COUNTRY OVERALL ECONOMIC POTENTIAL IN EACH SCENARIO BY DECADE AND FOR 2020-2050 PERIOD

All economic sectors	LESS	MESS	MESS
	Economic Potential in Millions $USD[41]	Economic Potential in Millions $USD	Economic Potential in Millions $USD
[2020-2029]	$1 769,4	$2 737,2	$3 734,7
[2030-2039]	$4 315,5	$7 209,0	$10 156,0
[2040-2049]	$8 172,2	$14 031,7	$19 978,5
[2020-2050]	$15 358,1	$25 884,3	$36 590,2

By comparing the economic potential scenarios with the 2020 GDP[31] value it is possible to observe the economic weight of these savings scenarios in Mozambique economy. This information is presented by Table 29.

TABLE 29- COMPARISON OF THE ECONOMIC POTENTIAL IN EACH SCENARIO BY DECADE AND FOR 2020-2050 PERIOD WITH MOZAMBIQUE GDP

All economic sectors	LESS	MESS	HESS
	Average % of the GDP[30] saved per year	Average % of the GDP[30] saved per year	Average % of the GDP[30] saved per year
[2020-2029]	0,42%	0,65%	0,89%
[2030-2039]	1,03%	1,72%	2,42%
[2040-2049]	1,95%	3,34%	4,76%
[2020-2050]	3,66%	6,16%	8,71%

From Table 29 is possible to conclude that in every scenario the economic potential for savings in Mozambique is quite significant. The implementation of energy efficiency measures could allow the authorities to use these savings to improve the national power grid, increase the number of off-grid systems (SHS, micro and mini grids) allowing more people to have access to electricity. Furthermore, these savings can be used to improve the population living standards.

5.3. Achievable Savings Potential

In the previous section of this Chapter four scenarios were defined to estimate the technical and economic potentials. These scenarios considered the immediate implementation of all Energy Efficiency (EE) measures/actions and a total appliance stock replacement.

However, due to several reasons (e.g country economic constraints, existence/inexistence of regulation (enforced or voluntary) for energy labelling and MEPS, cost-effectiveness of certain measures/programmes, etc.) not all technical potential is possible to be achieved. To refine these technical and economic potentials it is necessary to take into consideration, consumer acceptance, preferences, and families/companies budgetary constraints. The achievable potential, unlike the technical and economic potentials, represents a forecast of the likely consumer behaviour and penetration rates of energy efficient technologies, also taking into account the existing market, as well as the financial, political, and regulatory barriers that

41 This potential represents the cost of the fossil fuel (diesel and gasoline) avoid.

are likely to limit the amount of savings that might be achieved through energy efficiency programmes.

As experience in other countries shows, the achievable potential is at least 50% of the technical potential, depending on the above mentioned factors and in the implementation timeline of the proposed EE actions (see Chapter 6). As the analysis of the country technical and economic potential made in sections 5.1 and 5.2, considered three possible evolution scenarios (LESS, MESS and HESS), it is logical to make a similar estimation for the country achievable potential. The use of three scenarios will allow Mozambican authorities to continuously adjust the National Energy Efficiency Strategy and Action Plan to fit into the scenario that they considered the best for the countries according to its present conditions. The amount of effort and resources dedicated to the implementation the Energy Efficiency Plan will strongly influence the energy savings impact.

Taking all these factors into consideration, Table 30 summarizes the estimation for the achievable potential.

TABLE 30 - MOZAMBIQUE ACHIEVABLE POTENTIAL [2020-2050]

Mozambique Achievable Potential [2020-2050]							
		LESS		**MESS**		**HESS**	
	Economic Sector	**Energy Savings [TWh]**	**Economic Savings $USD[42]**	**Energy Savings [TWh]**	**Economic Savings $USD[32]**	**Energy Savings [TWh]**	**Economic Savings $USD[32]**
Grid Connected Systems	Residential Sector	18,9	$2 232,3	23,8	$2 812,3	30,2	$3 568,2
	Non-residential Sector	7,5	$445,2	10,1	$594,9	12,1	$712,8
	Industrial Sector	13,4	$659,4	17,3	$850,6	20,0	$987,7
	Transportation Sector[43]	1,3	$4 342,2	2,6	$8 684,3	3,9	$13 026,5
	Total	41,1	$7 679,1	53,8	$12 942,1	66,2	$18 295,2

[42] In Millions of USD

43 The obtained savings are related with the benefits of moving from vehicles powered by fossil fuels (diesel e gasoline) into electric vehicles.

6. Sectoral Recommended Actions

Achieving higher levels of Energy Efficiency (EE) is a multi-effort endeavour that requires the combination of policy instruments in order to address market barriers and failures that hinder the energy efficiency investments. Cost-effective energy efficiency opportunities are present in all economic sectors and across many types of technologies and end-uses. In order to overcome the usual barriers to energy efficiency policy makers have three basic tools to address those barriers: knowledge dissemination, regulations, and financial incentives or subsidies [45]. In other developing countries the combination of these tools has shown that it accelerates the rate of energy efficiency implementation.

The recommendations/actions presented in this report (see Table 31) are based on those basic policy tools, addressing five pillars that are essential to the implementation of energy efficiency actions. These pillars are:

- **Technical information dissemination** — Appliance energy labels, buildings energy performance codes, and best-practice sharing are some of the key programmes that are used to identify energy efficient products and practices, while educating consumers about the multiple benefits of higher efficiency products. This information will help consumers to make informed purchases and investment decisions, which will save them money over the lifetime of the end-use equipment;

- **Minimum Efficiency Performance Standards** (MEPS) — Product energy efficiency standards raises the efficiency level of the equipments sold in a country and eliminates the inefficient technologies and practices from the market. MEPS also stimulate technological innovation;

- **Capacity building** — Capacity development and training activities, at all technical levels, are crucial to promote energy efficiency best practices and technologies, ensure compliance with standards, and ensure that energy efficiency is an energy resource for Mozambique;

- **Public awareness** — Awareness campaigns are needed to inform consumers about the benefits of the programmes and policies being developed and also to increase the acceptance level and adoption of energy efficiency. Additionally, awareness campaigns also inform consumers about technology used, energy performance and life-cycle cost of a determined product;

- **Financial Support** — Financial support incentivizes energy efficiency investment by providing financing options to reduce the initial higher cost of more efficient equipment. Possible financing options include rebates, low interest loans, and other discounts, which can combined with technical assistance.

Each of these pillars has strengths and weaknesses. However if they are well designed and if their application is made through a combination of the five, it is possible to accelerate the deployment of energy efficient technologies. Moreover, the use of comprehensive policy packages that puts these five pillars into place has showed in other developing countries to be critical to the successful promotion of energy efficiency.

6.1. Table of actions

Table 31 summarizes the recommend actions to reach the identified achievable potential presented in section 5.3.

TABLE 31 - RECOMMENDED CROSS-SECTORAL ENERGY EFFICIENCY ACTIONS TO FULFIL THE COUNTRY ACHIEVABLE POTENTIAL

Section	Action number – Title	Economic Sector Focus
6.2	A1 – Creation of an energy efficiency bill	Cross-sectoral
6.3	A2 – Creation and mobilization of funds into the Environmental and Energy Efficiency Fund	Cross-sectoral
6.4	A3 – Creation of Mozambique Energy Efficiency Center (MEEC)	Cross-sectoral
6.5	A4 – Definition and enforcement of energy labelling and energy efficiency standards	Cross-sectoral
6.6	A5 – Capacity building and certification of energy efficiency professionals	Cross-sectoral
6.7	A6 – Adoption of an energy efficiency programme for the public sector	Cross-sectoral
6.8	A7 – Encourage market development strategies and support Energy Service Companies (ESCOs) operation and Energy Performance Contracting (EPCs)	Cross-sectoral
6.9	A8 – Promote energy efficient product purchases	Cross-sectoral
6.10	A9 – Development of an energy performance code for new buildings and major renovations	Cross-sectoral
6.11	A10 – Development of building energy use disclosure and benchmarking	Cross-sectoral
6.12	A11 – Creation of a platform to disseminate energy efficiency best practices	Cross-sectoral
6.13	A12 – Retrofitting inefficient buildings (public and private) using ESCOs	Cross-sectoral
6.14	A13 – Development of Municipal or regional energy efficiency action plans	Cross-sectoral
6.15	A14 – Inclusion of energy efficiency in education at all levels	Cross-sectoral
6.16	A15 – Energy Census - Inclusion of energy related questions in the next population Census	Cross-sectoral
6.17	A16 – Promotion of fuel switching to renewable and low carbon alternatives	Cross-sectoral
6.18	A17 – Creation of procedures within Mozambique public authorities for green public procurement	Cross-sectoral
6.19	A18 – Promote the use of clean cooking systems	Residential
6.20	A19 – Promote the use of household appliances with low stand-by consumption and strategies to reduce household stand-by	Residential
6.21	A20 – Promote the replacement of the existing lighting by LED technology	Residential
6.22	A21 – Promote the acquisition of high efficiency AC units and fans	Residential
6.23	A22 – Promote the acquisition of high efficiency refrigerators and freezers	Residential
6.24	A23 – Promote the acquisition of high efficiency televisions	Residential
6.25	A24 – Promote the acquisition of high efficiency washing machines	Residential
6.26	A25 – Promote the acquisition of solar water heaters	Residential and non-residential
6.27	A26 – Promote the penetration of high efficiency refrigeration systems	Non-residential
6.28	A27 – Promote the replacement or retrofit of existing lighting and lighting systems by other based on LED technology	Non-residential and industrial
6.29	A28 – Promote energy efficiency in small and medium enterprises	Non-residential and industrial

6.30	A29 – Promote energy efficient street lighting replacement by EDM or through the involvement of ESCOs	Non-residential and industrial
6.31	A30 – Promote the penetration of high efficiency HVAC equipments (AC units and fans included)	Non-residential and industrial
6.32	A31 – Promote the acquisition of high efficiency information and communications technology equipment	Non-residential and industrial
6.33	A32 – Development of regulations for energy audits, energy management systems and to promote the cooperation between industry and academia on energy efficiency activities	Non-residential and industrial (only for large consumers)
6.34	A33 – Creation of a recognition award to honour the energy efficiency champions	Non-residential and industrial (only for large consumers)
6.35	A34 – Promote the acquisition of high efficiency power drive systems (includes installation of energy-efficient motors and VSDs)	industrial
6.36	A35 – Promote clean industry development by replacing high pollutant fuels by other eco-friendlier options	industrial
6.37	A36 – Promote the use of cogeneration in industry	industrial
6.38	A37 – Promote power factor correction in the industrial sector as a way to improve the electric power system and the industrial sector energy performance	industrial
6.39	A38 – Introduction of fuel economy standards and labelling for vehicles	Transportation
6.40	A39 – Initiate the adoption and uptake of electric mobility	Transportation
6.41	A40 – Creation of a programme to replace large/medium urban buses by e-buses	Transportation
6.42	A41 – Encourage markets for energy access	Off-Grid
6.43	A42 – Development of product quality standards for off-grid equipment	Off-Grid

6.2. A1 - Creation of an energy efficiency bill

Economic Sector Focus: Cross sectoral

Description:
The energy efficiency bill is an essential framework document that provides the statutory basis for promulgation of rules and regulations to promote energy efficiency in Mozambique. This bill defines the rationales for pursuing Energy Efficiency (EE) and specifies the overall objectives and strategies to achieve them. The bill should also include specific regulations regarding Minimum Efficiency Performance Standards (MEPS), energy labelling for household appliances and other equipment types (e.g. electric motors, AC/HVAC, lighting, etc.). Moreover, this bill should include guidelines for the creation of regulation for energy audits and energy management systems for large consumers. The main benefit of the bill is to introduce a clear distinction between the country energy efficiency targets and the implementation of policies and programmes to improve energy efficiency.

To assist in the creation/definition of this bill, national authorities should consider the best practices available worldwide and use them as examples. Several institutions present periodic reports identifying, documenting and evaluating energy efficiency policies and trends around the world. One of these institutions is the World Energy Council which covers more than 85 countries and in its reports includes examples of framework policies implemented in different countries. These reports highlight the fact that, legal frameworks are essential in the adoption of regulations, such as, energy labelling, MEPS and other obligations for large consumers (e.g. Turkey and India). EE laws are also tools to provide a legal framework in the establishment of an energy efficiency fund (e.g. Thailand and Uruguay). Another institution is the International Energy Agency that produces a guidebook based on the experience of hundreds of energy efficiency experts around the world and in extensive research on case studies and literature concerning energy efficiency shining examples, good practices and good-governance examples.

6.3. A2 – Creation and mobilization of funds into the Environmental and Energy Efficiency Fund

Economic Sector Focus: Cross sectoral

Description:
The Environmental and Energy Efficiency Fund is a financial instrument capable of financing the actions outlined in this report. The scope of this fund should be aligned with the economic, social and territorial development policies to be promoted between 2020 and 2050, as well as with the evolution scenarios outlined in this report. This fund should be used to finance strategic EE projects with significant impact in the reduction of greenhouse gas emissions and energy consumption in all economic sectors, with particular attention on supporting low income consumers.

The energy efficiency fund can provide essential resources for implementing energy efficiency programmes, address the lack of affordable financing for energy efficiency and the lack of end-user incentives for investing in energy efficiency. In other countries, EE funds usual involve large capital transfers, which makes it important to guarantee transparency and validation of results through a simple, clear, and robust process of reporting, monitoring, verifying, and evaluating costs and benefits of the financed projects. The EE funds usually accelerate job creation, business growth, and new business investment. Furthermore, EE funds allow to develop skilled local workforces, often through the development of Energy Service Companies (ESCOs);

This fund should aim to support and promote in Mozambique a sustainable energy market through a collaborative approach by contributing to climate change mitigation and combining private and public capital for EE and climate related investments.

The resources to finance this fund could be obtained from a combination of different sources. Some of this sources include: i) annual subvention from the state budget; ii) creation of a gradual tax to be charged on appliance purchase according to the appliance/equipment efficiency level (lower tax on high efficiency equipment models); iii) a small percentage (e.g. 2-3%) of the cost of each kWh consumed could revert to the EE fund; iv) a carbon tax on fossil fuels; v) African Development Bank, World Bank, European Union and other donor agencies or NGO's willing to support Mozambique effort to improve its energy efficiency ratings.

A part of this fund can also work as revolving fund providing low-interest financing, that could be used to implement energy efficiency improvements identified through energy audit programmes, namely in industry and in large buildings. This will help to build experience among all stakeholders (energy efficiency suppliers, contractors, and consumers) and it could leverage the ESCO market. Furthermore, this type of financial arrangement helps to establish credit history among implementing parties and reduces barriers to access bank financing for future energy efficiency investments;

The Environmental and Energy Efficiency Fund could also finance specific programmes in:

i) Residential and non-residential sectors (e.g. lamp replacement programmes, discounts on acquisition of high efficient appliances such as refrigerators/freezers, AC/HVAC units, fans, televisions, etc.);

ii) Industrial sector (e.g. energy efficient motor systems lamp/lighting systems replacement programmes, AC/HVAC units, fans , etc.);

iii) Buildings retrofit, including improvements in the thermal envelope and promote the use of solar water heaters;

iv) In the transport sector promote fuel switching to natural gas (since Mozambique has large reserves) and electric mobility especially in urban public transportation (e.g. medium and large bus). In private transportation (e.g. light passenger vehicles such as cars and motorcycles which have a large potential of moving into electric vehicles.

Additionally this fund could support the installation of high efficiency appliances/equipment manufacturers in Mozambique, as well as other eco-friendly technological projects.

6.4. A3 – Creation of Mozambique Energy Efficiency Center (MEEC)

Economic Sector Focus: Cross sectoral

Description:
The creation of the Mozambique Energy Efficiency Center (MEEC) is an important step towards the efficient use of energy. This institution will be responsible for the design and implementation of EE measures in the country. MEEC will also be responsible for the implementing and monitoring all regulation related EE, including energy labelling, Minimum Efficiency Performance Standards (MEPS), development of a national product registration database, establishment of an appliance testing laboratory (national or at SADC level), etc.

The MEEC will also work in cooperation with the market surveillance authority (Ministry of Economy and Trade) whose mission is the supervision of the market regarding equipment imports, manufacturers/retailers, product compliance with energy efficiency regulations. The development of EE regulation for new buildings and major building renovation could also be developed within MEEC competences in cooperation with academia.

This center will have staff with experience and adequate professional education/training in EE allowing the MEEC to provide scientifically founded advice for decision-makers in politics, business and government. The focus of MEEC lies on promoting EE and climate and environmental protection, working closely with government authorities, FUNAE and other institutions to improve the country electricity access rate. MEEC could also assist FUNAE and other government authorities in the development of strategies for sustainable and secure renewable energy supply, providing advice and training and establish a networking platform to enable a faster industrial development.

Moreover this center will be responsible for providing capacity building, training and certification of EE professionals. Dissemination and awareness raising campaigns: The introduction of EE in the education systems could also be made by the MEEC.

6.5. A4 – Definition and enforcement of energy labelling and energy efficiency standards

Economic Sector Focus: Cross sectoral

Description:
Standards and Labelling (S&L) programmes play an important role in terms of energy efficiency in developing countries, its introduction represents an important milestone in the path of improving the country overall energy performance [46]. These programmes are considered as the cornerstone of energy efficiency programmes worldwide and have been implemented in more than 85 countries, covering more than 50 different types of energy using products in the residential, non-residential (commercial) and industrial sectors [46].

S&L programmes encourage the removal of inefficient technologies from the market, promote the recycling of old equipment models and empower consumers to make informed purchasing by choosing high efficient equipment models. These programmes are responsible for significant savings and are essential in the market transformation towards into more energy efficient technologies. S&L usually encourage innovation, research and development of high efficient equipment models. Enforcement, namely to avoid the importation of low efficiency equipment types, is critical to accelerate the market uptake and to drive manufacturers into the efficiency path;

This action includes three types of sub-actions:

- **Definition and enforcement of an Energy Labelling scheme and Minimum Efficiency Performances Standards (MEPS) -** The definition of an energy labelling scheme and MEPS will have a direct impact in product quality and in the reduction of energy consumption of all energy related products imported into the country. The enforcement of energy labelling and MEPS and is necessary to ensure the compliance of all energy related products with the established energy efficiency requirements. From an end-user perspective the enforcement of these regulations also guarantees the overall quality and efficiency of the product. Furthermore, this enforcement will remove the inefficient equipments from the market and should define clear penalties for manufacturers and others that do not meet the requirements considerer in those regulations;

- **Development of national product registration database -** The development of a national product database where energy related products sold in the country are registered (as well as their technical characteristics (e.g. energy consumption, year of manufacture, noise and energy class, etc.) according to the adopted energy labelling scheme). It is essential that national authorities keep track of the equipment models being sold in the country. This database can be used to provide information to Mozambique energy information system which is currently under development. This database is important for the market surveillance authority allowing to check if the available equipments in market comply with the information registered in the database. Additionally this data will help authorities in the planning of the market evolution for energy related products. Manufacturers and retailers that are starting to introduce their products in Mozambique may benefit from the information available in this database;

- **Establishment of a testing laboratory (in Mozambique or SADC) –** These laboratories are necessary to verify the compliance in terms of energy efficiency of all equipment models available on the market. These facilities can either be government owned or independent companies, usually require a suitably equipped facility and human resources with high level of skills to operate them. Due to the fact that testing facilities require qualified staff, they support the growth of local technical capacity. In some countries these facilities are located at universities to facilitate training. Another possibility is to consider using international testing facilities or making arrangements with laboratories in the neighbouring countries to certify equipment models according to Mozambique regulations. Regional collaboration and harmonization of regulations with neighbouring countries should be considered, to facilitate regional market trade.

The creation of energy labels and MEPS labels should consider as guidelines the good examples of regulations and good practices being used in neighbouring countries (e.g. Ghana, South Africa, Kenya, Uganda, etc.) and also European Union (according to a local survey made for Chapter 4 of this report, some appliances arrive at Mozambique with an energy label similar to the EU first version). Additionally Mozambique authorities should also consider the implementation of international standards used in SADC and the possibility of requesting technical assistance from international experts/institutions.

6.6. A5 – Capacity building and certification of energy efficiency professionals

Economic Sector Focus: Cross sectoral

Description:
Energy efficiency is not only important to reduce energy consumption but is also an opportunity in terms of job creation, new business areas and a way to stimulate investment (foreign and national). However, to implement energy efficiency it crucial to improve the human resources skills. Staff training, professional certification and other capacity building programmes are essential to develop expertise in energy efficiency methods and good practices.

The existence of certification schemes for certain professional (e.g. energy managers, qualified energy efficiency experts, etc.) constitute an important signal of credibility. After making these trainings and certifications, the professionals have developed the right combination of skills and are qualified to implement and monitor EE measures, conduct energy audits and implement energy management programmes.

Certification schemes may also create professional associations (e.g. engineers, electricians, HVAC technicians, etc.) which can be used as a channel to share information on best practices, lessons learned, and the latest developments in technology. Capacity building and certification of professionals should focus on the different aspects of energy efficiency implementation and in the specific necessities of each economic sector. These associations can help authorities in the development of training materials, curricula, and guidebooks for professionals.

Finally, it is essential to have an institution responsible for the accreditation of energy efficiency professionals. MEEC can play this role with the support of professional associations, to verify the if the professionals have successfully completed the training and other certification requirements.

There are institutions worldwide who can provide technical assistance to Mozambican authorities in order to help them in the implementation of capacity building programmes and other training actions in industry. On of this institutions is the United Nations Industrial Development Organization (UNIDO) who offers training and implementation support to promote energy management systems. Since 2015, UNIDO EE programmes are active in 17 developing countries and emerging economies, including Egypt and South Africa.

6.7. A6 – Adoption of an energy efficiency programme for the public sector

Economic Sector Focus: Public sector

Description:
Typically the public sector includes a large number of buildings with a diversity of uses. These buildings include government buildings, municipalities, hospitals, schools, military facilities, prisons, etc. These types of buildings usually are energy intensive consumers and its load diagram has its peak demand during the day. Therefore, by reducing the consumption in these buildings the public sector will give an important contribution to reduce the peak demand.

There are many reasons to promote energy efficiency within the public sector, including the following:

i) Energy savings allows the government and other public sector entities to devote higher budgetary resources to other actions (increase the energy access, rural electrification, social support, education, healthcare, etc);

ii) Lower energy demand can reduce dependence on fossil fuels and oil importation;
iii) Reducing energy demand at peak times will defer the need for additional investment in the power system infrastructure, freeing up scarce public and private capital for the many other non-energy infrastructure investments needed for economic growth;

iv) Saving energy in the public sector helps reducing air pollution and greenhouse gas emissions, which generally have high costs in terms of public health;

v) The public sector can be a shining example of good practices for other sectors to follow. This is specially the case of education buildings, which will train future energy efficiency stakeholders.

In addition to the direct benefits presented above, the public sector buying power can stimulate or expand the market for high efficiency products and energy services.

The creation of an EE programme for the public sector is an important tool to promote EE in the country, attract foreign investment and expertise (through the participation of foreign ESCOs) and reduce the public sector energy bill. This programme must include all ministries through inter-ministerial engagement, other government agencies, regional administrations, and municipalities. It seems particularly relevant to make a survey on the existent public buildings stock that may benefit from retrofit or renovation. This programme may also open the door to the inclusion of green procurement procedures by the Mozambican Government in the existent procurement programme.

The inclusion of EE and climate change concerns will help the country to save money in short-medium term. Experience has proven that in most countries it is relatively easy to achieve significant energy savings in the public sector only with the implementation of low-cost energy management solutions, which are highly cost effective means of reducing the energy bills.

6.8. A7 – Encourage market development strategies and support Energy Service Companies (ESCOs) operation and Energy Performance Contracting (EPCs)

Economic Sector Focus: Cross sectoral

Description:
The Mozambique energy efficiency center should encourage the market development by encouraging private companies and investors to use innovative tools and strategies in the implementation of EE projects, namely by the creation of a legal framework to support an ESCO market and also the implementation of Energy Performance Contracting (EPC) services.

The implementation of cost-effective energy efficiency projects has major barriers related to the lack of awareness, technical expertise related to the available options. Even when this expertise is available, there may be a shortage of capital to implement projects with a large energy savings potential. Both types of barrier can be overcome with the support of ESCOs which have both the technical expertise and the access to capital to analyse, design, implement and operate those projects.

An EPC takes place when an ESCO is engaged to improve the energy efficiency of a specific location (e.g. building, company facility, commercial space, etc,). By guaranteeing a determined level of energy savings, the EPC provider (ESCO) is able to recover the capital investment and services required to implement the EE measures. Under an energy performance contract, the ESCO examines the mentioned location, evaluates the level of energy savings that could be achieved, and then make a proposal to implement the project and guarantees those savings over a defined period, under a signed contract. EPC projects are usually turnkey services, where the ESCO provides all of the necessary services to design and implement a comprehensive set of EE measures at the customer facilities, as well as the capital investments. The project includes an initial energy audit into the customer facilities and for the period considered for the EPC a long-term Measurement and Verification (M&V) plan is defined to check if the obtained savings are in line with the savings defined in the contract.

The EPC consists in a comprehensive set of energy efficiency measures to fit the needs of a particular facility and in addition can include renewable energy systems and water conservation. The key elements of any EPC project are:

- A precise definition of energy performance goals to be achieved within certain duration of time;

- Guaranteed savings: The EPC provider guarantees the achievement of the contracted level of energy savings. The ESCO is obligated by contract to repay savings shortfalls over the life of the contract. At the end of the specific contract period, the energy savings full benefits will revert to the facility owner;

- Performing an M&V plan related to energy consumption and energy efficiency gains;

- The EPC provider (ESCO) assumes the risks of technical implementation, operation, maintenance and guarantees the outcomes for the duration of the contract. The ESCO takes over negotiations and business arrangements for the client, in relation to the capital and operational expenses of the projects, thus decreasing the commercial risks on the client side.

6.9. A8 – Promote energy efficient product purchases

Economic Sector Focus: Cross sectoral

Description:
Similarly to other countries, the decision to buy a determined appliance/equipment is based on several factors: desire to improve operational and technical performance, as well as improve the living standards, comfort, replacement of a damaged/obsolete unit, acquisition cost, appliance design, social reasons (neighbours or friend have a similar appliance), overall quality, brand, etc.

In the residential sector, depending on the family education level/knowledge and monthly income, some factors tend to have more weight in this decision. For example, in families with low monthly income the acquisition cost tends to have more influence [47]. If the family education level/knowledge is higher, as well as the income, other factors may be taken under consideration (e.g. brand, overall quality, design and energy efficiency). To incentivize the purchase of energy efficient products, it is important that the most inefficient products (including imported used equipment) are removed from the market or subjected to a higher taxation, pushing the consumers towards a behavioural change. At the same time it is important to raise consumer awareness through information campaigns (outdoors, TV and radio campaigns, social media, etc.) advising them on the financial/performance/environmental benefits of energy efficient appliances/equipment. It is important to clearly explain consumers about the economic advantages in terms of fast recovery of the extra cost in purchasing a high efficient appliance/equipment. These information campaigns are cross sectoral and can be applied to all types of equipment (household appliances, AC units, HVAC, electric motors, etc.).

After informing consumers, if the price differential between as standard appliance and an energy-efficient appliance is too large for most consumers, it may be necessary to give financial incentives to decrease the financial barrier of higher initial cost to encourage them to purchase higher efficient appliances. The budget for this action may come from the Environmental and Energy Efficiency Fund according to the conditions mentioned in action A2.

Some countries encourage consumers purchase of high efficiency appliances by giving them "Efficiency Vouchers". These vouchers are used in the purchase allowing consumers to have a direct discount on a high efficiency appliance/equipment models. In some cases these discounts can go between 10% and 30% (the Environmental and Energy Efficiency Fund then refunds the vouchers to the stores). Another option, which can be implemented through the electricity distribution utility, is allowing people to pay the high efficiency appliances in soft monthly payments in the electricity bill. Both options have the advantage of incentivizing the acquisition of energy efficient products and at the same time support the formal (registered) traders and stores.

6.10. A9 – Development of an energy performance code for new buildings and major renovations

Economic Sector Focus: Cross sectoral

Description:
The buildings sector (residential and non-residential) represents a large share of the total energy and electricity consumption in Mozambique. Sustainable buildings are required not only to reduce energy and environmental impacts, but also to provide health and comfort to building occupants [17]. These improved conditions lead to a better population health, as well as to an increased productivity of the workers in the buildings. Figure 66 shows the general strategy to progress towards high comfort, low energy buildings, by a progressive three step approach:

- Minimization of the building energy consumption through improved building design, drastically reduces the energy demand. Building codes have a critical role to ensure that new buildings are sustainable from the energy and environmental point of view;
- Use of cost-effective end-use equipment (e.g. space conditioning, lighting, appliances, etc.) to provide the required energy services;
- Integration of renewable energy generation (e.g. solar photovoltaic generation to cover partial or totally the remaining power demand).

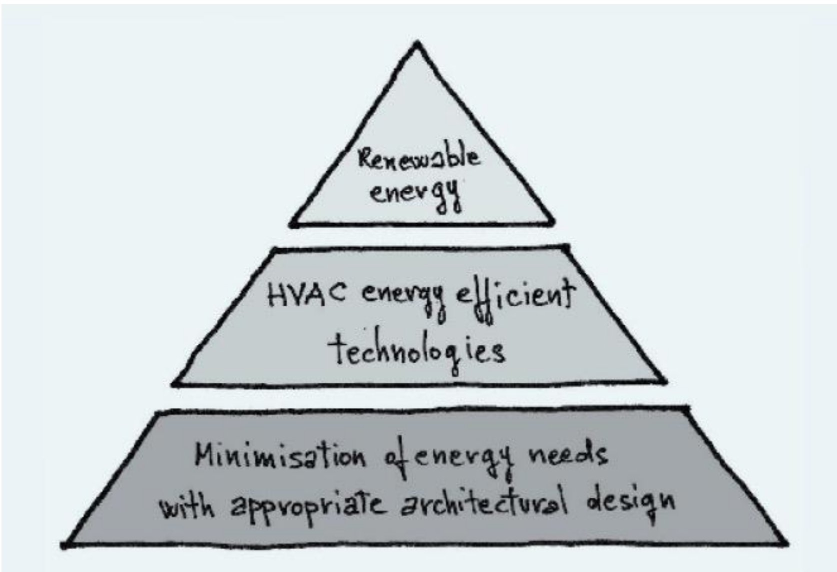


FIGURE 66 - PRINCIPLES OF SUSTAINABILITY FOR BUILDING DESIGN FOR TROPICAL CLIMATES. SOURCE: [48]

Building codes have historically proven in several countries to be a valuable public service by setting minimum requirements for public safety. By introducing an energy efficiency code into buildings regulation, national authorities will be defining legal requirements for buildings energy performance occupants health and comfort, allowing to address energy consumption for heating/cooling, lighting, thermal insulation, etc. Energy efficiency codes can cover different types (e.g., residential, non- residential, and industrial) or sizes of buildings. Additionally, building codes can also cover renewable energy requirements (e.g. gradual transition to zero energy buildings). It possible to observe in Figure 67 that many developing economies still do not have mandatory building energy codes despite their high construction rates. However, changes are beginning in Sub-Saharan Africa regions that, traditionally the countries in this region do not have building energy codes, with the exception of South Africa [49]. Taking this under consideration, Mozambique can potentially lead by example and introduce an innovative building energy code, using as much as possible local raw materials.

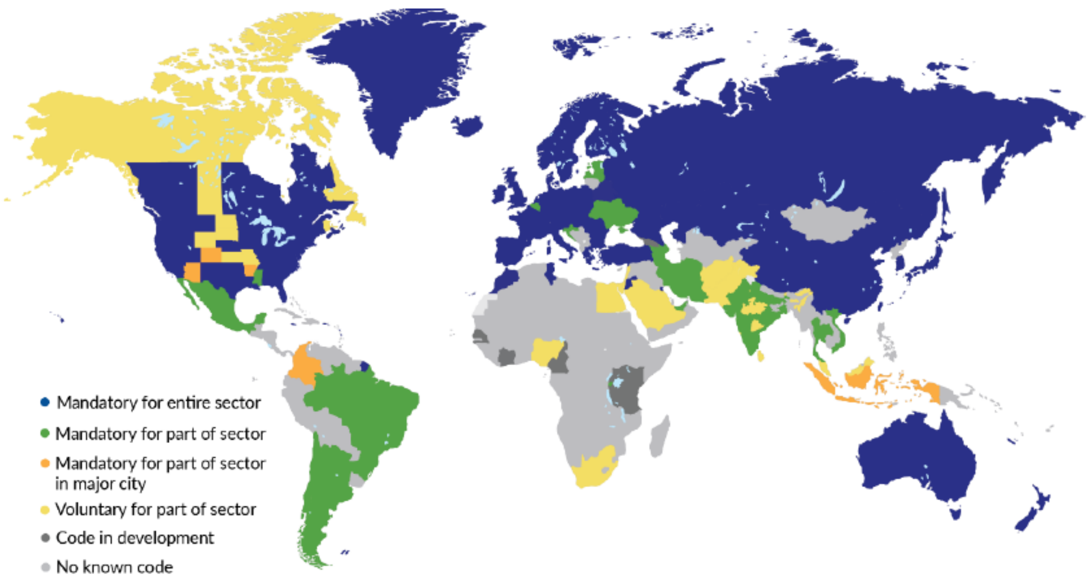


FIGURE 67 - BUILDING CODES AROUND THE WORLD. [49]

In developing countries with a strong economic growth, the rate of new construction and major building renovations (defined as when more than 75% of the building structure is subject to refurbishment) usually is very high, and also the building stock has a significant number of buildings that needs major renovations. In these cases, building codes can save significant impact in terms of energy savings in the medium to long term. The building energy code should be considered from an early stage, in new buildings at the project and design stage, as well as in renovations in the elaboration of the renovation project. This code must be seen as a way to unlock an EE potential that otherwise it would normally be unreachable during the building lifetime. Two types of codes can be developed:

i) **Prescriptive code** that sets performance criteria for the building thermal envelope (thermal transfer coefficients for walls, roofs, and windows) and for building equipment (heating/cooling system, lights, fans, pumps, etc.);

ii) **Overall building performance code**, which is a code based on the buildings annual energy consumption. In several countries the first version of the code trends to have focus on the technical requirements (prescriptive approach) due to the lack of information to define the baselines for the overall building performance (annual energy consumption). After some time, there is information available to define the building baselines and it can be added to the code, allowing it to evolve towards an overall building performance approach.

To develop an energy code for buildings four important steps need to be taken into account:

- **Development of energy efficiency specifications for buildings** - Code development requires data collecting to assess building energy use across different building types (hotel, offices, schools, hospitals, commercial stores, etc.), climate zones, and energy-using components/end-use equipment. It is also essential to identify construction techniques, and materials that will allow to obtain energy savings. Moreover, the use of native materials with good energy performance (e.g. for insulation, doors and windows, ventilation, etc.) is extremely important to be included in the data collection. This data collection is the starting point in the development of energy efficiency specifications (energy labelling and MEPS) for buildings. These specifications should be clear and straight forward for all stakeholders and at the same time allowing building owners and tenants to fully understand the energy consumption profile of their buildings;

- **Engagement with stakeholders** - To be effective, the building energy codes should be developed through a process that involves all the stakeholders (architects, engineers, consultants, designers, builders, energy authorities, property developers, etc.). This involvement includes the code development, adoption, implementation and compliance verification. The enforcement should be guaranteed by local authorities (municipalities) who are usually responsible for licensing and land-use planning;

- **Training of the construction sector workforce** - By setting a baseline for efficient building construction, energy codes set in motion training and education across multiple industries (e.g. design, engineering, and construction). All their staff needs to incorporate energy efficiency into their skills and professional certification processes, which will allow them to be prepared for future challenges. The adoption of a building code is a process that requires awareness and educational training for the above mentioned stakeholders. Once these professionals become fully committed and the code enforcement is in place, new technology developments will create opportunities to go beyond the code. Typically this will stimulate the need to develop new standards with higher energy efficiency requirements.

- **Pilot projects** – A way to leverage the building energy code is through demonstration of buildings constructed according to the code requirements and use them as pilot project to demonstrate to the market (population and all stakeholders involved in construction) the multiple benefits and the potential of energy efficient and sustainable construction. The projects can be used to show that the code is an opportunity and that buildings constructed according to its requirements are easier to sell and typically have less maintenance problems, provide improved health and comfort to building occupants, while they are environmental friendlier.

The Energy Efficiency Building Codes (EEBC) are able to provide to national authorities and municipalities the baseline to benefit from energy saving measures through passive building design, energy efficient equipment and renewable energy systems in buildings. EEBC should address the energy efficiency requirements for the design, materials, construction techniques and energy conversion equipment used in new buildings and major renovations.

These requirements affect the overall energy efficiency of any building structure and can reduce the energy needed to maintain a healthy and comfortable indoor environment. EEBC should provide guidelines, indications and technical characteristics for energy efficiency for all types of buildings, which may include the following topics:

- Passive design strategies according to the climate zone, building orientation, natural lighting, natural ventilation, passive cooling/heating, adequate building materials, sun shading, etc.;
- Building envelop - Technical characteristics, appropriate window to wall ratios for walls, ceiling, doors and windows according to the climatic zones in each country;
- Building materials – Requirements and recommendations for the use of appropriate local building materials;
- Requirements for energy efficient appliances and energy services (e.g. lighting, ventilation systems and cooling/heating systems);
- Requirements for water efficient appliances (e.g. water efficient fixtures such as low flow taps and shower heads, water recycling and reuse, rainwater harvesting, etc.);

Other topics which are receiving increasing attention around the World include:

- Built-in renewable energies solutions (solar, wind and solar water heating systems);
- Other environmentally friendly solutions for buildings, such as: sewer treatment options at the building scale, solid waste sorting and management provisions at the building scale.

To help in the development and implementation of this code, authorities should consider the examples and good practices made in other similar countries. Some of these examples are:

- **South Africa:** Has developed and implemented a building code, named SANS 204:2011, published in 2008. This code became mandatory for all new construction after the amendment in 2011. One of this code mandatory requirements is that 50% of hot water consumed in a building must be provided by means other than electric resistance (e.g., solar water heater, heat pump, etc.).

- **Ghana**: In 2016 the country started a project to improve energy efficiency in commercial and public buildings. The first phase of the project included energy audits to provide inputs to a baseline study on the annual energy consumption by building type. The second phase consists in the development of energy efficiency standards and regulations for public and commercial buildings. The project also involves stakeholder collaboration and public education mechanisms to ensure that the new standards are well accepted and fully integrated in building projects and design as well as in the construction techniques. Chapter 37 of the Building Code, still under development addresses energy efficiency aspects, including as examples, the following measures:

    - Minimum efficiency requirements for electric air-cooled systems – Energy Efficiency Ratio of 2.8;
    - Maximum lighting power densities and efficient luminaires based on building typology.
    - All lighting must have occupancy sensor controls.
    - Renewable energy generation is required for homes over 75m^2 and commercial/industrial buildings over 5000 m^2.

- Reviewing existing building energy codes, energy labels, and financial instruments in the EU, United States and India as well as ongoing developments in other African countries may also offers shared experiences and best practices that can inspire Mozambican authorities in the development of country building code.

The enforcement of solar water heaters in new constructions or major renovations is an excellent example of the possible requirements that Mozambique building code could include. This enforcement is one step to fulfil the government objectives in this area [50], which are:

- 100.000 solar water heaters until 2025;
- Having 3,4 million square meters of solar water collectors in 2030;
- 0,1 m^2 of solar water heater collector area per individual living in Mozambique by 2030.

6.11. A10 – Development of building energy use disclosure and benchmarking

Economic Sector Focus: Cross sectoral

Description:
Building owners and tenants should at all times have access or known their building energy label, energy consumption and energy use in the building. This will allow them to maintain or change their behaviours to save energy and avoid any energy waste. It is also important to disclose building energy label and other mentioned information to prospective property owners and tenants, which will help to increase efficiency awareness among these people and also among real estate developers. Information disclosure and building energy use benchmarking is only possible by enforcing a building energy certificate and energy efficiency label. Both of these instruments are essential to future owners and tenants make their decisions and compare different real estates in terms of energy efficiency.

For example in Portugal, the energy certificate is issued to a building or a building fraction (e.g apartment) by the Portuguese energy agency ADENE (in Mozambique could be MEEC or in the future an energy agency could be created to deal with all types of energy certification) and discloses to owners and tenants at the time of sale or rental. The energy certificate summarizes the building energy related information and presents a comparison between the building consumption in lighting, space cooling and heating necessities, hot water and the benchmark value for these end uses. Through this comparison an energy class is attributed to the building. The energy class obtained has influence in the building municipal property tax. This tax takes under consideration the building age, location and energy performance. The more efficient the building is, the less tax it pays. Mozambique may consider the implementation of a similar program due to the fact that the Portuguese building certification, energy use disclosure and benchmarking is internationally recognized as a successful case.

To implement this action, it is important to:

- **Establishment of a legal basis for efficiency reporting** - The energy efficiency bill considered in action A1 could also include this matter. The legal framework should define which buildings are subject to mandatory disclosure (e.g. new buildings and major renovations), the energy performance metrics, energy label, the energy certificates structure, etc. This legal framework can also be built on a combination of legislative actions;

- **Development of energy certification criteria** - Criteria must be clearly defined for the types of buildings subject to mandatory disclosure, as well as the requirements to evaluate and report the energy performance. Additionally, the type of performance indicators to be measured and disclosed must also be defined, these could include watts per square meter or the estimated annual energy consumption. A threshold may be set (e.g., floor area, type of use), to determine which buildings are subject to the mandatory disclosure of energy performance;

- **Creation of a buildings benchmarking database** – this database is essential to assess the energy related characteristics of the existing building stock and also to keep record of the new buildings and major renovations evolution in terms of performance metrics and compliance with buildings code standards;

- **Develop the necessary procedures for issuing energy certificates** - The effectiveness of the application of energy labels (in buildings as well as in other appliances/equipment) strongly depends on the consumers awareness/knowledge and especially on their confidence in the energy efficiency regulation. Therefore, it is important that the energy certificates are developed though a robust process based on successful examples from other countries (several good examples in EU and South Africa) and implemented and monitored by staff with adequate professional certification and expertise;

- **Incentivize buildings to outperform** – Upfront cost is usually the biggest barrier to energy efficiency in buildings. However, a variety of support programmes can be used to overcome this barrier and encourage higher investments in energy efficiency in buildings. Grants, discounts and tax incentives help to compensate some of the upfront costs, buildings have log lifetimes and loans from revolving funds can be a powerful tools to enhance energy efficiency investments and make them more attractive at the medium/long term. Non-financial incentives (e.g. expedited building permitting) should also be considered to leverage the sector with more energy efficient building;

- **Definition of efficiency targets for building** – These targets could be designed to be achieved in a determine period (e.g. every 10 years). These efficiency targets could be established through a voluntary agreement signed by all the stakeholders in the construction sector, real estate agents/developers, professional associations (e.g. engineers, architects, etc.), owners and tenants associations.

6.12. A11 – Creation of a platform to disseminate energy efficiency best practices

Economic Sector Focus: Cross sectoral

Description:
The creation of a platform to disseminate energy efficiency best practices and to support the professionals working in this area of expertise is a crucial tool for the successful large-scale implementation of energy efficiency in the country. This platform can result from a combination of tools (e.g. website, outdoors, social media, technical support office, media campaigns, etc.) in order to raise awareness between the population, professionals and country legislators.

This platform should provide information in the different economic sectors for people interested in energy efficiency and provide technical assistance to professionals projecting, implementing and monitoring energy efficiency measures. Additionally, the platform may also provide information concerning regulation (e.g. standards, energy labels, other relevant legislation, etc.) to manufacturers and other stakeholders.

Moreover, this knowledge platform should include examples of good practices either in energy efficiency implementation and in construction techniques.

6.13. A12 – Retrofitting inefficient buildings (public and private) using ESCOs

Economic Sector Focus: Cross sectoral

Description:
Usually cities have a large number of degraded buildings (public and private), and most often building owners and municipalities do not have the financial capacity to retrofit these buildings. ESCOs can play an important role and establish a bridge between financial institutions/investors and buildings owners allowing to finance the buildings retrofit through the savings obtained with the implementation of energy efficiency measures (including renewable energy production).

EPC will allow building owners and managers to upgrade old and inefficient assets, including end-use equipment, while recovering capital required for the upgrade directly from the energy savings guaranteed by the ESCO. Municipalities are direct beneficiaries of ESCO activities, due to the increase in the overall quality of the city building stock, job creation, possible reduction on criminal activities in retrofitted areas, improvement on local population living standards and of the local economy.

Authorities should stimulate the creation and establishment of ESCOs as a way of attracting foreign investment, retrofitting the existing building stock and encourage the construction of new high efficient buildings.

6.14. A13 – Development of Municipal or regional energy efficiency action plans

Economic Sector Focus: Cross sectoral

Description:
Energy consumption is typically highest in urban areas. Due to the synergy between increased efficiency and economic development, many cities around the world are pursuing innovative strategies to improve their infrastructure, stabilize their power supply infrastructure, reduce operational costs for businesses and create jobs through energy efficiency. Based on the National Energy Efficiency Plan, a municipal or regional energy efficiency plan can often be more rapidly executed than a nationwide programme and can play an important role in leading other regions forward by developing best practices. Working on energy efficiency at a municipal or regional level is an effective method to capture economic development benefits including job growth, business support, and infrastructure improvement.

Local authorities can assist the Environmental and Energy Efficiency Fund and the MEEC in implementation dissemination of EE through local communities, identification of the most relevant stakeholders and establish a bridge between EE authorities and municipality/region necessities in terms of energy efficiency.

These municipal/regional plans are a powerful tool to identify opportunities for EE (e.g. public and/or private buildings suitable for retrofit, old public lighting equipments that need refurbishment, etc.). Municipal/regional authorities have better field knowledge than national authorities. Due to this fact, it is important to have in each municipality or region, a EE professional to identify potential opportunities to implement energy efficiency projects.

The involvement of local/regional authorities, as well as of the electricity distribution companies, in dissemination campaigns to promote energy efficiency is essential to reach out all the population sectors and provide them important information that will help in future acquisition of equipment (e.g. refrigerators, fans, AC units, lamps, etc.) by demonstrating the benefits (economic and health related) of energy efficiency.

6.15. A14 – Inclusion of energy efficiency in education at all levels

Economic Sector Focus: Cross sectoral

Description:
To implement this action it is important to establish a long term mechanism for higher public awareness regarding the importance of EE by integrating in the curricula and into the education system at all levels, as well as the adult population.

The Mozambican education system should include energy sustainability contents (e.g. energy efficiency, renewable energies, environmental impacts, climate change) which will allow to improve future generations knowledge levels, may attract young people to work in the EE area and is an important tool in behaviour change. For example, the energy consumption in a household can be reduced with a "simple" EE measure without any cost. This measure consists of behaviour change (e.g. turn off lighting in unoccupied rooms, reduce the amount of time a refrigerator is open, low flow shower-heads, etc). The best way to change behaviour is through education, by teaching people the best practices which translate into more energy efficient behaviours. Students (EE educational programmes must be adapted according to age) can play an important role acting as an information vehicle taking information from schools into their homes and to their families. By transporting information, students will become key actors in the dissemination of energy efficiency information.

Depending on the education level (primary, secondary or university) the strategy used to take this information into students must be adapted. For younger children educational games and videos are strategies that usually achieve better results. At secondary schools showcases, educational outdoor activities were students are able to make their own experiments usually tend to better. At university level, the most important change could be the inclusion of Sustainable Energy Systems (SES) in the existent undergraduate courses or even the creation of a new post-graduate training in SES. The educational system could also work closely with private companies (industries, hospitals, hotels, shopping centers, etc.) allowing benefits both for students that receive field knowledge related to EE (e.g. ESCOs can give important inputs into the educational system) and companies which may help universities and technical schools to make courses that are more suitable for the labour market necessities.

All the activities developed for schools/universities can also be used in other dissemination events, also targeted at the general population (e.g. festivals, fairs, markets, etc.) to take EE and SES into the general population.

6.16. A15 – Energy Census - Inclusion of energy related questions in the next population Census

Economic Sector Focus: Cross sectoral

Description:

The census is a well-known instrument and should be well accepted by the population of Mozambique once its usefulness is explained. The inclusion of energy related questions in this census is a good opportunity to collect important data related to energy consumption in households, population level of knowledge regarding energy consumption and efficiency of each equipment type, energy labels meaning (after the implementation of this regulation), etc. The Census should have a specific section for these questions, named Mozambique Energy Census and the collected information could be used to support for the country energy information system which is being developed at the moment. This could be an excellent opportunity, without additional costs, to enquire the population about their energy consumption habits (e.g. refrigerator use, space condition use, average number of hours watching TV, lighting type, number of lamps used and hours of use, monthly expenditure with electricity, etc.).

The energy census could be a powerful tool to establish the country energy consumption profile in each economic sector (residential, non-residential, industrial and transport sectors). Additionally, the census could also include questions related to electric mobility, advantage of using environmental friendly technologies and their advantages for health and in the improvement of people living standards. The collected information could be important to determine the focus that needs to be given to the energy efficiency in future dissemination campaigns.

6.17. A16 – Promotion of fuel switching to renewable and low carbon alternatives

Economic Sector Focus: Cross-sectoral

Description:
Electric mobility is one of the key directions that most countries are taking in terms of fuel switching. EVs using electricity from renewable sources are the vehicles that have the lowest impact in CO_2, help in reducing health problems related to air pollution (especially from diesel vehicles) and also help in cities noise reduction. Worldwide there are countries moving away from internal combustion vehicles (e.g. in Germany only EV will be produced from 2030 forward). Mozambique should lead by example and adopt regulation to stimulate EV market and promote the use of clean technologies in the transportation sector. The natural step is to promote the fuel switching in the most pollutant vehicles that circulate in cities, such as urban buses, two-wheel and three-wheel motor vehicles.

Considering the country energy mix has a strong presence of renewable energy, especially hydroelectric power, and several solar power projects being developed, EV using electricity from renewable energy sources are the cleanest transportation and the one with the highest impact in air pollution (and public health) reduction.

Although not as clean as EVs, since Mozambique is a Natural Gas producer, authorities may also promote moving from dirty fossil fuels (such as coal and heavy oil) into NG, which is a cleaner option. Light passenger vehicles and buses are the most suitable to move into NG.

Some light passenger vehicles manufacturers have factory models ready to operate with NG. However, the number of vehicles models that leave factories ready to use NG is much smaller than the number of EV models available in the market. Regarding buses there are several manufacturers that have NG models as well as electric models, but there is a large trend to move to electric urban buses around the world.

Fuel switching is also possible in cooking. In urban areas bottled gas is widely used. In rural areas inefficient solutions are most often used for cooking (e.g. open wood stoves). Replacing these solutions by high efficiency appliances (e.g. electric cook stoves powered by electric grid or by solar systems) is a good solution. However, this fuel switching needs financial support, especially for population with low monthly income. One possible mechanism to promote the transition to low carbon solutions is tax incentive in the purchase of these high efficient solutions (e.g household appliances, NG vehicles, EV, etc.).

6.18. A17 – Creation of procedures within Mozambique public authorities for green public procurement

Economic Sector Focus: Public sector

Description:
It is essential to define a clear public procurement code that defines clear rules and criteria that applicants must follow to make their proposals eligible for public procurement. This code must include economic criteria but also environmental criteria that will be used to evaluate the proposal made by each applicant. The creation of green public procurement procures faces many challenges and barriers. One of the biggest challenges is to determine the main categories of products and services where Green Public Procurement (GPP) can be used. Portugal, as well as EU defined guidelines and best practises for GPP and considered the following categories: i) Paper; ii) Office equipment; iii) Stationary; iv) Energy and energy related products; v) Cleaning services and products; vi) Construction; vii) Transports. All public procedures for the acquisition of products and/or services under these categories have started to include environmental criteria (e.g. percentage of recycled materials, environmental friendly production, CO_2 emissions, energy savings, etc.).

In order to increase stakeholders awareness on green public procurement, it is important to create a communication plan that clearly explains the advantages of including products and services that eco-friendly when applying to public procurement procedures.

To implement a successful GPP, Mozambique need to create an entity or agency responsible for monitoring the GPP implementation and continuous update. One possible way is to have a modernised, centralised and professionalised GPP system is to create a central procurement agency, and a purchasing body, who is responsible to create the procurement procedures, launch the call for applicants and evaluate the proposals. This agency makes the nationwide procurement procedures, local authorities may still have their own autonomy for public procurement but may also publish their procurement procedures through the national GPP system. One good example of GPP is the acquisition of electric bus fleets made by several cities worldwide (e.g. Bogotá-Colombia, Santiago-Chile, etc.).

6.19. A18 – Promote the use of clean cooking systems

Economic Sector Focus: Residential

Description:
As indicated in the Chapter 4, biomass is widely used as the main source of energy in the country for cooking. The traditional biomass (wood, charcoal and agricultural waste) account for more than 88% of total energy consumption in the residential sector. Most of the energy from biomass

is used for cooking by domestic households especially in rural areas, due to this fact the clean electric cooking access rate was only 4% in 2018.

The reliance on traditional biomass has resulted in deforestation of the natural forest resources, as well as in health problems due to fire smoke and other emissions [12, 51, 52]. Additionally, cooking is generally done using inefficient open fires in poorly ventilated spaces, exposing the people to serious indoor air pollution. As biomass will remain the primary source of basic energy consumption, it is important that the available energy is being used in a cleaner and safer way. This action shall focus on programmes promoting the use of improved cook stoves and cleaner fuels trough the existing technologies that have proven to be adequate on similar contexts.

Regarding low-electricity cooking, there are new energy-efficient technologies (smart pressure cookers) which provided low operation costs, and which are available with business model (PAYG - Pay as You Go) for fast market implementation [53, 54] and which have been successfully implemented in other East African countries.

As main incentives for a successful implementation of efficient cooking programmes, this action it should include a well elaborated communication plan, training workshops for the people engaged in the cooking activities and follow-up activities ensuring the operation and maintenance of the cook stove. These dissemination campaigns should be designed and planned according to the specific needs and traditions of each community and based on the preferences and needs of the end users.

6.20. A19 – Promote the use of household appliances with low stand-by consumption and strategies to reduce household stand-by

Economic Sector Focus: Residential

Description:
Stand-by power use, also known as vampire power or leaking electricity, is the electricity consumed by appliances and other equipment when they are switched off (but still plugged into the energy socket) or not performing their primary purpose. That is why some suggest that unplugging idle appliances around homes may saves a lot of electricity.

In the residential sector the biggest attention regarding stand-by losses must be paid to the following appliances: coffee-espresso machines, TVs, Video Cassette Recorder (VCR), set top boxes, printers, computer monitors, laptop chargers, internet routers, air-conditioners (AC), and microwave ovens. It is essential that these devices are switched off when they are not in use, especially at night or during the weekends. These appliances need a small amount of electricity to maintain signal reception capability, i. e. remote control, monitoring temperature, powering internal clock and continuous display. The typical stand-by consumption for household appliance can range from as little as 1 W to as high as 15 W [55, 56].

At first glance, the stand-by consumption seems to be low, but the combined effect of all appliances and the fact that stand-by power consumption occurs 24 hours per day makes the combination small consumptions a significant use of energy. Recent data estimates that stand-by consumption in a household ranges from 3-10% of the total electricity consumed in that household.

Modern regulations in many developed countries limit stand-by consumption to 1 Wh or less but in developing countries where inefficient appliances prevail, the stand-by consumption can naturally be much higher.

There are several possible strategies to address the stand-by consumption. Some of these strategies include the use of high efficiency appliances that have low stand-by consumption and the use of equipment that allow to easily disconnect appliances from the grid (e.g. extension cords with switches, etc.). Additionally, consumer awareness campaigns focused on reducing stand-by power consumption should be implemented targeting the general population through outdoors, TV and radio campaigns, social media, etc. Moreover, a public campaign sponsored by EDM, MEEC and MIREME could distribute free extension cords with switches or intelligent extension cords (one unit per household) to raise awareness to the high costs of stand-by consumption.

6.21. A20 – Promote the replacement of the existing lighting by LED technology

Economic Sector Focus: Residential

Description:
Lighting is the most basic use of electricity in a home. Lighting share in the total residential electricity consumption is estimated to be 13,6% in urban areas and 31,7% in rural areas of the total electricity consumption in the residential sector.

The lighting market is undergoing a rapid transformation as Light Emitting Diodes (LED) become the number one source of efficient lighting worldwide. The LED market evolution is continuing with a steep decline in cost per unit, a higher energy-efficiency, improved colour rendition and a longer lifetime.

The quality of efficient lighting is a key component of a successful transition. Low quality lamps have poor performance with reduced visual comfort, which will result in lamps not meeting the expected energy and greenhouse gas savings, hampering policies and project implementation.

Inefficient incandescent lamps remain the least expensive (in terms of acquisition cost) technology for end users. The initial cost of efficient lighting can be seen as the biggest hurdle to overcome. However, the total life cycle cost of a LED is much lower than the inefficient incandescent lamps.

In this context, education and awareness raising campaigns can contribute to increase the usage of efficient lighting technologies. These campaigns should highlight the benefits of efficient lighting and include messages such as:

- Efficient lighting products (LEDs) consume much less energy than inefficient incandescent lamps for the same lumen output;
- Consumers electricity bills will be reduced;
- Efficient lighting has a longer rated lifetime than incandescent lamps, resulting in fewer purchases contributing to additional economic savings;
- The use of high efficiency lamps (LEDs) will result in peak power demand reduction which leads to lower investments on power system infrastructures.

In spite of high awareness levels, consumers with weak purchasing power may continue to buy inefficient incandescent lamps. Therefore, supporting policies and financial incentives are necessary to achieve a transition to efficient lighting (LEDs). The implementation of fiscal policies and subsidies, as well as the utilization of promotional mechanisms can have a positive impact on the penetration of efficient lighting. The successful implementation of efficient lighting programmes usually involves the following Policies and Mechanisms:

- Increased awareness campaign and promotional activities;
- Energy labelling and MEPS;
- Financial incentives;
- Taxation of incandescent lamps (which can revert to the Environmental and Energy Efficiency Fund).

Monitoring, verification and enforcement assures the success of the transition to efficient lighting, which heavily depends on a well-functioning system of market monitoring, control, and testing facilities capable of ensuring enforcement and full compliance with energy labelling and MEPS. Unless effective and timely market surveillance systems are enforced, substandard products will continue to enter the country in increasing numbers, which reduce energy and financial savings. Poor quality products may also create unfulfilled expectations and disappointment on the part of end users who will refrain from purchasing these products on an ongoing basis in the future. Additionally, they ensure that government regulators fulfil the objectives of their efficient lighting initiatives.

To promote the transition from inefficient lamps into LEDs, the Environmental and Energy Efficiency Fund with the support of MEEC, MIREME and EDM can promote a free lamp replacement program. Each can go to specific stores (e.g. supermarkets, MEEC kiosks in fairs and market, etc.) and take one inefficient lamp and receive without any cost a LED lamp. The cost of this exchange programme can be supported by the entities involved (or in alternative by the Environmental and Energy Efficiency Fund, including the tax on incandescent lamps).

6.22. A21 – Promote the acquisition of high efficiency AC units and fans

Economic Sector Focus: Residential

Description:

In 2018, 26% of the total global cooling demand came from the residential AC sector. In households and in the non-residential sector in countries with hot climate, the AC can represents more than 50% of total electricity consumption. As incomes and living standards improve, more people will naturally want to have more comfort in their houses and will buy and use air conditioners and fans. Wider access to cooling is necessary since it brings benefits to human development, health, well-being and economic productivity. However, it will have a significant impact on countries overall energy demand, especially during peak hours, putting pressure on electricity grids and driving up local and global emissions [57].

The reduction of the energy and of the peak demand lies first in improving the efficiency of air conditioners and fans, which can quickly reduce the growth rate of cooling-related electricity demand. The opportunity for efficient cooling lies in the fact that there is a significant number of inefficient equipment available in the market and there is a huge disparity in terms of efficiency of air conditioners sold today across the globe. Considering all this factors, there is a huge potential for improvements in the efficiency of AC units and fans available in the country.

Meeting current and future cooling demand in a sustainable way require innovative approaches including improvement of product design, consumer behaviour change, policymaking, and greater engagement from industries. Passive cooling involving optimising building design can also have an important role toward reducing the thermal load of the AC systems through building orientation, exterior shading, cool roof surfaces, energy saving windows, efficient insulation in roofs and windows, a correct selection of materials, etc.

Household fans are playing an important role in meeting growing cooling demand as they are much more affordable than a standard AC. It is expected the household fan ownership to grow rapidly as more people gain access to electricity, providing greater comfort until households can afford to buy an AC.

Low cost fans use low efficiency single–phase induction motors. There are now available on the market high efficiency fans using permanent magnet motors (also called brushless DC motors), which use about half of the power for same air flow cooling effect. These fans are more expensive but their lifecycle cost has a short payback time (typically under two years)

The actions towards the rational use of energy in the context of high efficient air conditioning and fans can be divided in the following categories:

- **Regulation** – The introduction of energy labels and Minimum Energy Performance Standards MEPS) for AC units and fans will allow to remove the inefficient equipment from the market. These regulations will set the minimum limits of efficiency that allow the equipment to be available in the market. Additionally, this regulations will allow to prohibit the importation of used and inefficient equipment (e.g. AC units and fans, as well as other household appliances). Moreover, the mandatory implementation of a maintenance for AC units (condition for accessing financial and fiscal incentives) will be essential for the equipment to maintain its efficiency levels over the years;,

- **Financial incentives** - To stimulate end-users to adopt high efficient AC units or fans financial incentives are important. These incentive can include “Efficiency Vouchers” to be used in the acquisition of high efficiency equipment. These vouchers allow consumers to have a direct discount on a high efficiency AC units or fans. The Environmental and Energy Efficiency Fund will refund the vouchers to the stores. For more information concerning the efficiency voucher please look at action A8;

- **Targeted information** - Orienting consumers to buy high efficiency AC units and Fans and guidelines to educate them on the correct use of these equipment units. These information campaigns with emphasis on educational and awareness aspects, should oriented to the different stakeholder groups (Importers, distributors, retailers, trade associations, utilities, administration and consumers). The campaigns can include short workshops, mass media advertising and distribution of properly designed materials (e.g. TV and radio spots, flyers, brochures, etc.) providing valuable information about the principles of air conditioning and fan equipment selection, etc.

Another option, to support the acquisition of high efficiency AC units, can be implemented through the electricity distribution utility, is allowing people to pay the equipment in soft monthly payments included in the electricity bill.

6.23. A22 – Promote the acquisition of high efficiency refrigerators and freezers

Economic Sector Focus: Residential

Description:
A refrigerator is one of the most useful appliances to be bought once an electricity connection becomes available. Thus, the number of refrigerators in the country will have a huge increase as the national grid electrification programme gets closer to its objective of giving access to all Mozambicans 2030, as well as living standards are likely to improve. Refrigerators and freezers are operated 24 hours a day, every day of the year, so they are significant consumers of energy in households. Purchasing a more efficient refrigerator or freezer will save electricity for years to come (typically over 15 years).

This means that residential refrigerator units have a high impact in total load diagram either due to the stock currently in use, as well as due to the new appliances entering the stock. If appropriate measures are not taken to reduce the electricity consumption through the introduction of high efficiency refrigerator/freezers, the difficulties in meeting a fast growing power demand may cause problems in terms of quality of service. Apart from the benefits of less stress on the electricity grid, high efficient refrigerator/freezers can reduce electricity bills for families and reduce GHG emissions. In the case of a power cut, an efficient refrigerator and freezer can keep the food in good condition if the power outage is not too long (e.g. less than 12 hours).

To protect consumers from purchasing inefficient refrigerators/freezers, energy labels and MEPS need to be enforced to drive the market towards higher energy efficiency levels. A key consideration for consumers when buying a refrigerator/freezer is size and price. The larger the refrigerator/freezer, the more electricity the appliance will use. Consumers should carefully consider the refrigerator/freezer size required for their household and purchase an appliance with the appropriate capacity in order to avoid unnecessary energy consumption.

As mentioned in the Action A2, incentive programmes address market barriers and complement mandatory standards. These programmes accelerate the market penetration of the higher efficient equipment (above minimum level). In countries with inexistent or slow-moving labelling programmes and standards, incentive programmes can promote the implementation of market transformation to achieve the penetration of higher efficiency models.

Incentive programmes for refrigerators/freezers are proven to influence consumer purchase decisions. These decisions need to be made considering the household necessities and constraints, as well the equipment overall energy performance/efficiency. For that to happen, it is essential to educate the public on the multiple benefits of high efficiency equipment Additionally, a strong media campaign that includes, TV/radio spots, outdoors, publicity in daily local and national journals, social media, etc. will be extremely important to raise consumer awareness on energy efficiency matters. At local level workshops to educate the persons responsible for food preparation, can be organized, on the proper selection and on the correct way to use the appliance.

To promote the acquisition of high efficiency refrigerators/freezers, as well as the removal of old/used inefficient equipment, the following mechanisms can be used:

- Efficiency vouchers will allow consumers to have a direct discount, if the appliance purchased is above a minimum level, as mentioned in action A8. The Environmental and Energy Efficiency Fund will later refund the store on the vouchers value (e.g between 10-25% of the appliance acquisition cost);

- Another option, to finance the acquisition of high efficient refrigerator/freezers can be implemented through the electricity distribution utility. This option allows people to pay the high efficiency appliance in soft monthly payments included in the electricity bill.

It is also important to target households that have more than one refrigerator and/or freezer. In some cases when people buy a new unit, if the old one still works they will keep running as a backup or to have additional space for food. Other situation is in high income households where it is usual to find more than one refrigerator/freezer. Both these situations need to be addressed to avoid the use of the inefficient appliances. The combination of an efficiency voucher with the delivery of the old unit will take care of the problem, in the measure described below:

- Efficiency vouchers combined with the delivery of an old and inefficient equipment for scrapping/disposal, will allow consumers to have a direct discount, as mentioned in action A8. The Environmental and Energy Efficiency Fund will later refund the store on the vouchers value (e.g between 20-35% of the appliance acquisition cost);

6.24. A23 – Promote the acquisition of high efficiency televisions

Economic Sector Focus: Residential

Description:

The television industry has gone through a dramatic transformation, which has led to a decrease of approximately 75% in the per-unit energy use of new flat-screen televisions from 2008 to 2012 [58]. Television energy use accounts for approximately 4% [58] of residential energy use worldwide and has been growing due to the increased number of televisions, the increased hours of use of each television, and a trend towards larger televisions that consume more energy.

Prior to 2005 these efforts focused only on standby power usage, or the power used by the television when the consumer considered it to be “off”. The energy requirement for standby power has been reduced from 25 watts to as low as 1 watt (on high efficiency equipment models). The television market moved very rapidly, with yearly advances in technology in the last 10 to 15 years, many of which had major effects on the energy use of televisions. The main technology advances with impact on the energy-efficiency include:

- replacement of CRT, rear projection televisions and plasma screens by flat panel technologies such as liquid crystal display (LCD), LED or organic LED (OLED) display technology ;

- Transition from analogic to digital televisions;

- Introduction and adoption of other advanced power management systems for televisions;

- The possibility of accessing internet through the TV, which increases the number of hours passed in front of TV.

In Mozambique, the market offers television sets of diverse origins and brands. Some imported TV sets are from famous brands and have labels that follow the MEPS used in the country of origin. Others are cheaper, have low quality and are substandard. This substandard equipment is usually bought by in its majority by low-income people. To avoid those substandard appliances, it is essential to introduce and enforce an energy labelling scheme and MEPS which will guarantee that consumers are acquiring a high efficiency and high quality equipment.

Moreover, the regulation should prevent the importation all the inefficient (substandard) and used equipment.

As in other proposed actions for the residential sector the best way to promote the acquisition of high efficient TVs is through awareness raising and dissemination campaigns to educate people on the multiple benefits of energy efficiency. Additionally, the combination of the efficiency voucher with the delivery of the old inefficient TV could be important top guarantee the scrapping/disposal of this equipment.

6.25. A24 – Promote the acquisition of high efficiency washing machines

Economic Sector Focus: Residential

Description:
This appliance, besides its main used (washing clothes) is also able to save time and reduce the physical burden of the people(s) responsible for clothes washing in a household.

Worldwide the rising affordability of washing machines and the growing increase in urban population is driving the development of the washing machine market. Despite the large penetration of this appliance worldwide, in Mozambique its presence is most common in urban areas and their only represents 3,3% of the residential sector electricity consumption. However, considering the country population growth, which is likely to live in urban areas, it is probable that this appliance will have a significant increase in its market penetration.

Taking these facts under consideration it important to guarantee that inefficient washing machines stops being imported and traded in the country. The introduction of high efficiency washing machines utilizing technology for the efficient use of electricity and water is of the utmost importance. For this, the enforcement of energy labels and MEPS is essential to remove the inefficient and imported used equipment from the market.

To promote the acquisition of this appliance the Environmental and Energy Efficiency Fund can use the same strategies used in other EE action for the residential sector. These strategies include efficiency vouchers to obtain a discount in the purchase of a high efficiency washing machine. Later the Environmental and Energy Efficiency Fund refunds the store on the efficiency voucher value. Another option is the acquisition of the high efficient washing machine through the electricity distribution utility, allowing people to pay the equipment in soft monthly payments in the electricity bill. Moreover it essential to launch awareness raising and dissemination campaigns to educate people on the multiple benefits of energy efficiency and user workshops for people responsible for clothes washing to show them the benefits proper equipment selection and operation of this appliance.

6.26. A25 – Promote the acquisition of solar water heaters

Economic Sector Focus: Residential and non-residential

Description:
Mozambique is a country with a high availability of solar radiation, with the global horizontal radiation varying between 1785 and 2206 kWh/m^2 per year [59]. This radiation makes the installation of solar water heaters a very cost-effective energy efficiency measure. However, at the moment these systems still represent a considerable cost for most families. Due to this fact it is necessary to encourage its use and acquisition through a support programme.

The support to the installation of solar water heaters, needs to have different focus in each economic sector (residential and non-residential). In the residential sector, the Environmental and Energy Efficiency Fund can create a specific initiative with the implementation support of MEEC and FUNAE, to create a solar water heater programme to support families in the acquisition of this equipment. This support can be given as discount (e.g. 40-60%, to be supported by the Environmental and Energy Efficiency Fund) on the acquisition cost or through soft monthly payments charged together with the electricity bill. The sizing of the solar system (the area of the solar panels and capacity of the tank are a function of the family size), should be defined with the support of the funding agency.

Regarding the non-residential sector, the use of solar water heaters will drive to significant energy savings, due to the fact that this equipment will be able to run without any energy backup most of the year. The companies included in this sector (e.g. hotels, hospitals, restaurants, etc.) need to implement an energy audit (M&V) plan to determine the energy consumption related to hot water (sanitary use and for food preparation). Additionally, it is recommended to implement a Measurement and Verification (M&V) plan to register the obtained savings due to the solar water heater systems, to apply for a tax incentive under this action. This incentive might be calculated as in action 31, where at the end of the year the obtained savings (confirmed by the M&V plan) are transformed into net financial gain.

The implementation of this action is of the utmost importance to fulfil the Mozambican Government [50], which include:

- 100.000 solar water heaters until 2025;
- Having 3,4 million square meters of solar water collectors in 2030;
- 0,1 m^2 of solar water heater collector area per individual living in Mozambique by 2030.

Another possible application for solar water heaters is in Mozambique healthcare clinics. For example, in Eswatini, most people do not have access to hot water for cooking, personal hygiene or hand-washing which is a key weapon in the fight against the Covid-19. In Eswatini healthcare clinics never had hot running water for patients, nine out of ten clinic did not even have hot water for daily base necessities. However, in a small period of nine months this situation radically changed. A solar sanitation project installed in the outside of all the 92 clinics scattered across the country, solar powered hot water stations, allowing people to have access to hot water. Figure 68 presents an image of this system.

FIGURE 68- SOLAR WATER HEATER IN HEALTHCARE CLINICS IN ESWATINI. SOURCE: [60]

6.27. A26 – Promote the penetration of high efficiency refrigeration systems

Economic Sector Focus: Non-residential and industrial sectors

Description:
Refrigeration systems in the non-residential sector are responsible for 16 % of the sector energy consumption. Upgrading the existent inefficient equipment by more energy efficient types may represent savings that range from 40% to 65%. The use of units with high efficiency compressors and permanent magnet motors can have a significant reduction in the energy consumption.

As in the residential sector, the environmental and Mozambique Energy Efficiency Centre and the Environmental and Energy Efficiency Fund must promote the use of high efficient refrigeration systems in the non-residential and industrial sectors by providing information and training for maintenance technicians and managers (in hospital, hotels, schools, shopping centers, supermarkets, commercial stores, food industry, etc.).

By showing these people the technical and economic benefits of replacing the existent refrigeration units by others with high efficiency they are able to provide accurate information to decision makers which will most certainly make them consider energy efficiency as a tool to reduce the monthly expenditure in energy.

Tax incentives, efficiency vouchers, rebates, or efficiency awards can be created to stimulate the replacement of the inefficient refrigeration units. Tax incentives is the most common away to encourage consumers, allowing companies to have a reduction on their tax and used the capital to investment in energy efficiency, in this case in high efficient refrigeration units. The efficiency voucher is a tool to incentivize the acquisition of refrigeration equipment with high efficiency levels and at the same time promote market transformation.

6.28. A27 – Promote the replacement or retrofit of existing lighting and lighting systems by other based on LED technology

Economic Sector Focus: Non-residential and industrial sectors

Description:
The replacement or retrofit of lighting systems is normally a very cost-effective measure in all economic sectors. However, in non-residential and industrial sector the cost-effectiveness can be even higher due to the fact that usually exists a larger number of lights/lighting systems per facility and the number of operating lighting working hours is very large. Also, the existing lighting typically has a short-medium (10.000 to 20.000 hours, compared typical 50.000 hours for LEDs) lifespan which leads to large operational/maintenance costs. In the non-residential and industrial sector it is important to have adequate luminance levels to allow workers and users to have good a performance in the execution of their tasks (e.g offices, class rooms, surgery rooms in hospitals, etc.). Most often old lighting systems are inefficient and sometimes do not comply with the international standards that define the minimum levels of luminance to perform a specific task.

It is important to target specific dissemination campaigns for decisions makers in these sectors (non-residential and industrial) to show them the multiple benefits (economic, increase in work productivity, social, etc.) of replacing/retrofitting the existing lighting and lighting systems by other based on high efficiency LED technology. Some of these multiple benefits include:

- Improved energy efficiency - LED technology is highly energy efficient and will significantly reduce energy consumption in all facilities. Switching from traditional lighting to LED lighting solutions will reduce the energy consumption with lighting up to 70% with the use of control systems (depending on the existing old technology);

- Reduced maintenance - LED lights can last up to 5 times longer than tubular fluorescent lighting. This increased lifespan reduces the maintenance cost of both indoor and outdoor lights;

- Low heat production – Incandescent, CFL or tubular fluorescent lights have a significant production of heat, which in some cases combined with the heat irradiated by the human body usually results in additional cooling consumption from AC or HVAC units (e.g. offices, hospitals, government buildings, etc.). LEDs have a very low level of heat production which reduces the building cooling necessities/costs.

- LED are environmentally friendly – Old inefficient lighting systems used hazard material such as mercury vapour and the materials used to produce LEDs are much more environment-friendly;

- Focused Lighting - Unlike many other types of lighting, LEDs produce light in a specific direction, which allows the light to be focused on the desired location without the need for reflectors;

- LEDs require very little maintenance, as they only need the regular dusting and inspection which may help LEDs to last longer and prevent eventual component failure.

6.29. A28 – Promote energy efficiency in small and medium enterprises

Economic Sector Focus: Non-residential and industrial sectors

Description:
The energy consumption in a small and medium enterprises (SMEs) is typically small, and energy is not a priority for most of the SMEs. However, typically a large number of companies fall under this category, which makes the number of SMEs per country to be considerable and their energy consumption is quite significant. Unlike larger energy intensive consumers, an SME rarely has access to substantial financial incentives or has the possibility to use the company own resources to plan and implement energy efficiency activities. SMEs are not an homogenous in a sector as households, since SMEs work in an extremely large variety of activities which makes it very hard to target specific energy efficiency measures. This measures must be drawn according to the SME business activity and location. SMEs usually have less financial capacity and usually do not have in their staff people with training or expertise in energy efficiency and for this reason are less aware of the opportunities to reduce energy consumption. It is important to raise awareness (leaflets, brochures, training) about the multiple benefits of energy efficiency, including the reduction of energy costs. To encourage SMEs, emphasis needs to be placed on sharing information on best practices and on successful examples of implementing efficiency improvements.
Another possible way to unlock the SMEs energy efficiency potential is to establish a bridge between SMEs and ESCOs, which can help to identify cost-effective energy efficiency opportunities and reduce the energy consumption, maintenance costs and at the same take advantage of the available Government energy efficiency initiatives.

6.30. A29 – Promote energy efficient street lighting replacement by EDM through the involvement of ESCOs

Economic Sector Focus: Non-residential

Description:
Cities around the world have been able to obtain substantial savings (in energy and maintenance) as a result of retrofitting public street lighting. By replacing existing street lights with high efficiency LED lamps, cities and/or utilities can cut energy and operational costs related to street lighting by 20 to 50% [61]. However, the cost of this retrofit is quite significant due to the fact that usually cities have hundreds or even thousands of street light lamps.

Investing in energy efficiency measures to improve urban street lighting systems is essential for the economic, technological, safety and social development of cities. The entity responsible for the public street lighting management (municipality, EDM or other) is often struggling with the lack of budget or difficulties in accessing credit for their usual activities, and street lighting refurbishment/expansion is usually left behind. In these cases, besides EDM, ESCOs can also play a key role and finance the retrofit or renovation of existing street lighting systems by replacing them by LEDs. The new street lighting system allows to have significant energy savings and these savings are used to pay the ESCO through an energy performance contract, the cost of the street lighting replacement. The ESCOs through their own funding or other mechanisms (e.g. third part financing) finances the retrofit, which can be repaid through the resulting energy savings in a period defined in the energy performance contract, which often is around 5 to 10 years. After this period the property of public street lighting system returns to the previous owner (EDM, municipality, etc.). The result is a city with more efficient street lighting system from day one without any need for capital from street lighting owner.

A quick analysis of the present situation of street lighting (grid connected and off-grid) is presented in Table 32 and Table 33. Table 32 presents the grid connected public street lighting situation in 2020 and it is possible to observe that only 6,4% of the grid connected street lighting is LED.

TABLE 32- GRID CONNECTED PUBLIC STREET LIGHTING CONSUMPTION

Grid connected public street lighting – Electricity Consumption[44]		
Type of Lamp	**Number of lamps**	**Total energy consumption per year**
Non-LED Technologies		
Mercury Vapor	8762	88,2 GWh
LPS -Low Pressure Sodium	7314 (Estimating that 50% of lamps are from each type)	
HPS -High Pressure Sodium	86807 (Estimating that 25% of lamps are from each type)	
LED Technology		
LEDs	**7000**	2,7 GWh

Mozambique also has a significant number of street lighting powered by off-grid solutions, Table 33 summarizes this situation.

TABLE 33- OFF-GRID PUBLIC STREET LIGHTING CONSUMPTION

Off-grid public street lighting – Electricity Consumption[45]		
Type of Lamp	**Number of lamps**	**Total energy consumption per year**
Non-LED Technologies		
Mercury Vapor	**122**	300,4 MWh
HPS -High Pressure Sodium	**147**	
LED Technology		
LEDs	**89913**	9,5 GWh

According to the collected information the largest part of the electricity consumption in street lighting is still made with inefficient lamps (e.g mercury vapour and LPS). Replacing the existing lighting systems by LED, will allow to reduce the energy consumption associated with non-LED technologies around 50% (in grid connected systems more than 44 GWh per year and in off-grid systems around 150 MWh per year). Moreover the introduction of energy management systems in street lighting (e.g. reduction of luminous flux in certain hours, use of motion sensors or other technologies) may allow to obtain additional savings even in streets where LED are already in use.

Even in off-grid street lighting there are opportunities for improvement since almost 300 MWh per year are consumed by non-LED technologies. The use of energy management systems for

[44] Public street lighting in 2020. The working period used was 12 hours per day.
[45] Off-grid street lighting in 2020. The working period used was 12 hours per day.

these systems is also a viable option. At the moment, off-grid street lighting is a much smaller market and may not be able to attract ESCO interest, but a large-scale rural electrification program may create a huge market. By extending the off-grid street lighting network to more locations (where grid access is not available), cities and regions may attract ESCOs interest into this market segment.

6.31. A30 – Promote the penetration of high efficiency HVAC equipments (AC units and fans included)

Economic Sector Focus: Non-residential and industrial sectors

Description:
In intensive-use applications (HVAC in hotels, hospitals, etc.) it is possible to achieve very high savings by installing the best available equipment in the market when compared to other low cost equipment. HVAC (AC units and fans included) are responsible for 23% (in the non-residential) and 6% (industrial sector) of the electricity consumption per year.

To encourage these improvements or replacement of HVAC systems, a programme similar to the one used in South Africa could be launched. Companies/businesses within the non-residential and industrial sector will received a financial incentive for each kWh saved due to the installation of high efficiency HVAC systems (e.g. with a certain minimum COP-Coefficient Of Performance). The savings obtained with the high efficiency HVAC (AC units and fans included) have to be verified by a M&V plan made by certified professionals. This incentive could be valid for a period between one to three years.

One possible option is to provide tax incentives. In the end of each year a company/business has a net profit which will be taxed according to Mozambique tax rates. If the company implements the replacement of the existent HVAC system (control system included) by a high efficiency system it should qualify for the tax incentive under this action. At the end of the year the obtained savings (confirmed by the M&V plan) are transform into net financial gain.

A potential practical example is a company that has an annual net profit of $2 000 000 that is to be taxed. The marginal rate of tax for the company is for example 32% (in Mozambique the tax rate is between 32-35%). If the company/business implements the replacement of the existent HVAC system by a high efficiency system it qualifies for the tax incentive under this action. At the end of the year the obtained savings (confirmed by the M&V plan) the tax incentive is calculated in the following way:

- Energy savings – 100.000 kWh;
- This translates into a foregone revenue (Y) of 100.000 x R x 32%. R is the value of each kWh saved ($0,05 USD in industry and $0,06 USD in non-residential sector);
- Considering application of the marginal rate of tax (32% mentioned above) to the annual net profit, the result is $640.000;
- The amount of tax the company/business has to pay to Mozambique tax administration is $560.000 - Y

Other forms of incentive to support companies/businesses include the Environmental and Energy Efficiency Fund with may support a percentage of these systems through the presentation of invoice and technical report to proof the acquisition and the high efficiency of the purchased equipments. As a control mechanism, the Environmental and Energy Efficiency Fund may request the yearly presentation of a M&V to certified the savings obtained with the new HVAC system.

6.32. A31 – Promote the acquisition of high efficiency information and communications technology equipment

Economic Sector Focus: Non-residential and industrial sectors

Description:
In non-residential and industrial sector the ICT infrastructure (LAN and WLAN equipment, routers, servers, computers, screens, printers, set top boxes, etc.) have a significant impact in electricity consumption (around 9% in non-residential sector and 5% in industry). Some of this consumption is possible to be avoided through educational campaigns targeting the staff of these companies with the objective of moving into more energy efficient behaviour and equipment selection.

For example in office buildings, workers often leave their computers, screens or printers connected when they leave the office. The creation of awareness raising campaigns to demonstrate the multiple benefits (for the company, environment, etc.) will help to motivate a behaviour change in workers which will result in the reduction of the energy consumption. Additionally, it is important to show to decision makers the achievable energy savings by changing old and inefficient ICT equipment (e.g. computers, screens, etc.) by more energy efficient equipment which in the short-medium allow a fast recovery the cost of the high efficiency equipment.

To address the possible reduction on energy consumption concerning ICT equipment, a partnership could be established between the Environmental and Energy Efficiency Fund and EDM to disseminate information about the multiple benefits of energy efficiency (including ICT equipment) alongside with the monthly energy bill (by email or by postal letter). This can be one possible way to inform decisions makers. Another possible option is the organization of workshops in events and fairs directed to the non-residential (tourism fairs and other events), as well as for the industrial sector (equipment and machinery fairs). In these events company managers/decision makers can be given important information on EE which will allow them to take EE under consideration in future equipment purchasing related decisions.

During the winter and cool nights, when the outside temperature is below 15ºC, outside air can be used to cool data centers, instead of compressor based cooling.

6.33. A32 – Development of regulations for energy audits, energy management systems and to promote the cooperation between industry and academia on energy efficiency activities

Economic Sector Focus: Non-residential and industrial sectors (only intensive consumers)

Description:
Across the globe, countries have been designing and implementing national programmes and policies to improve the energy efficiency of the industrial sector. In several countries governments have encouraged energy efficiency through voluntary agreements (for intensive consumers) to achieve significant energy savings. An intensive consumer is a facility/building that has a high energy consumption per year (e.g. energy intensive consumers can be defined as having an energy consumption above 1000 toe[46] - tons of equivalent oil).

[46] One toe is equivalent to 0,0116 GWh

Most companies that have a large energy consumption, usually look for opportunities to gain greater control over their energy use, especially when it reduces the operational costs and increases productivity and competitiveness. Intensive consumers in the industrial and non-residential sector typically have a large potential to reduce energy consumption with the support of regulation which can be based in other countries good practices and international standards, to accelerate its implementation in Mozambique.

In countries where voluntary agreements were implemented, some of the actions used to encourage EE include energy management systems using ISO 50001 certification (international standard for energy management systems), mandatory periodic energy audits, availability of on-site energy managers, the adoption of MEPS for electric motors, and strategies to promote combined heat and power (CHP) also called cogeneration, in industries requiring both process heat and electricity.

An energy efficiency programme needs to be supported by clear, well-defined and strong legal framework that establishes in a clear way all the rules, procedures and the professional qualification necessary to implement an EE project, as well as the guidelines and procedures to be followed by the EE project promoter. The first step is the definition of the facility energy consumption baseline which must be made through a detailed energy audit, followed by the creation of a plan that identifies the EE actions to be implemented and energy savings to be achieved. These savings will be monitored in the duration of the project by an M&V plan that assures that the savings estimated in the project are being achieved.

Examples from other countries, where the implementation of energy audits has successfully been established include the European Union countries, South Africa, etc., and should be considered by Mozambique authorities as a way to accelerate the implementation of this action for the industrial and non-residential sectors.

To develop and implement regulation for energy audits and energy management systems, Mozambique national authorities should also promote cooperation between the industrial sector and academia in order to accelerate the uptake of EE in these economic sectors, as well as to increase the training of human resources.

The mobility of scientific competences from universities to intensive energy consumers enables companies to absorb and use the knowledge developed in academia. Market competition and globalization in engineering and energy efficiency is motivating industrial and academic institutions to improve their collaborations. There are shining examples of fruitful collaboration between universities, industrial partners and start-ups. Many of the ideas resulting from R&D in Universities are put to use through collaboration between universities and companies. The MEEC with the collaboration of EDM, may serve as a bridge between intensive energy consumers and the University Eduardo Mondlane in the creation of innovative solutions to reduce energy consumption in the non-residential and industrial sectors. .

6.34. A33 – Creation of a recognition award to honour the energy efficiency champions

Economic Sector Focus: Non-residential and industrial sectors (only large intensive consumers)

Description:

The creation of an energy efficiency award for companies in the non-residential and industrial sectors may attract attention from the general population for EE and for the companies can be a way of obtaining free publicity and recognition for their effort to reduce energy consumption, as a key strategy to achieve environmental sustainability. The nominated energy efficiency projects and prize winners could be selected by an expert jury made up of representatives from MIREME, MEEC, CEOs and Managers from Mozambique largest companies, academia, and EE experts (foreign or nationals). There are several successful international awards of this type, that MEEC could use as an example to help in the preparation of a Mozambique national energy efficiency award.

To apply for the energy efficiency award companies need to submit a detailed application with all the technical elements of the EE solutions implemented, as well as the results from the M&V plan. The jury members evaluate all the submitted energy efficiency projects according to uniform standards based on the criteria of innovation, cost-effectiveness, energy savings, climate protection relevance, market potential for the realisation of similar projects in other companies and economic efficiency.

The winners of the energy efficiency award will be honoured in a public ceremony and through media campaigns where they are designated as energy efficiency champions. For companies the use of the EE champion title of even a champion logo might be a signal of trust for their customers. The cost of organizing the energy efficiency award, the award ceremony and an eventual monetary price could be supported by donors and event/award sponsors.

6.35. A34 – Promote the acquisition of high efficiency power drive systems (includes installation of energy-efficient motors and VSDs)

Economic Sector Focus: Industrial sector

Description:
Worldwide the industrial sector is facing pressure to reduce energy consumption and carbon dioxide (CO_2) emissions. As a consequence, many Governments worldwide have imposed regulations, also known as MEPS for numerous equipment types, including electric motors. One major opportunity for cost-effective electricity savings is associated with energy-efficient motor systems.

The largest part of all electricity consumed in the industrial sector (about 75%) is used by the millions of electrical motors installed worldwide. Every year, several more millions of electric motors are added to the world stock [43, 62]. These motors are driving compressors, fans, pumps, conveyors, etc. in all industrial sub-sectors. The replacement of old inefficient motors, pumps and fans are examples of some of the equipment with the greatest energy saving potential. Targeting these applications is a great way to begin an energy saving initiative. This initiative needs to be supported by a legal framework that prohibits selling inefficient motors and the importation of used inefficient motors. According to international IEC (International Electrotechnical Commission) standards IE1 is the least efficient class and IE4 is the most efficient. Most countries around the World are specifying a minimum efficiency class IE3 for industrial applications [43, 62]. For new applications, in industries with more than 2000 hours of annual operation, the payback time is under two years.

In Mozambique MEEC can launch an initiative targeting the most energy intensive industries (with the support of EDM) to replace old and inefficient motors, when they fail (by at least IE3 motors). The replacement of these motors could be made through ESCOs and energy performance contracting or through tax incentives (in a similar way as proposed in action A31).

6.36. A35 – Promote clean industry development by replacing high pollutant fuels by other eco-friendlier options

Economic Sector Focus: Industrial and power sector

Description:
The MEEC and other Government agency related to natural resources and environmental protection should promote the reduction of CO_2 emissions and the replacement of high pollutant fossil fuels (coal and heavy oil) by other eco-friendlier options (natural gas, biomass or other renewable energies) as a way to protect natural resources and the environment, reduce healthcare costs and improve the population living standards.

The fossil fuels burned in industry emit more than just carbon dioxide. For example, a power plant using coal is responsible for dangerous mercury emissions and sulphur dioxide emissions (which contribute to acid rain) and also for a large percentage of the small particles in the air.

The combination of mandatory policies, voluntary agreements (e.g. code of conduct for clean industries) and tax incentives (calculated according to the same formula as in action A31 but regarding to the avoid emissions and the type of fuel used in a scale that classifies the fuel on its degree of danger for the environment) might accelerate the clean industry development and the replacement of hazardous pollutants. Additionally, a green certificate could be created to identify clean industries which may be used by companies to show customers that their industry is environmentally safe.

6.37. A36 – Promote the use of cogeneration in industry

Economic Sector Focus: Industrial sector

Description:
Cogeneration or combined heat and power (CHP) is defined as the generation of two different forms of useful energy from a single primary energy source, usually thermal and mechanical energy. Thermal energy can be used either for direct process applications or for indirectly producing steam, hot water, hot air for dryers or chilled water for process cooling. Mechanical energy may be used either to drive an alternator for producing electricity or rotating equipment such as motors, compressors, pumps or fans for various purposes. Cogeneration can be applied in various economic activities, and the overall efficiency of energy use in cogeneration mode can go up to 85%.

Cogeneration is often associated with the combustion of fossil fuels (the recent trend has been to use natural gas) for cogeneration but can also be carried out using other sources of thermal energy (e.g. biomass, solar energy, waste burning, etc.). The paper and sugar industries are examples of industries in which the biomass waste can be used for cogeneration. CHP appears to have significant long-term prospects in global energy markets, primarily due to its numerous operational, environmental, and economic benefits. In addition, since cogeneration installations are usually located close to consumers, the grid losses can be reduced when cogeneration is applied.

Cogeneration can be an attractive option for facilities with high electric rates and/or with high levels on consumption of process heat and electricity. Usually, the higher the electric rates, the greater the savings with cogeneration and the lower the payback period. For the implementation of CHP projects the industrial might use own funds or use ESCO expertise and capital to finance these systems. Additionally industries that implement CHP systems and obtain significant energy savings might apply for tax incentives that could be calculated as in action A31.

6.38. A37 – Promote power factor correction in the industrial sector as a way to improve the electric power system and the industrial sector energy performance

Economic Sector Focus: Industrial sector

Description:
Power factor (PF) is the cosine of the phase angle between voltage and current in an AC circuit, and it is equal to the ratio of the real delivered electric power divided by the apparent power (Voltage x Current) . To deliver the same amount of power at a low PF, all the electrical equipment (e.g. generators, transformers, and distribution and transmission lines, etc.) in a power grid or a facility need to be designed for a larger capacity, which causes higher investment and higher operational/maintenance costs. Additionally, low PF also causes energy losses (since energy losses are proportional to the square of the current), which results in poor efficiency and voltage fluctuations of the power system leading unreliable equipment operation. To keep the voltage within the admissible limits, a voltage regulator equipment must be installed. This is an additional cost for the facilities that operate with low power factor.

Taking these factors under consideration the improvement of the PF has proven to be a highly cost-effective measure, in many countries around the world. Power utilities usually impose a penalty for low power factor installations (e.g. a PF below a certain number such as 0,85) in the industrial sector as in the non-residential sector.

Worldwide electricity tariffs are designed in a way to penalize the consumers with low PF and encourage them to install power factor correction equipment. The PF of a facility can be improved, for example by connecting a capacitor bank in star or delta in parallel with any equipment that is operating at a low power factor.

The implementation of PF compensation systems has a considerable impact in the reduction of heating in power systems switchgears, generators and transformers which will improve the efficiency and reliability of these equipment and of the facility. Additionally, by maintaining a high power factor, a facility can yield direct savings such as reduction of electricity bills, elimination of penalties on reactive energy, improvement of the facility voltage level stability, decreases the peak demand for kVA, and increases the power available at the secondary side of an MV/LV transformer. Summarizing PF correction in a very cost-effective measure in industry that makes the entire facility electrical system more energy efficient, leading to short payback times (typically less than one year).

To promote power factor correction in the industrial sector, Mozambican authorities can use support mechanisms that include utility or tax incentives (calculated according to the same formula as in action A31) or through a direct support from the Environmental and Energy Efficient Fund.

6.39. A38 – Introduction of fuel economy standards and labelling for vehicles

Economic Sector Focus: Transportation sector

Description:

Most often vehicles (e.g. buses, trucks, vans, etc.) at the end of their lifecycle are exported to from several regions to emerging economies. This is a way of removing them from their original markets (e.g. Europe, United States of America, etc.) due to environmental restrictions or non-compliance with fuel economy standards. These highly pollutant vehicles are easily sold in developing countries due to its low price. Mozambique needs to create a legal framework that can include policy restrictions to the age of second-hand vehicles imported into the country (e.g. imported vehicles can for example have a maximum of ten years), implementation of a vehicle inspection programme to assess the overall security and emissions according to vehicle age, and the creation of an annual circulation tax based on the results of annual inspection on fuel economy and CO_2 emissions. This tax should revert to the Environmental and Energy Efficiency Fund.

The introduction of energy labels and fuel economy standards is one of the best way to prepare the introduction of zero emission vehicles (namely electric vehicles), reduce the external fossil fuel dependence, encourage the reduction of CO_2 emissions and improve the air quality (especially in cities where there is a larger concentration of motorized vehicles). The fuel economy standards should include the maximum amount of fuel and CO_2 emissions that each type of vehicle may consume per 100 Km to be sold in the country. These standards should be ambitious to drive market into the adoption and uptake of electric vehicles and natural gas vehicles.

Additionally, fuel economy can also be promoted through vehicle traffic management, which includes development and implementation of flow management plans, the use of smart transportation management (e.g. intelligent traffic lights that adjust release intervals to reduce traffic jams, adopting one-way street systems, intersection and roundabout improvement and development/enhancement of traffic control centres) to reduce reliance on police officers for traffic control and improve urban road transport will reduce fuel consumption and emissions.

6.40. A39 – Initiate the adoption and uptake of electric mobility

Economic Sector Focus: Transportation sector

Description:
Worldwide there is evidence that electric mobility is the future to achieve sustainable mobility. Several car manufacturers already stated they will stop producing internal combustion vehicles (powered by diesel) in 2030. At the moment most manufacturers already have several EV models available.

Taking a closer look at Mozambique reality and considering the fact that country is a natural gas producer, it is likely that the transition to cleaner fuels in the transportation sector will have an intermediate stage (namely for buses and trucks) where vehicles powered by NG may have a relevant role. NG vehicles can represent a transition stage between internal combustion vehicles and zero emission vehicles (EVs). As in other countries the electric mobility uptake time depends on the country economic situation and policies. Mozambique needs to create the necessary conditions (regulatory and in the power grid infrastructure) to initiate the adoption of electric mobility.

Usually the biggest barriers that the EVs face are the acquisition cost, people reluctance on charging time, availability of charging stations and vehicle autonomy. The Environmental and Energy Efficiency Fund can create a programme (financed by a carbon tax on fossil fuels) to overcome these barriers and at the same time encourage the adoption of EVs. This programme can be based in:

- Tax incentive or subsidies in the acquisition of an EV (which will allow to reduce the acquisition cost);

- Reduction on annual circulation tax for EVs;

- Support the creation of a network (in larger cities) of EV charging stations (grid connected or solar powered with energy storage) managed by the Environmental and Energy Efficiency Fund or by other entity (EDM, FUNAE, MIREME, etc.);

- Reduced import taxes for electric vehicles (e.g. cars, bicycles, motorcycles and three-wheel taxis/tuk-tuks, etc.);

- When a building energy code is introduced in the country, this code must have guidelines for mandatory incorporation of charging stations in public buildings and in new buildings (e.g large commercial stores, shopping centres, condominiums, etc.);

- Dissemination campaigns focused on the advantages of EV (reduced maintenance, cost per 100 Km is much smaller than in conventional vehicles, environmental friendly because it has no emissions, it produces no sound pollution, etc.) are extremely important to show how EVs can be a good solution for the present and for the future.

Electric Vehicles (EVs) must be introduced into the Mozambican transportation sector through a robust programme that strongly promotes and encourages the transition into electric mobility.

6.41. A40 – Creation of a programme to replace large/medium urban buses by e-buses

Economic Sector Focus: Transportation sector

Description:
Buses are the backbone of any public transportation system and in some cases are the only mean of public transportation in cities. Worldwide buses are responsible for 83% (or 450 billion journeys) of the total public transportation journeys and are also responsible for a large part of the air pollution. Air quality is a growing concern in many urban areas and has a direct impact on the population health. Internal Combustion Engines (ICE) emissions are one of the largest sources of harmful pollutants, such as nitrogen oxides and particulates (PM10 and PM2.5, particulates that have diameters of 10 and 2,5 microns). Urban buses are typically responsible for 40% of urban transportation pollution.

The world urban population continues to grow, and recent data shows that air pollution leads to almost 4,5 million premature deaths per year and afflicts many more, particularly children. It is important to find sustainable and cost effective public transportation options. E-buses are a solution to reduce harmful emissions and to improve the overall air quality in cities. At the moment diesel and compressed natural gas are still the dominant fuels used in bus fleets around the world. However, in several cities conventional buses are being replaced by electric bus (E-bus). Some examples of cities/countries that are one step ahead in the transition to E-buses include:

- Shenzhen in China stopped purchasing ICE buses and is only buying E-buses and have replaced the entire fleet of 16,500 diesel buses by E-buses, since 2017;

- Santiago in Chile, by the end of 2020 already had a fleet 800 E-Buses, and 2021 opened a tender for the acquisition of an additional 2000 E-buses. The cities has the objective of full bus electrification by 2035;
- Bogotá already has 1485 E-buses in their fleet;
- Glasgow recently acquired 126 E-buses (91 double deck and 35 single deck buses);
- The UK recently launched a nationwide initiative with a budget of more than $4 billion dollars to promote the transition to e-buses in several cities over the next years. This initiative includes the acquisition of 4000 E-buses as well as its charging infrastructure;
- Winterthur in Switzerland, has just announced a framework contract for the acquisition of 70 battery-powered articulated trolleybuses;
- Uganda has installed a plant to manufacture electric urban buses.

Other cities have established ambitious objectives for their urban transportation system:

- Barcelona – From 2025, all new buses procured will be E-buses;
- Cluj-Napoca (Romania) – By 2025, the city entire bus fleet will be E-buses;
- Copenhagen – Since 2019, all new buses procured are E-buses;
- Warsaw – From 2025, 20% of the bus fleet has to be E-bus;
- Paris – Targets that in 2025 the bus fleet will have 4700 E-buses;
- Amsterdam – By 2025 all buses will be electric.

Mozambique may lead as example in the SADC by creating an innovative programme with the support of the government, Environmental and Energy Efficiency Fund, EDM MIREME, FUNAE, etc. to replace all urban large/medium buses in the larger cities. Funding for this programme can be obtained from the state budget and operational budgets of the entities above mentioned, as well as from foreign donors or financing agencies.

6.42. A41 – Encourage markets for energy access

Economic Sector Focus: Off-grid

Description:
Encouraging ESCOs to participate in the objective of universal energy access in Mozambique by 2030 is of the utmost importance. The conventional grid expansion will take much more time and/or will not be possible, due to its low cost-effectiveness for many remote consumers.

ESCOs can install within a decade many thousands of mini-grid systems in rural areas. The ESCO business model for mini grids in remote areas may be supported by a Pay as You Go (PAYG) system. This system is well known in Mozambique for grid-connected customers. The Government, EDM, MIREME, FUNAE and the Environmental and Energy Efficiency Fund should stimulate the creation of a partnership to encourage ESCOs to enter the off-grid market. By entering this huge market, ESCOs will have access to millions of consumers that at the moment do not have access to electricity or energy services and are most certainly looking forward to use them.

This strategy can be an important step to increase the number of people with access to electricity in the country and to transform Mozambique into one of the countries with 100% rural electrification rate. The installation of pilot projects (financed by the Environmental and Energy Efficiency Fund or other national institution) has been extremely important to demonstrate to ESCO the economic profitability of these projects and also a way leverage ESCO confidence in rural electrification projects and in the off-grid market.

6.43. A42 – Development of product quality standards for off-grid equipment

Economic Sector Focus: Off-grid

Description:
The market for off-grid equipment is presently characterized by a wide variety of products with variable levels of quality and durability. Some have efficient design and manufacture quality, while others fall short of expectations for safety, durability, efficiency and performance [63, 64, 65]. For many end-users with low monthly income, purchasing an off-grid product is a major decision and an investment. Spending limited funds on a poor quality product could be devastating for the consumer and harm the reputation of off-grid solar products generally. To avoid this, it is important to create regulation to protect consumers from low quality products.

Quality standards for off-grid equipment is an emerging topic of interest for policymakers and several stakeholders in the off-grid market in Africa [62, 63, 65]. High quality/efficiency equipment including household appliances will allow end users to maximize the benefits of their solar home systems. The development of these quality standards will work as market quality assurance mechanism that will allow to remove from the market all the inefficient and poor quality off-grid equipment.

The off-grid solar market in Sub-Saharan Africa is growing at a fast rate, due to this fact some governments (e.g. Kenya, Ethiopia, Rwanda and Tanzania) are considering the adoption of standards and regulations for an increasing number of off-grid equipment [63, 65]. Standards ensure that low quality products are removed from the market and ensure that end-consumers are buying quality and high efficient equipment.

MEEC, FUNAE and other stakeholders in the off-grid market should work together to develop quality standards for off-grid equipment to avoid the importation of used and low-quality equipment. Mozambique future quality standards for off-grid equipment can be based in international standards to accelerate the implementation of this regulation. On example of this international regulation is the IEC TS 62257-9-8 that sets the baseline requirements for the quality, durability and advertising accuracy for off-grid renewable energy products with the aim of protecting consumers. The evaluation of these requirements is based on the test methods defined in IEC TS 62257-9-5. Both of these publications are part of the IEC 62257 series which focus on rural electrification [63, 65].

7. Summary and Conclusions

This report makes a comprehensive analysis of energy efficient measures which can be implemented in Mozambique in the different economic sectors. Energy efficiency, coupled with distributed renewable generation, is not only relevant to reduce energy consumption and decrease the environmental emissions, but is also a large opportunity in terms of job creation, development of new business areas and a way to stimulate investment (foreign and national).

This report lays out three realistic scenarios for energy savings that strongly depend on country commitment and on the allocation of resources into the execution of this plan. Considering all these factors the savings potential can go from the low savings scenario (LESS) to the high ambition savings scenario (HESS).The technical potential presented in this report does not include economic constraints, but even considering conservative cost-effectiveness conditions, 50% of the technical potential is economically feasible and achievable. This provides a strong argument for program implementation due to the multiple benefits of energy efficiency actions.

A breakdown of the different types of opportunities for each sector reveals the existence cost-effective options across all economic sectors and end-uses. The most competitive and impactful opportunities include the following measures addressing the following end-uses:

- **Residential sector on-grid -** in lighting, refrigerators, freezers, solar water heating, cooking, fans and air conditioning;
- **Residential sector off-grid -** in lighting, refrigerators/freezers, solar water heating, cooking and fans. The adoption of super energy efficient technologies has as a major benefit in the substantial decrease of the investment cost of solar energy supply, including energy storage;
- **Non-Residential sector:** in lighting, refrigeration systems, solar water heating, cooking, fans, distributed and centralized air conditioning (HVAC);
- **Industrial sector:** in lighting, electric motors, variable speed drives, refrigeration systems and cogeneration;
- **Transportation sector:** electric mobility, including urban buses, cars and two and three-wheel motor vehicles. Conversion of longer distance buses and trucks to natural gas is another possible option. Additionally, the introduction of electric vehicles into the country and the use of natural gas can be an important step to reduce the external oil dependence.

Mozambique has a huge potential to reduce its energy consumption and to improve the energy efficiency at all levels. However, to take advantage of these opportunities for energy savings, there is a need to create an institutional and regulatory framework:

- **MEEC – Mozambique Energy Efficiency Centre -** The creation of an institution focused on the development and implementation of energy efficiency in the country is essential to guarantee a successful programme implementation;
- **Environmental and Energy Efficiency Fund -** It is important to have a suitable funding mechanism to successfully implement the proposed energy efficiency actions. This fund will get its budgetary capacity through a series of taxes (on inefficient equipment, carbon tax, etc.), government funding and external donors, mentioned in each of the proposed action in Chapter 6;
- **Energy labels and Minimum Energy Performance Standards (MEPS) –** The introduction and enforcement of energy labelling and MEPS for energy related equipment across all economic sectors, as well as for the off-grid market is essential to remove the inefficient and used equipment from the market, most of it imported from Asian countries;

- **Market surveillance and compliance agency-** The effective and timely use of market surveillance and compliance mechanisms are essential to avoid substandard products from entering the country. This mechanisms ensure the protection of other public interests such as the environment, security and fairness in trade. Additionally, market surveillance and compliance mechanisms include actions such as product withdrawals, recalls and the application of sanctions to stop the circulation of non-compliant products;
- **Building Energy Codes -** The building sector in Mozambique has also a huge potential for improvements. The introduction and enforcement of a building energy code made with the collaboration of all stakeholders will have a critical role to ensure that new buildings and major renovation are sustainable from the energy and environmental point of view. Considering the foreseen population growth, the creation of a building energy code will be essential to reduce the expected growth in energy demand in the next decades;
- **Capacity building -** The implementation of energy efficiency requires qualified and skilled professionals, for this capacity building initiatives are essential to improve the human resources competences. The cooperation with professional associations (e.g engineers, architects, maintenance technicians, etc.) is extremely important to improve these professionals knowledge level and expertise concerning energy efficiency. It is also essential to raise the population awareness about the availability of energy efficient technologies, together with its potential multiple benefits;
- **Energy audits and M&V plans –** The implementation of energy audits and M&V plan in large energy consumers will allow to reduce and optimize the energy use in the non-residential and industrial sector and can also lead to improvement in the industrial process efficiency and competitiveness;
- **Integration of renewable energy systems –** The integration of these systems will have an important role in driving buildings towards a nearly zero energy consumption. The inclusion of solar thermal systems for hot water production and solar photovoltaic for electricity production can be used to reduce the buildings increasing energy demand and also to reduce the carbon footprint of buildings;
- **Off-grid market equipment regulation –** This market also need to be regulated, through energy labelling and standards, to ensure lower investment costs to supply cost-effective energy services and to remove the poor quality and low efficiency equipment from the market.
- **ESCO framework –** The introduction of ESCOs into the energy sector is essential to leverage the energy services sector development. These companies are able to bring into Mozambique expertise, capacity building for the local workforce and capital to invest in energy efficiency. ESCOs can be a good opportunity for the renovation/rehabilitation of old inefficient buildings, street lighting and even for the industrial sector improvement/expansion.

Addressing these elements in an integrated, balanced and well-sequenced way is key strategy to achieve energy efficiency and ensuring its sustainability. This report can be used to track progress on the implementation of each proposed action in the short, medium, and long term in Mozambique.

The following Figures (69, 70, 71, 72 e 73) respectively present a proposal for the implementation chronogram for the action presented in Chapter 6 for the residential, non-residential, industrial and transportation sectors. Additionally, Figure 73, presents some essential actions design for the off-grid market which indirectly will help to support the Government effort/objective to give access to secure and affordably electricity for all the population by 2030.

Figure 69 presents the implementation timeline for energy efficiency actions in the cross sectoral.

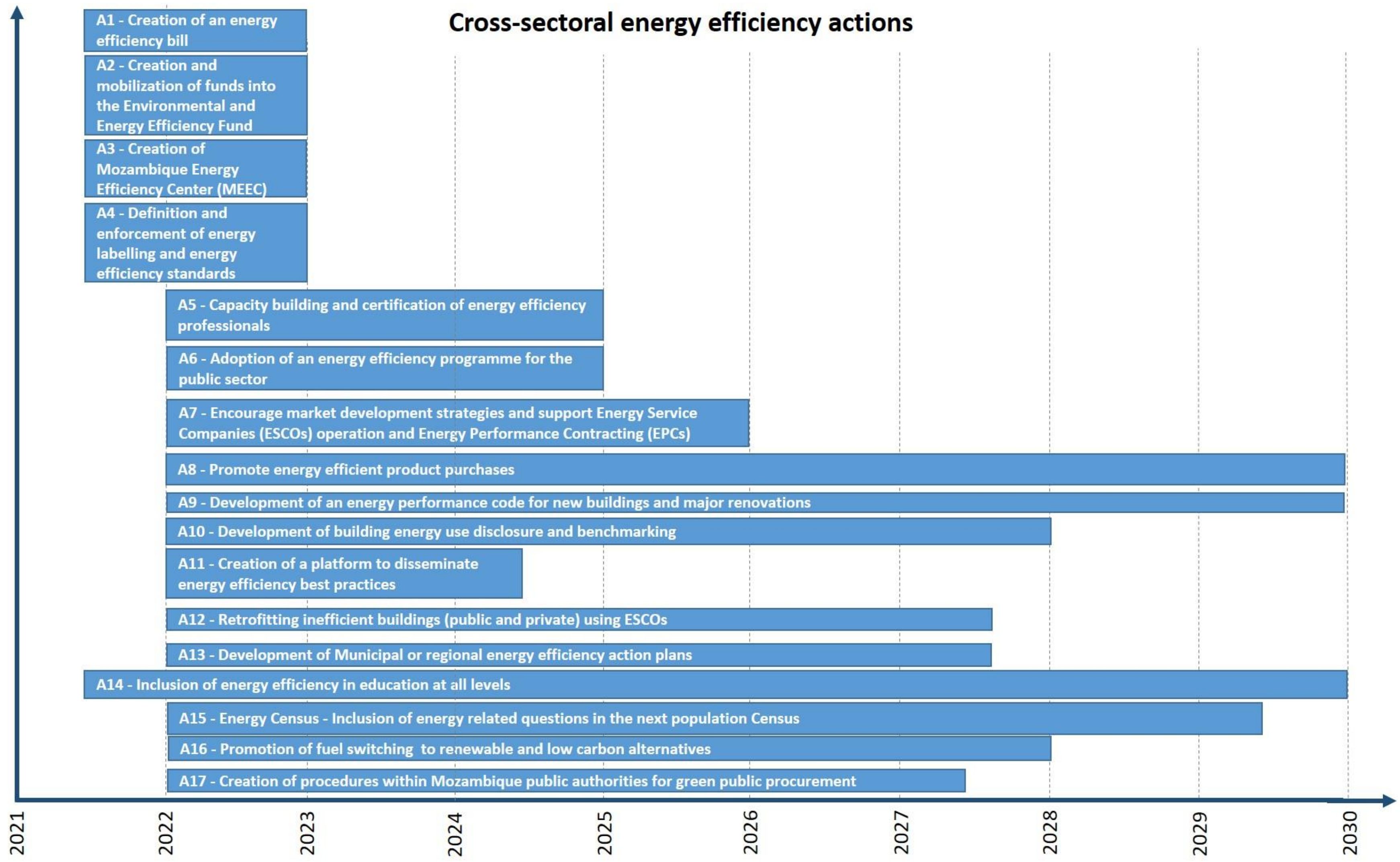


FIGURE 69 - IMPLEMENTATION TIMELINE FOR CROSS SECTORAL ENERGY EFFICIENCY ACTIONS

Figure 70 presents the implementation timeline for energy efficiency actions in the residential sector.

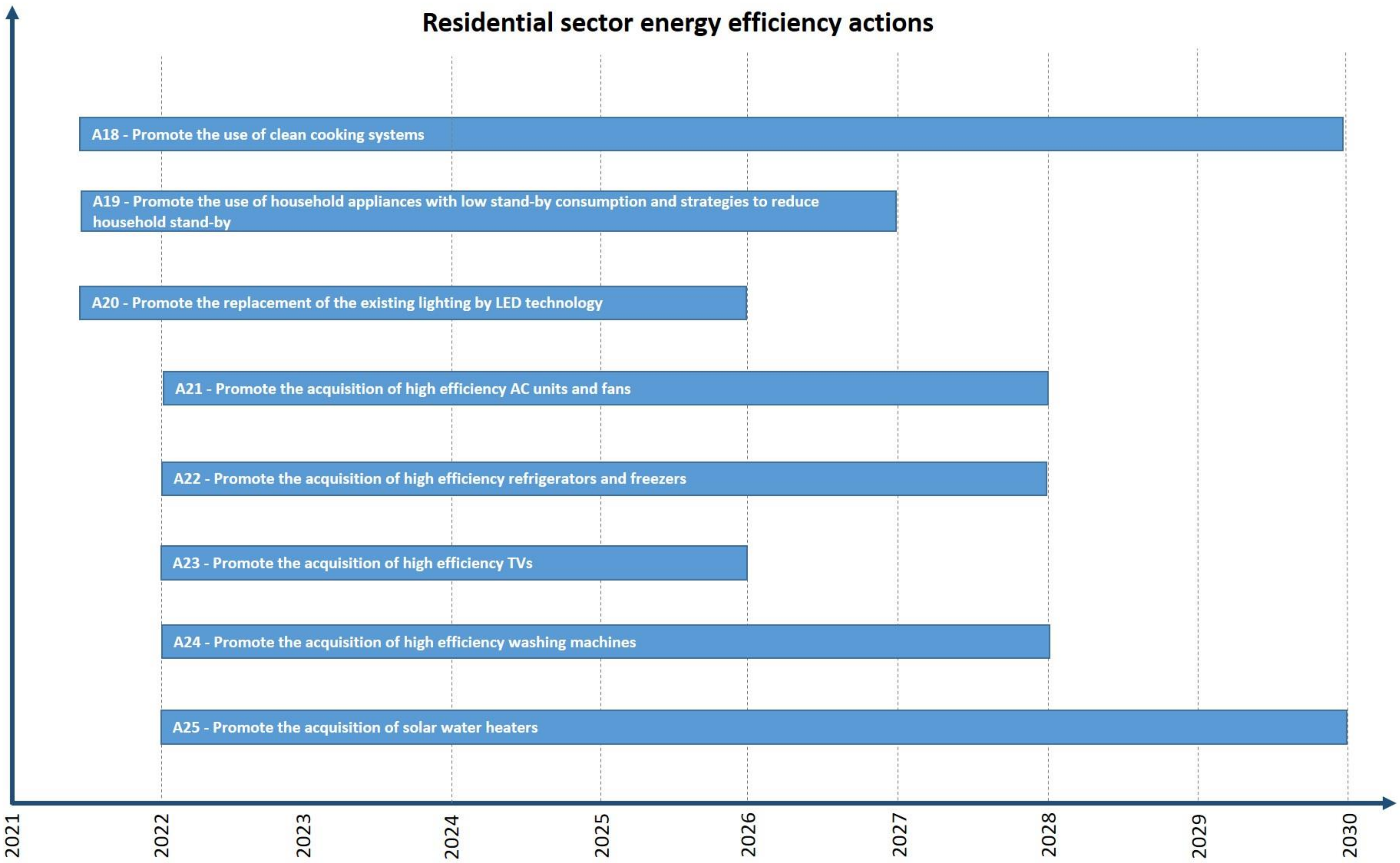


FIGURE 70- IMPLEMENTATION TIMELINE FOR ENERGY EFFICIENCY ACTIONS IN THE RESIDENTIAL SECTOR

Figure 71 presents the implementation timeline for energy efficiency actions in the non-residential sector.

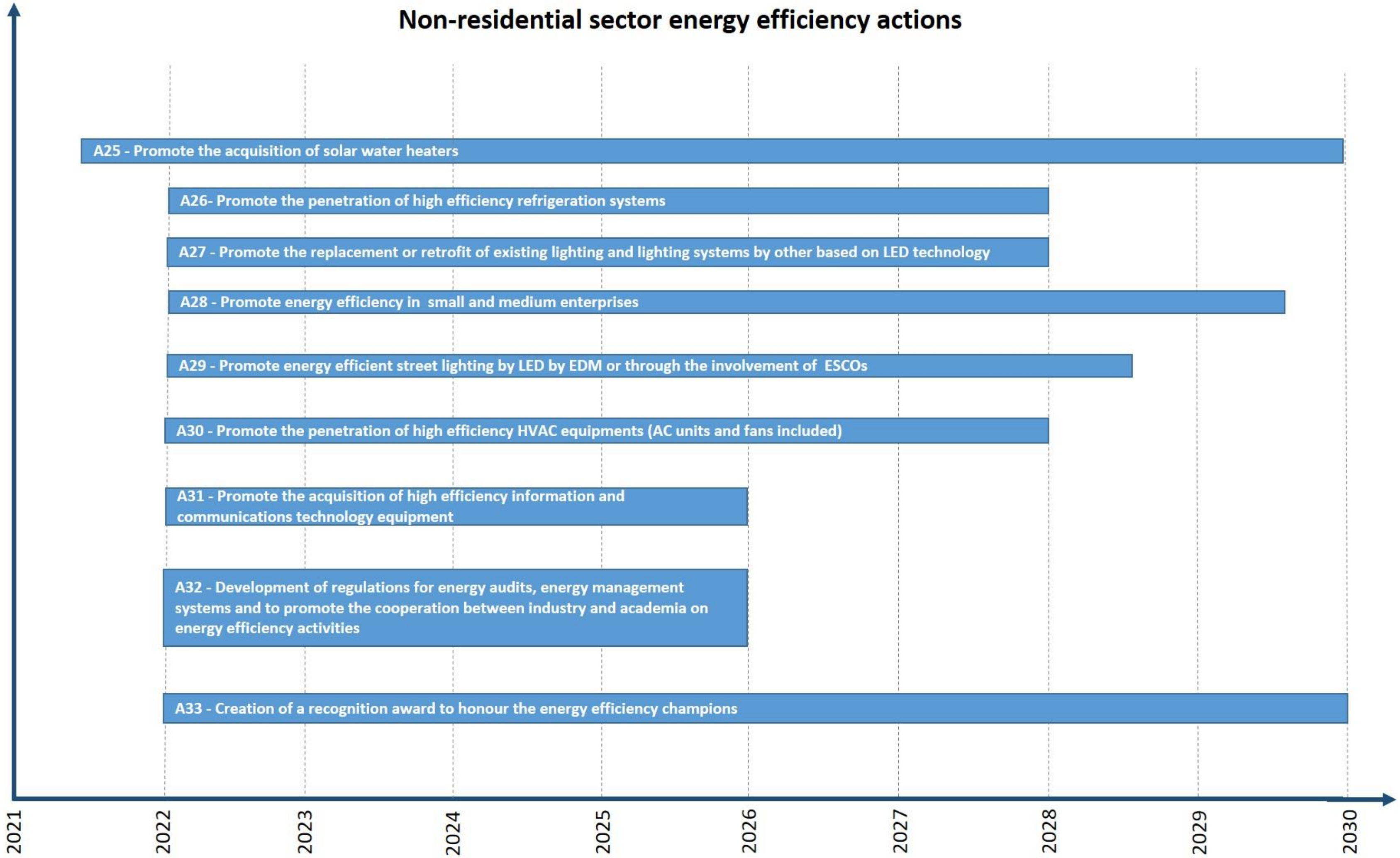


FIGURE 71- IMPLEMENTATION TIMELINE FOR ENERGY EFFICIENCY ACTIONS IN THE NON-RESIDENTIAL SECTOR

Figure 72 presents the implementation timeline for energy efficiency actions in the industrial sector.

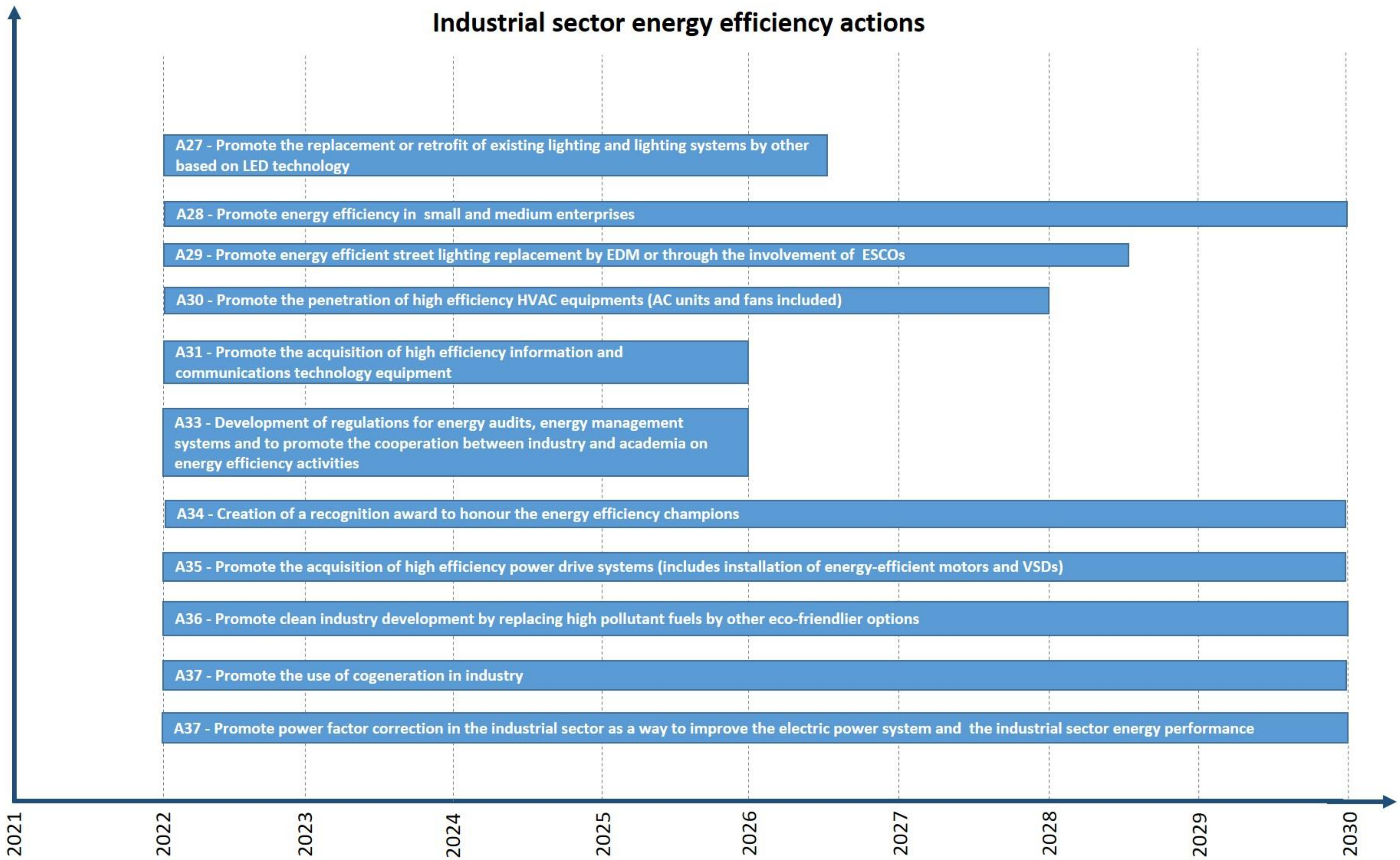


FIGURE 72- Implementation Timeline for Energy Efficiency Actions in the Industrial Sector

Figure 73 presents the implementation timeline for energy efficiency actions in the transportation sector and for the off-grid market.

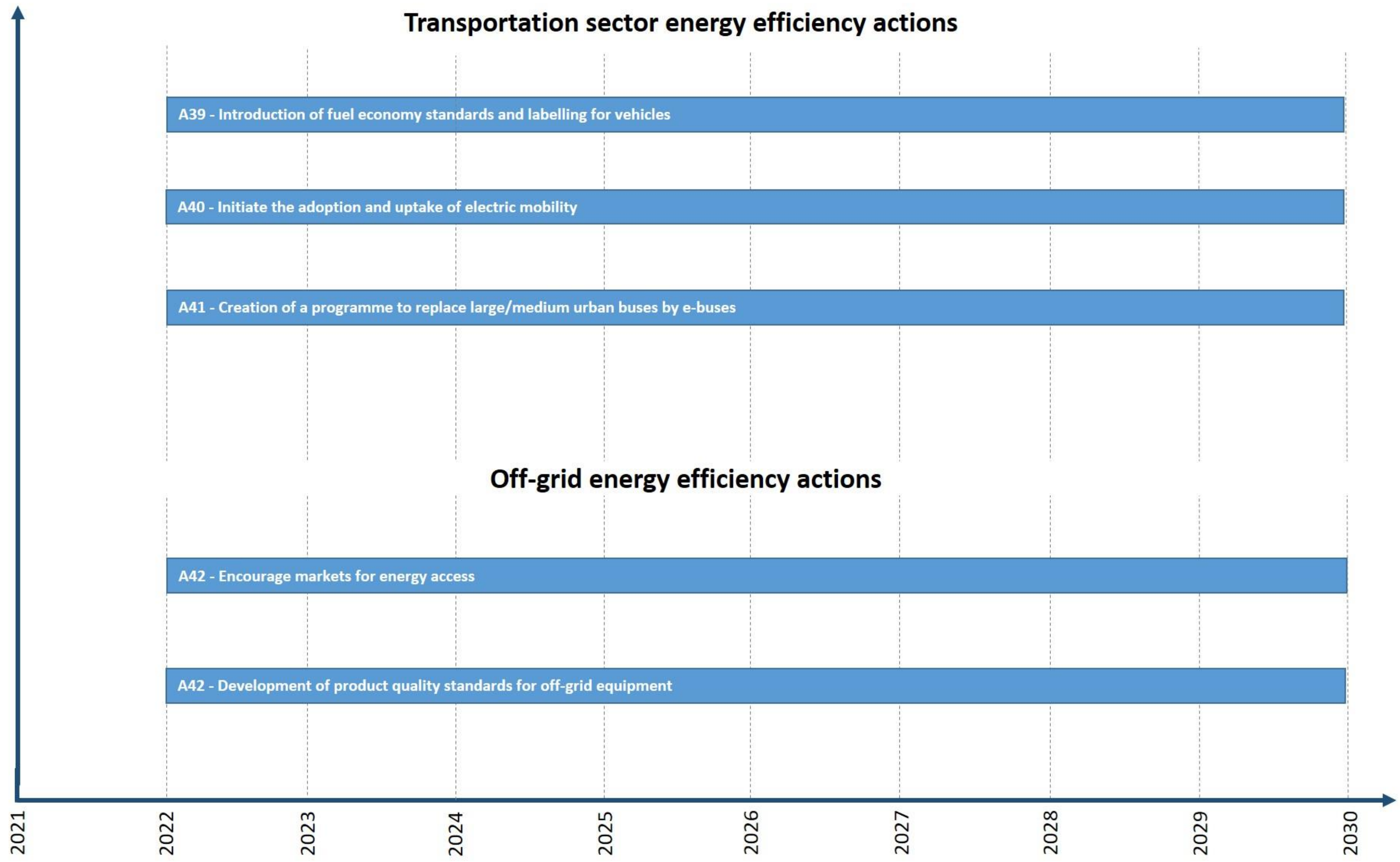


FIGURE 73- IMPLEMENTATION TIMELINE FOR ENERGY EFFICIENCY ACTIONS IN THE TRANSPORTATION SECTOR AND IN THE OFF-GRID MARKET

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