UNIVERSITY of RWANDA COLLEGE OF SCIENCE AND TECHNOLOGY ACE-ESD AFRICAN CENTER OF EXCELLENCE IN ENERGY FOR SUSTAINABLE DEVELOPMENT

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COLLEGE OF SCIENCE AND TECHNOLOGY

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Thesis Title: An Assessment of Rwanda's Achievements in Transitioning to a Low Carbon Economy: A focus on the Energy Sector

A proposal submitted to the African Center of Excellence in Energy studies for sustainable development (ACE-ESD) in partial fulfillment of the requirement for the degree of MASTERS OF SCIENCE IN ENERGY ECONOMICS

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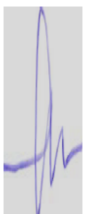
Declaration

I, CHIKONKOLO MWABA the undersigned, declare that this thesis work is my original work, and has not been presented for a degree at University of Rwanda or any other universities. All sources of materials which have been used in this thesis work have been fully acknowledged.



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This thesis has been submitted for examination with my approval, as the supervisor.

Dr. Alexis Muhirwa

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LIST OF ABBREVIATIONS AND ACCRONYMS

AFREA	Africa Renewable Energy Access
CH_4	Methane
CO_2	Carbon Dioxide
CDKN	Climate and Development Knowledge Network
DRC	Democratic Republic of Congo
EA	East Africa
ESMAP	Energy Sector Management Assistance Program
EVs	Electric Vehicles
LHS	Left Hand Side
GHGs	Greenhouse Gases
GoR	Government of Rwanda
IBEC	Irish Business and Employers' Confederation
ICE	Internal Combustion Engines
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
LPG	Liquefied Petroleum Gas
MININFRA	Ministry of Infrastructure
MOI	Means of Implementation
NISR	National Institute of Statistics of Rwanda
NSCCLCD	National Strategy on Climate Change and Low Carbon Development
OECD	Organization for Economic Cooperation and Development

RE	Renewable Energy
RHS	Right hand side
RDB	Rwanda Development Board
REG	Rwanda Energy Group
RRA	Rwanda Revenue Authority
SDGs	Sustainable Development Goals
SSEE	Smith School of Enterprise and Environment
UKDFID-Rwanda	United Kingdom Department for International Development
UNCTAD	United Nations Conference on Trade and Development
UN-DESA	United Nations Department of Economic and Social Affairs
UNEP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
UNGA	United Nations General Assembly
UN-OHRLLS	The United Nations Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States
USAID	United States Agency for International Development

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ABSTRACT

Most countries around the world, including Rwanda, have set a goal of becoming carbon-neutral by 2050. The study within this dissertation report aims at assessing the achievements made so far by Rwanda in transitioning to a low-carbon economy. The applied investigation methodology consists in online survey aiming at assessing the status of Rwanda towards its engagement into carbon reduction scheme. Four indicators of a transition to a low-carbon economy in the energy sector have been selected for investigation, namely; low-carbon energy share of total installed electricity capacity, access to clean energy for cooking, electric vehicles use and clean energy investments. These postulates have been analyzed to check how Rwanda has performed so far towards a carbon-neutral nation by 2050, as to set targets of Rwandan Government in line with Sustainable Development Goals. The study made use of secondary type of data which was obtained from websites of leading global energy research institutions such as the International Renewable Energy Agency and the International Energy Agency as well as from the websites of companies and institutions managing the energy sector of Rwanda such as Rwanda Energy Group and the Ministry of Infrastructure. This data was analyzed using a method known as the before-and-after data analysis method. The levels of each indicator, between the years 2010 and 2020, were analyzed to check if each indicator is increasing or decreasing. The decision criteria was that if we subtract the 2010 level of each indictor from its 2020 level and we get a positive value, then it means that an achievement has been made in that particular indicator; and if we get a negative value it means that no achievements has been made. The results obtained from the analysis of these indicators showed that between 2010 and 2020, Rwanda's energy sector has made achievements in transitioning to a low-carbon economy. None of the selected indicators gave negative a negative value after their analysis. Microsoft excel and Origin Pro 8.0 computer softwares were used to produce graphs, bar charts and pie charts employed to present the trends of the chosen indictors in Rwanda.

Key words: low-carbon economy, low-carbon economy transition, before-and-after data analysis method.

1. INTRODUCTION

1.1 Country Background

The Republic of Rwanda is a sub-Saharan country located in central Africa, just south of the equator. It shares borders with the Democratic Republic of Congo (DRC) at the west, Uganda in the north, Tanzania in the east and Burundi in the south, as shown in Figure 1. Its capital and largest city, Kigali, is located at the centre of the country. The terrain is mostly grassy uplands and hills and the relief is mountainous with a generally declining altitude from the western to the eastern province. The highest point is Mount Karisimbi (4,519 m), the lowest point is the Rusizi River (950 m).

Rwanda is a landlocked nation that covers 10,169 square miles (26,338 square kilometers) of surface area. In addition to such a limited expanse, Rwanda is densely populated. With reference to 2019 census, its population was 12.63 million people with a density of 1242.0 people per square mile (479.5 people per square kilometer) (World Population Review, 2021). This makes Rwanda, one of the densely populated countries in Africa and the world as a whole.

Figure 1: Map of Rwanda (Dekelver, Ruzigana, & Lam, 2005)

1.2 An Outlook on Rwanda's Energy Sector

Despite setbacks such as poverty, small and landlocked expanse with the highest population density in Africa, and beyond all, the unprecedented tragedy on the continent of Genocide against Tutsis; Rwanda has registered incredible changes 27 years ago since that historic rough patch

(USAID, 2021). One of its ambitious intervention areas has been "the energy sector" that usually fuels all efforts to sustainable self-reliance, such as a vibrant industry, infrastructure acquisition, communication, transport etc., and the well-being of citizens, as a whole (Bimeyimana & Li, 2018).

Energy has then been set at the forefront of all development plans central to the Rwanda's economy. Energy supports all sectors, including housing and urbanization, industrial manufacturing and processing, agro-processing, mining, tourism and IT services. As such, Rwanda's energy sector plays a major role in achieving the country's national goals (MININFRA, 2018).

The Rwanda's energy fold comprises three subsectors: electricity, biomass and petroleum. Electricity is getting increasingly used/needed and it is expected to drive the economic growth of Rwanda in few years to come. However, it currently accounts for only 2% of all energy consumed under various forms (MININFRA, 2018). Electricity in Rwanda is sourced from a range of generation technologies and resources namely; hydro, solar, methane gas, oil and peat; where a low proportion is imported from neighboring countries. The national grid is being broadened in coverage and resources so as to increase access to electricity. The rise of off-grid technologies in recent years has been a major innovation and contributing enhanced access. Figure 2 depicts the energy mix conducive to electricity generation in Rwanda, as of 2019 data.

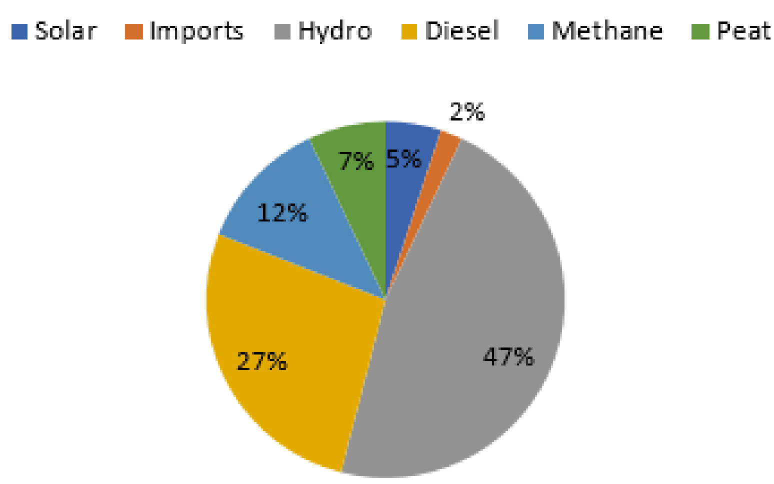

Figure 2: Rwanda's current energy mix (REG, 2019)

Beside these electrical energy resources, the biomass plays a major role in developing countries subsistence mostly in rural areas where half the world's population lives (Moss, 1983) (). This energy subsector covers bio-products and these are fuels derived from biological materials. The latter are divided into wood-based materials such as wood and charcoal, and the biogas obtained from organic waste. The largely exploited energy fuel in Rwanda is Biomass and accounts for 85% of all energy mix (Energypedia, 2020) (MININFRA, 2018). Vastly consumed for cooking, biomass is dominantly used by rural households under wood form whereas urban households prefer the more convenient charcoal form. The biomass subsector in Rwanda is being regulated by the development of the Biomass Energy Strategy in 2018. The latter document analyses the supply and demand of biomass and coins a strategy to progressive reduce the mean reliance on wood and charcoal.

As the fossil fuel of Petroleum and its products such as diesel, kerosene, Liquefied Petroleum Gas (LPG) and natural gas, are not locally unearthed, related services focus on import procurement and storage. About 13% of the country's total energy consumption is from petroleum. Petroleum is used in transport, electricity generation and as LPG in cooking. The use of LPG in cooking is expected to increase significantly as urban households are switching from using firewood. Figure 3 partitions the energy consumption in subsector.

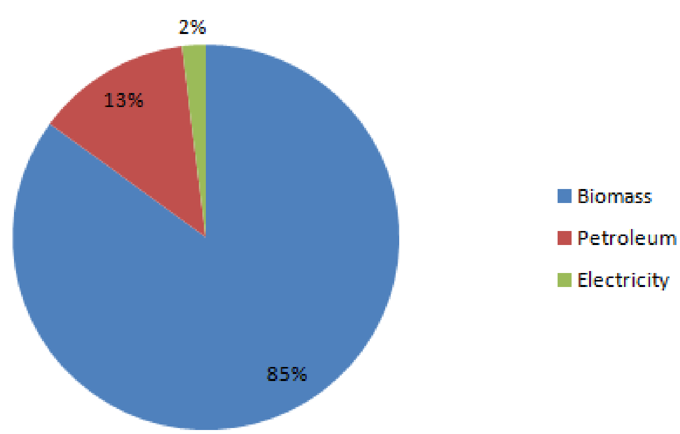

Figure 3: Energy consumption by subsector in Rwanda (MININFRA, 2018)

The mission of the Rwanda energy sector is to create conditions conducive to safe, reliable, efficient, cost-effective and environmentally appropriate energy services to households and to all economic sectors on a sustainable basis (MININFRA, 2015). The management of energy systems involves various ministries and government agencies as well as private entities and individuals. The main parties involved in the energy sector of the country include; the Ministry of Infrastructure (MININFRA), the Ministry of Natural Resources (MINIRENA), the Ministry of

Local Government (MINALOC), the Ministry of Finance and Economic Planning (MINECOFIN), the Ministry of Trade and Industry (MINICOM), Rwanda Energy Group (REG), Rwanda Utilities Regulatory Agency (RURA) and the Independent Power Producers (IPPs) (MININFRA, 2015). MININFRA is responsible for the development of national policies and strategies related to energy generation in the country. The government of Rwanda, through the Ministry of Infrastructure, sees its role in the off-grid energy sector including training, strategy and development of technical specifications for energy equipment and recommendation of strategies for the development of the private sector. Regulation of the energy sector is done by the Rwanda Utilities Regulatory Agency (RURA). Rwanda Energy Group is a government-owned company established in 2014. It carries out operations by two subsidiaries, the Energy Development Corporation Limited (EDCL) and the Energy Utility Corporation Limited (EUCL). EDCL supports new capacity and transmission development both by itself and with Independent Power Producers (IPPs), while EUCL provides energy utility services in the country through operation and maintenance of existing generation plants, transmission and distribution network and retail of electricity to end-users (Eustache, Sandoval, & Venant, 2019). The utility also play a key role in the execution of Power Purchase/Power Sales Agreements with IPPs and other regional utilities for import and export. The aim is to make the whole electricity transmission and distribution process as safe, efficient and reliable as possible.

1.2 Statement of the Problem

The threats posed by climate change have made countries, both developed and developing countries, to have an urgent need to curb their greenhouse gas emissions by transitioning to a low-carbon economy. In 2015, this urgent need has led to a worldwide convention, known as “Paris Agreement”, endorsed by 192 parties (191 countries + EU). It is therefore important that the path to a low-carbon economy for these counties are closely monitored and evaluated regularly to assess the adherence level to their commitments to progressive curb greenhouse gas emissions.

1.3 Objectives of the Study

1.3.1 Main objective

The main objective of this research was to single out major achievements that Rwanda’s energy sector has made in transitioning to a low-carbon economy, using four selected indicators of a transition to a low-carbon economy in the energy sector: Share of low-carbon (renewable) power in total installed electricity capacity, Access to clean cooking energy, electric vehicles use and, Investments in renewable energy. The research had a purpose of finding out areas in which the energy sector of Rwanda is accordingly performing well and provides recommendations for areas found to be facing shortfalls to reach the global targets.

1.3.2 Specific objectives

To achieve the main objective, the following specific objectives are presented and they have been evaluated with a 10years time spell (2010 – 2020):

1. Assess the change in low-carbon energy share of total installed electricity capacity.
2. Assess the change in peoples' access to clean energy for cooking in Rwanda.
3. Benchmarking the Rwanda energy sector achievement in terms of low-carbon energy share and access to clean energy for cooking with respect to neighboring East Africa countries.
4. Find out what has been the change in the use of electric vehicles in Rwanda.
5. Asses the trend of investments in clean energy in Rwanda.

1.4 Scope and Limitations of the Study

The transition to a low-carbon economy for a country or region involves most, if not all, sectors of the economy such as agriculture, mining, transport, energy, waste, manufacturing and construction sector, among others. Pollutant gas emissions evolve from many aspects, typically the some refrigerants vaporization, heat-based industrial processes, fertilizers, municipal and animal waste etc. This study narrows down that lengthy list to industrial processes with a focus to the energy sector. As such a study can be differently carried out worldwide with diversified outcomes; the present investigation has chosen the study case of the republic of the Rwandan, as a stand-alone entity with its specific policies and enforcement strategies. Furthermore, many indicative factors can be used to assess a country's whereabouts along the transition pathway towards a low carbon economy. A crosscutting indicator for all sectors is the level of carbon emissions. However, this study applies four energy-based indicators to evaluate the transition process to a low-carbon economy; low-carbon (renewable) energy share over total installed electricity capacity, access to clean cooking energy, e-Mobility use and clean energy investments. By means of these four indicators, past and current trends within a time frame of ten years (2010-2020) are investigated in Rwanda.

1.5 Significance of the Study.

This research serves as a useful model in evaluating the paths to achieving low-carbon economies, especially in their energy sectors, for Paris Agreement signatory nations. The study typically provides information about the progress made by Rwanda's energy sector in the four selected indicators pertinent to a low-carbon economy transition. Another part of this research will fill part of the knowledge gap or information search tool on the importance of a transition to a low-carbon economy.

1.6 Research Questions.

The central and main question of this thesis focuses on Rwanda's energy sector transition to a low-carbon economy by 2050, which is in line with the Rwanda National Strategy on Climate Change and Low Carbon Development. Thus the main question is; what has been the achievements made so far by Rwanda's energy sector in transitioning to a low Carbon economy? A few sub questions, based on the indicators of a transition to a low-carbon economy that has been chosen for this study, were deducted from the main question. These sub questions are:

1. By what percentage has low carbon energy share of total installed electricity capacity increased in Rwanda from 2011 to 2020?
2. By what percentage has access to clean energy for cooking in Rwanda increased from 2010 to 2020?
3. What has been the increase of the use of electric vehicles in Rwanda from 2010 to 2020?
4. What has been the trend of investments in clean energy in Rwanda from 2010 to 2020?

2. LITERATURE REVIEW

2.1 Low-carbon economy Transition

A low-carbon economy is defined as way of thinking, behaving and operating that minimizes carbon emissions while enabling sustainable use of resources, economic growth and quality of life improvements. A low-carbon economy is an economy that uses power primarily obtained from less carbon-intensive energy sources such as solar, wind and hydro electric power (DBSA, 2021). The "low-carbon economy" refers to the green ecological economy based on low energy consumption and low pollution. The term low-carbon economy was first published in a white paper for the British Department for Trade and Industry, titled, "Our energy future-creating a low-carbon economy", in 2003. Former British Prime Minister Tony Blair, at the Davos World Economic Forum, called for countries around the world to establish modes of production and consumption patterns corresponding to the low-carbon economy, and to develop products and engineering technology with low CO_2 emissions over the whole process of production, use, waste as well as the technological development of CO_2 capture, recycling and geological disposal. At the same time, Blair called for them to set up domestic and international policies, a legal system and the market mechanisms to encourage low-carbon economy development (Wang, 2017).

A low-carbon economy has a focus on both economic and environmental issues and represents a major economic and social transformation (Baranova & Lynch, 2017). Transitioning to a low carbon economy mean growing the economy in an environmentally sustainable way. This involves promoting growth and development while reducing pollution and greenhouse gas emissions, minimizing waste and inefficient use of natural resources, maintaining biodiversity, and strengthening energy security (IBEC, 2018). The pathway to a low-carbon economy begins with a decreased reliance on fossil fuels, reducing, and ultimately eliminating carbon from the burning and production of these energy sources (Sugarman & McDougall, 2021). Such change will help lessen the impact of climate change and global warming on the environment, and definitely, on the wider population.

2.2 Climate Change and the need to Transition to a Low Carbon Economy

Climate change is not about changes in the weather in some distant future. It is already with us. People in different parts of the world are experiencing more extreme weather such as droughts and floods, uncertain rainfall and rising sea levels. These climate changes are a threat to health, jobs, livelihoods, and in the end, our survival on the planet (COSATU, 2017). Climate change is caused by our present system of production, distribution and consumption; a system which is both unjust and unsustainable. It is an urgent need to change the means by which energy is harnessed, the way of working and that of producing goods and provide services. It is vital to create a low-carbon economy in order to preserve our planet for future generations and reduce the impact of climate change water, food, livelihoods and other necessities (COSATU, 2017).

In the 2015 Paris Agreement on Climate Change, countries around the world agreed to keep global warming well below 2 degree Celsius above pre-industrial levels, while pursuing efforts to limit the temperature increase to 1.5 degree Celsius (UN, 2015). To limit global warming, GHG emissions from a variety of sources, such as transportation, energy production and industrial processes need to be dramatically reduced. The bulk of GHGs consists of carbon dioxide (CO_2) and methane (CH_4). Carbon dioxide enters the atmosphere through the burning of fossil fuels and natural materials. Methane is predominantly emitted during the production of natural gas and oil, and it is also a by-product of livestock and organic waste. The shift to renewable in place of oil and gas in the context of the low carbon transition will dramatically decrease carbon dioxide emissions and eliminate methane by-products that are flared and leaked across the value chain (Sugarman & McDougall, 2021).

2.3 Benefits of a low-carbon economy

The move to a low-carbon economy is a significant transition, on par with other major transitions in human socio-economic history. If it can be carried out, as most experts have insisted it can, it will differ from previous waves of change in that it is at least in part intentional, and in that it pays more careful attention to the welfare of those that might otherwise be caught in the painful process of unplanned structure change (UN-DESA, UNCTAD, & UNEP, 2011). The low-carbon economy is more than just environmental in scope; it is also about development and the economy. From a development perspective, there are a number of ways in which a low-carbon economy might benefit both developed and developing countries. A low-carbon economy can not only maintain, but can also enhance the value that the poor in developing countries derive from agriculture, fisheries and forest harvest and all activities that depend fundamentally on a sound environment. It can help reduce energy poverty through the provision of low-cost distributed renewable energy systems. And if successful, it can help reduce the vulnerability of the poor to the impacts of unchecked climate change, desertification, ocean degradation and loss of biodiversity as well as the impacts of local air, soil and water pollution. In developed and developing countries alike, a low-carbon economy can spur new innovative activities, activities which create more jobs than traditional sectors, increases energy security and industrial efficiencies. Bringing clean energy to the rural poor is one of the most important contributions that a low-carbon economy can make to developing countries (UNEP, UNCTAD, & UN-OHRLLS, 2011). The notion of low-carbon economy has provided growing investment opportunities in buildings, transport, and energy and waste sectors as well as in manufacturing, agriculture among others.

A low-carbon economy also has environmental benefits, and these are obvious enough to need no length explanations. It can help address global challenges such as climate change, loss of biodiversity and desertification. It can also contribute to national and regional level efforts to address local pollution of air, water and soil (OECD, 2015). A shift to a low-carbon economy can also generate economic benefits. One of such economic benefits is the opening up of new markets, such as new markets for bio fuels, and for renewable energy technologies such as solar panels and wind turbines (UN-DESA, UNCTAD, & UNEP, 2011). Opportunities in these markets may be driven by demand in the export markets alone or by a combination of foreign demand and domestic capacity development in response to stringent domestic environmental standards. The benefits of a low-carbon economy are clear, from improving air quality and human health to reducing the future risks of climate change, creating jobs and economic opportunities. There are innumerable benefits to cutting down on carbon.

2.4 International support for low-carbon economies as a tool in fighting climate change

The need for a global transition to a low-carbon economy has gained a lot of attention in recent years following the adoption of the Paris Agreement in 2015 whose main aim is to reduce greenhouse gas emissions, thus necessitating a shift from fossil fuels to renewable energy sources (Nalule, 2020). In September 2015, the United Nations General Assembly adopted a resolution (Resolution 70) that set out a global agenda of transforming the world towards sustainable development (UNGA, 2015). The resolution set out 17 global Sustainable Development Goals (SDGs) and 169 targets that were to underpin this transformation agenda. Goal number 13 focused on climate change, with the objective to take urgent actions to combat climate change and its impacts.

Similarly the adoption of the Paris Agreement on Climate Change, in December 2015, also marked a major milestone in international efforts to mobilize actions towards responding to climate change. There is broad consensus that responding to climate change would require the development of a global economy that is based on a low-emissions pathway (Makomere, 2020). The entry highlights the dynamic and broad variety of climate actions across diverse regions, actors, institutions, and levels of governance and the linkages to the development of low-carbon economies. Climate action has evolved over the years both in definition and scope. Initial focus was on reducing and stabilizing human-induced GHG emissions in the atmosphere. It has been expanded to include other elements such as adaptation to climate change, loss and damage, and support for Means of Implementation (MOI) through capacity building, climate finance, and technology development and transfer. Additionally, the scope of climate actors has also broadened over the time, from primary focus on states and other parties to the UNFCCC and related agreements to non-state actors such as cities, private sector, civil society and multilateral development institutions among others.

2.5 Rwanda's Strategy to Transition to a Low-carbon economy

In 2011, the government of Rwanda developed the National Strategy on Climate Change and Low Carbon Development (NSCCLCD) as a collaborative effort between the Government of Rwanda, the Smith School of Enterprise an Environment (SSEE) at the University of Oxford, and the donor institutes; UKDFID-Rwanda and the Climate and Development Knowledge Network (CDKN) (GoR, 2011).

The purpose of the NSCCLCD is to:

1. Guide national policy and planning in an integrated way;
2. Mainstream climate change into all sectors of the economy; and
3. Position Rwanda to access international funding to achieve low-carbon climate resilient development

By building on and bringing together existing strategies related to climate change and development, the NSCCLCD provides a framework for a holistic approach to Rwanda's socio-economic development by integrating Rwanda's traditional development agenda with Rwanda's climate change adaptation and mitigation needs. By acknowledging that successful adaptation to climate change is critical to Rwanda's ability to maintain and enhance its economic growth and social progress, the government of Rwanda is trying to leapfrog old technologies and ineffective development pathways by taking a low-carbon path to development and building a low carbon economy (Nash & Ngabitsinze, 2014) The vision outlined in the NSCCLCD looked beyond 'Rwanda vision 2020' to 2050, by which time it is hoped that Rwanda will be a developed low-carbon climate resilient economy. Three strategic objectives are outlined under the vision 2050, though this study has major interest on the first strategic objective:

1. To achieve energy security and a low-carbon energy supply that supports the development of green industry and services and avoids deforestation.
2. To achieve sustainable land use and water resource management that results in food security and, appropriate urban development and preservation of biodiversity and ecosystem services; and
3. To ensure social protection, improved health and disaster risk reduction that reduces vulnerability to climate change impacts.

2.6 Indicators of a Transition to a Low-carbon Economy

This section gives a literature review on the selected indicators of a transition to a low carbon economy. The section describes these indicators and also explains the roles which they play in reducing carbon emissions which is the main factor behind the need to transition to a low carbon economy.

2.6.1 Low-carbon (renewable) energy share of electricity installed capacity.

Low-carbon power is electricity produced with relatively lower GHG emissions than conventional fossil fuels. Low carbon power generation sources include wind power, solar power, nuclear power and mostly hydro power. These are mostly renewable. The term" low-carbon power" largely excludes conventional fossil fuel plant sources, and is only used to specifically those that are successfully coupled with a flue gas carbon capture and storage (CCS) systems. Globally almost 40% of electricity generation came from low carbon sources in 2020 (Wikipedia, 2021). Producing power from low carbon sources offers substantial reductions in GHG and other pollutant emissions. The capture and storage of carbon dioxide from fossil fuel based power plants offers also substantial reduction in GHG emissions, but without the benefits of reducing other types of pollution such as pollutions causing eutrophication and acidification (UNEP, 2018). Renewable energy also reduces dependence on finite resources of fossil fuels. Having a bigger share of low-carbon power in the national or regional power grid mean that most of the power in the grid has been generated from renewable energy sources. This is important for combating climate change. Low carbon or renewable energy share in the national grid is an important indicator of a transition to a low-carbon economy.

We have entered a decade of renewable energy. Global renewable energy capacity additions in 2020 reflect unprecedented momentum for the energy transition. Despite the COVID-19 induced economic slowdown, the world added more than 260 gig watts (GW) of renewable energy in 2020, exceeding expansion in 2019 by close to 50%. Furthermore, around 80% of new electricity capacity was renewable, showing that it is increasingly the preferred source of new power generation globally. Solar and wind in particular have shown remarkable growth, with 127 GW and 111 GW of new installations in 2020, respectively. Together, they make up more than 50% of total installed renewable capacity (IRENA, 2021). Table 1 shows the trends of percentage share of low-carbon (renewable) energy in total installed electricity capacity in the world and Africa.

Table 1: Renewable energy share of total installed electricity capacity in the World and Africa from 2011-2020 (IRENA, 2021)

%	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
World	25.1	26.1	27.2	28.2	29.5	30.8	32.1	33.2	34.6	36.6
Africa	18.7	18.8	19.1	19.6	20.2	20.1	21.1	21.6	21.7	22.3

Looking at Figure 4 and Table 1, it can be noted that the percentage of renewable energy share in total installed electricity capacity globally has been increasing. However, in Africa the RE has been a bit stagnant. Some measures have to be taken to adapt to the worldwide move of reducing the carbon emission aired from the energy sector.

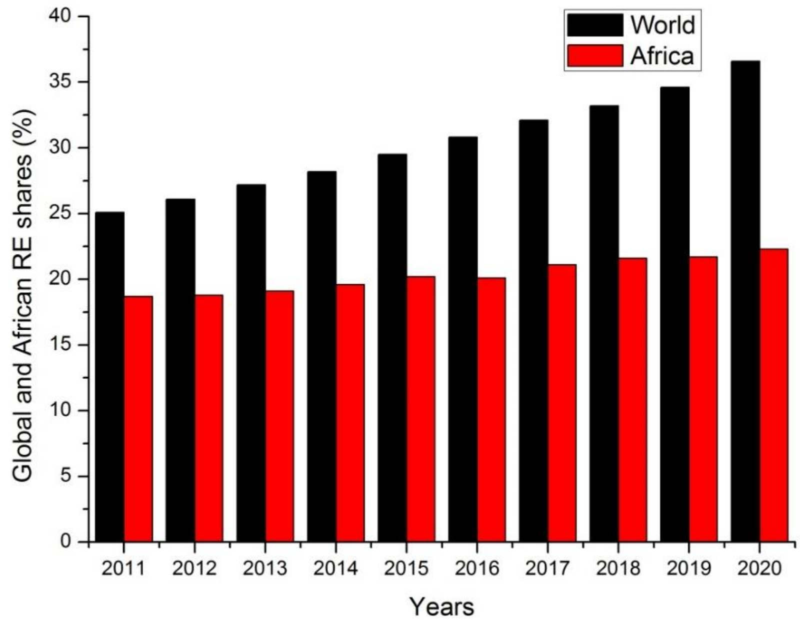

Figure 4 : Renewable energy share, Africa versus the world

2.6.2 Access to clean cooking energy

Cooking is a fundamental part of life. It is an activity that brings families together and has cultural and social significance around the world. But in most developing countries, solid fuels like firewood, charcoal and coal are often used in traditional stoves for cooking. The use of such polluting fuels and technologies results in household air pollution, causing respiratory illness, heart problems and even death. In fact indoor air pollution causes more than 4 million premature deaths every year, 50 percent of which are children under the age of 5 years (World Bank, 2019). Women and children are affected most by household air pollution due to the levels of exposure in that they often spend a significant part of their day cooking and collecting the fuel, for instance firewood, needed to cook a meal. Residential solid fuel burning accounts for up to 58 percent of global black carbon and approximately 2 percent of global carbon dioxide emissions per year. These facts make the use of solid fuels for cooking one of the major contributors of global warming.

Universal access to clean and modern cooking fuels and technology is an integral element of ensuring that the broader aims of SDG 7 (universal access to modern energy services) are achieved by 2030. Cooking solutions also advance other SDGs, including good health and well-being, gender equality, climate actions, and eliminating poverty. Despite many decades of efforts, access to clean cooking energy and technologies has continued to be an issue with severe health, gender, economic, environmental and climate impacts. Nearly 3 billion people globally do not have access to modern cooking services, which is more than the combined population of China and India. The lack of access to clean cooking remains very acute in Sub-Saharan Africa with access increasing only slightly from 15% in 2015 to 17% in 2017 (IEA, 2020). Since 2015, only 25 million people have gained access to clean cooking in the region, meaning that the number of people without access to clean cooking increased to around 900 million in 2018 as population growth outpaced provision efforts. Sub-Saharan Africa is the only region where the number of those without access continues to rise significantly due to continued population growth. However, overall the percentage of people with access to clean energy for cooking in Sub-Saharan Africa has been increasing over the years as shown in Table 2.

Table 2: Proportion of the people with access to clean cooking in Sub-Saharan Africa from 2000 to 2018 (IEA, 2019)

	Proportion of the people with access to clean cooking				
	2000	2005	2010	2015	2018
Sub-Saharan Africa	10%	11%	13%	15%	17%

The vast majority of people in Sub-Saharan Africa thus rely on gathering biomass for cooking, particularly in rural areas, which dramatically damages health and impairs productivity improvements. Almost 490,000 premature deaths per year are related to household air pollution from the lack of access to clean cooking facilities, with women and children the worst affected. Forest degradation, sometimes leading to deforestation, is another serious consequence of the unsustainable harvesting of fuel wood (IEA, 2020).

The covid-19 pandemic and its effects now threaten to reverse the already insufficient progress that has been observed in recent years. Shifting government priorities, supply-chain disruptions and social distancing measures have slowed access programs and hindered activities in the decentralized energy access area. Above all, as a direct consequence of the increased poverty induced by the crisis, many households in rural or peri-urban areas could backslide to the use of charcoal, kerosene or fuel wood (IEA, 2020). Clean cooking must be a political, economic and environmental priority supported by policies and backed by investments and multi-sector participation. In order to make that kind of change, the level of commitment and the scale of investment matter (World Bank, 2019).

2.6.3 Electric Vehicles

Globally, road transportation constitutes about one-quarter of total greenhouse gas (GHG) emissions, second only to emissions resulting from electricity and heat generation. Road transportation also remains a major source of outdoor air pollution, through exposure to particulate matter that contributed to 4.1 million deaths from heart diseases, stroke, lung cancer, chronic lung diseases, and respiratory infections in 2016 (Bonsu, 2020). The level of the use of electric vehicles in a region or country is an important indicator of a transition to a low-carbon economy, in the sense that using electric vehicles reduces GHG emission which is a major component of internal combustion engines. Such environmental and health impacts from road transportation, have resulted in many international policy frameworks such as the Paris Declaration on Electro-mobility and Climate Change, encouraging nationally determined contributions towards low-carbon economies via sustainable transport electrification to levels compatible with less than 2-degree Celsius pathway. Electric Vehicles (EV) are gaining popularity among both governments and the private sector globally. This is being driven by worsening health effects of urban air pollution, international commitments to cut GHG emissions, the need to reduce dependency on oil imports, and a corresponding drive to tap the benefits of EV technology (Bower, 2020).

Over the past century, people have become more dependent on cars. The automobile is an icon of success. It is the second biggest single expenditure made by families after purchase of a house. It connects people to work, schools, shopping and recreation. The automobile is also a symbol of innovation and personal aspiration. People love cars. Expecting people to give up their cars or their dreams of owning cars is a dubious suggestion. Therefore, given the unlikelihood of private car ownership decreasing any time soon, many have concluded that we need to find a substitute for the internal combustion engine (ICE) vehicle, which is a prime source of air pollution (with its cardiovascular, pulmonary and respiratory consequences) and greenhouse gas (GHG) emissions. The electric vehicle (EV) is the heir apparent of ICE vehicles. It is the dominant form of personal and public transportation in the future.

EVs can be categorized into three types as shown in the Table 3. Hybrid Electric Vehicles (HEV) gets their propulsion energy from both liquid fuels and a battery. Plug-in Hybrid Electric Vehicles (PHEVs) are capable of recharging from an external power source, usually the grid. Battery Electric Vehicles (BEVs) draw their energy for propulsion from a battery.

Table 3: Types of Electric Vehicles (Scott, 2016)

Type of vehicle	Type of propulsion energy and emissions	Technology readiness	Infrastructure requirements
Hybrid electric vehicle (HEV)	- Propulsion energy from both consumable fuels and battery. - Battery recharged by regenerative braking and through internal combustion engine.	- Numerous car models in the market today.	- HEVs are compatible with existing refueling infrastructure.
Plug-in hybrid electric vehicle (PHEV)	- An HEV with a means of recharging its battery from an external power source. - Pollution benefits depend on driving cycles and on energy resources used to generate electricity.	- Several models on the market; recharging equipment needs to be cheaper.	- PHEVs are compatible with existing grids in most industrialized countries

Battery electric vehicle (BEV)	- Propulsion energy drawn entirely from battery. - No tailpipe emissions, but total pollution benefits depend on energy resources used to generate electricity.	- Battery improvements needed to extend driving ranges and shorten recharging time; battery costs must be cut.	- Substantial market penetration could exacerbate peak demand, requiring new power plant or solar PV investment, especially if smart grid technologies and pricing policies are not able to concentrate recharging into off-peak periods.

2.6.3.1 Importance of Electric Vehicles

Advocates of the electric car typically advance four arguments in favor of EVs: (1) lower pollution and GHG emissions, (2) enhancement to national energy security, (3) a symbiotic relationship with the electricity grid, and (4) the rapid pace of technical improvements (Benjamin K. Sovacool; Marilyn A. Brown and Scott V. Valentine, 2016).

(i) EVs Offer Pollution and Carbon Benefits

Electric vehicles can reduce or eliminate tailpipe pollution and curtail GHG emissions, but the extent of the gains depends on the type of EV and the carbon intensity of the electricity used to recharge the batteries. PHEVs have greatly reduced tailpipe emissions, while BEVs emit no tailpipe pollution. Grid-supported PHEVs and BEVs can drastically (and directly) mitigate GHG emissions and improve air quality in urban areas.

EVs could play a major role in supporting electricity industry reforms. As technology evolves, PHEVs and BEVs will be able to provide storage support for intermittent renewable energy generators, allowing reduce carbon dioxide emissions and air pollution in the electricity sector. In a vehicle-to-grid configuration, the batteries in the vehicles could store surplus electricity produced by renewable energy technologies such as wind turbines and solar photovoltaic and then provide power back to the grid when needed. Integrated systems of this type can offset the need for additional generation capacity or storage, allowing intermittent renewable energy resources to integrate more effectively into the grid.

(ii) EV penetration can enhance energy security

Advocates of EVs are quick to highlight the role these vehicles can play in reducing national dependence on oil, a dependence that has been acknowledged as detrimental to national security in many industrialized nations. This is due to the fact that most oil exporting countries are politically unstable, for example Middle Eastern countries. There are at least two obvious reasons that dependence on unstable nations for oil undermines national security. Firstly, the supply of oil can be interrupted during times of political upheaval, and oil-dependent nations face the risk of oil price inflation due to events beyond their realm of control. As a result, oil-dependent nations are incentivized to meddle in the affairs of oil-rich nations in attempts to preserve the status quo. A second way in which oil dependence undermines national security relates to the link between terrorism and oil revenues. In 2007 alone, OPEC (Organization of Petroleum Exporting Countries) income amounted to $535 billion, funneled into the coffers of a small number of powerful sheiks and barons. Some of these individuals allegedly tap into these revenues for supporting terrorism. For example, the wealth of Osama Bin Laden’s family came from government construction contracts that were financed by oil money (Friedman, 2008).

In the long term, reducing oil imports through greater EV penetration also promises a host of additional economic benefits. The most significant of these include a rise in domestic value-added economic activity due to the minimization of wealth transfer from oil consumers to producers and a reduced risk of economic disruption caused by wars, hurricanes, political unrest, or accidents that inflate oil price.

(iii) EVs can save Money and Improve Electricity Reliability

EV advocates also claim that consumers will profit from the use of EVs because electricity is cheaper than gasoline for equivalent distances traveled. At 2014 petrol prices, for instance, the annual fuel cost of driving a conventional ICE car in the United Kingdom was about £1,440 ($2,390) for driving an average of 12,000 miles. The cost for running an EV for the same period of time over the same distances was as low as £240 ($400). Although infrastructure is not yet comprehensive enough to provide adequate charging services for people in all areas, most homes in industrialized countries already have the requirement to charge vehicles in at least one key locale: electrical outlet in the home or garage.

Even though current electric utility technologies lack the asynchronous capacities to support smart grids, there are still useful synergies to be harnessed. One synergy stems from the fact that many electricity generators and electricity grids operate in a suboptimal fashion because systems have a great deal of slack capacity to deal with demand peaks and troughs. Particularly, in many countries, extreme over capacity occurs in the late evenings and at night, when most people are sleeping. Fortunately, recharging of EV batteries typically commences when people return home in the evening and can continue throughout the night. The result would be a system that could generate and deliver a substantial amount of energy to fuel the nation's vehicles at a very low cost.

Perhaps more exciting to EV advocates, is the use of cars as suppliers of power to the grid, especially during times of peak demand, which offers a fantastic opportunity to earn revenue and offset transportation costs. In a future supported by smart grid technology, EVs could be used as distributed storage devices, feeding electricity stored in EV batteries back into the grid (a process known as "vehicle-to-grid", or V2G). This could reduce electricity costs by providing affordable regulation of power flows, dampening peak power demands, and providing added reserve capacity without having to invest in power generation equipment.

(iv) EV Technology is Advancing Rapidly

A key criticism has been that technological advances are required before they can become a practical option. Advocates of the EVs argue that this is an increasingly unfounded criticism. In 2007, even the most advanced BEVs had limited charge ranges of about 100 to 160 kilometers, long recharge times of four or more hours, and high battery costs leading to comparatively high vehicle retail prices. A mere seven years later, the 2014 Tesla Model S came equipped with a battery supercharger that can provide 274 kilometers (170 miles) of ranges in as little as 30 minutes of recharging. Most travel times and distances are relatively short, which suggests that for most commuters the current technology should suffice. Given that about 60% of the vehicles travel less than 48 kilometers (30 miles) per day, EV technology is not far from being able to effectively service the travel needs of most motorists. All the while, research and development continues to improve EV performance and to make possible the integration of BEVs with other energy systems. As advocates of the EV would conclude, stay tuned for more exciting developments.

2.6.3.2 Global Electric Vehicles Use

The use of electric vehicles globally has taken a huge leap forward in the past decade. For example, looking at Figure 5, the number of electric vehicles globally increased from just about 450,000 in 2013 to 7,200,000 electric vehicles in 2019. The European Union, China and the United states have the highest share of global electric vehicles fleet (Sikora, 2020) But even though we have seen some incredible growth in the number of EVs worldwide, industry prediction would suggest that we have only scratched the surface.

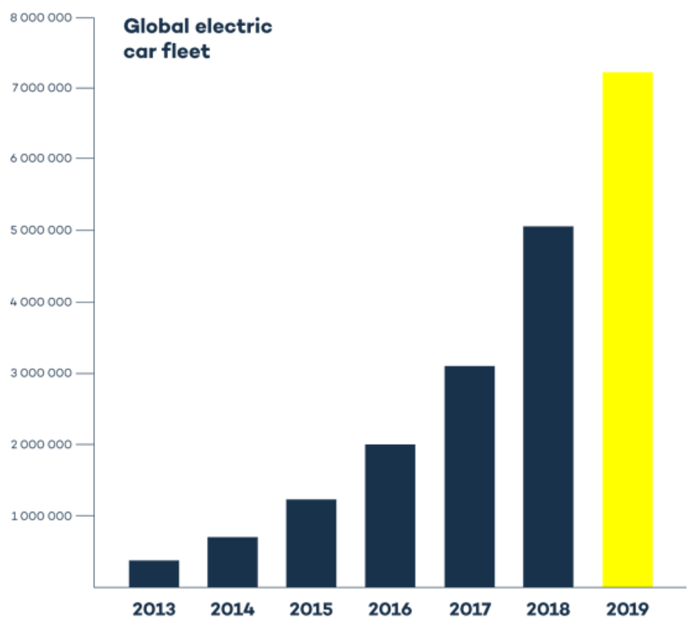

Figure 5: Global electric car fleet (Sikora, 2020)

The EVs market's collective achievements in recent years offer hope, despite the short-term impact of COVID- 19: a pattern of continued growth, which is expected to be sustained throughout the 2020s. As EVs sales surpassed 2 million vehicles in 2019, EVs staked their claim on a 2.5 percent share of all new cars sales in 2019 (Sikora, 2020).

According to the Global EV outlook 2020, the sales of electric cars reached 2.1 million globally in 2019, surpassing 2018, to boost the stock to 7.2 million EVs. In absolute terms, China remained the world's largest EV market, with 2.3 million electric vehicles in active use. To put that into perspective, that's nearly half (45%) of the global stock of EVs. Europe and the US are relatively far behind with 1.2 and 1.1 million EVs respectively. But in relative terms, the situation in Europe is looking a lot more positive. While only 5.2% of China's vehicles are electric, Norway had 56%

of its vehicles running on electricity in 2019, Iceland and Netherlands have reached 25.5% and 15% EV penetration respectively (Virta, 2021). The future of transportation appears to be electric. More and more people across the globe are opting for electric vehicles and the industry is undeniably on a positive trajectory. According to the International Energy Agency, the number of electric cars, trucks, vans and buses on the world's roads is on course to increase from 11 million to 145 million by the end of the decade (Odhiambo, 2021). This growth is being driven by the technological advancements in charging systems and battery ranges, as well as policies being adopted by governments to divest from fossil fuels and address the climate crisis. The substantial investments automobile giants are making to go electric are further signs that electric vehicles are the future.

The African continent is also part of this growing electric-powered transport wave. Several African countries such as Kenya and Rwanda have adopted tax incentives to encourage electric vehicles imports and are working on developing their own electric two and three-wheelers. In many African countries, minibuses are the main mode of public transport, complemented by motor-cycles. It is estimated that some 90% of urban air pollution in developing countries is attributed to vehicle emissions. Furthermore, emissions from transport-related sources are a major cause of chronic respiratory-related illnesses and premature deaths in Africa. Thus, the efforts to increase the use of electric vehicles are welcome strategy to decarbonizes transportation and improve air quality in African urban centers.

As demand for electric vehicles grows, African countries such as the Democratic Republic of Congo (DRC), Zimbabwe, Zambia, Namibia and South Africa will be supplying the raw materials used in their production such as lithium, copper and cobalt. To benefit from the global move towards electric-powered transport, Africa should ensure that it is in control of its own electric vehicles agenda. Commendably, there are already initiatives across Africa aiming to localize vehicle electrification. In Uganda, Kiira Motors has launched locally manufactured electric buses. In Kenya, the National Youth Service has supported the development of an electric three-wheeler prototype, and there are ongoing electric bus pilot schemes in Cairo, Addis Ababa and Nairobi. Such initiatives should and are being encouraged as they will go a long way in helping Africa build on electric vehicle agenda that is considerate of local realities and challenges.

2.6.4 Renewable energy investments

A big investment in clean energy, clean transportation, energy efficiency deployment and research and development (R&D) can generate substantial returns on job growth and emissions reductions. Boosting these areas now can be a crucial step toward building a 100% clean economy over the next 30 years, a science-based goal that calls for allowing no more climate pollution produced than can be removed from the atmosphere across all sectors of the economy (Capanna, 2020). Achieving SDG7 and meeting the goals of the Paris Agreement requires sound domestic policies and regulations to scale up public finance and mobilize private sector investment.

Ambitious national targets and strengthening and adopting policies to evolving market conditions have historically led to progress on sustainable energy outcomes (SE4ALL, 2020). Mobilizing investments and innovations in low-carbon technologies, especially in renewable energy generation, is central to keeping the global average surface temperature increase well below 2°C. Successfully attracting investment and innovation in renewable energy requires not only core climate policies, such as pricing carbon, but a focus on the broader investment environment (Rottgers, 2017).

The well below 2°C goal of the Paris Agreement implies a 29% increase in total investment volumes in low-carbon energy infrastructure in the next 15 years. Steep decrease in the cost of some critical renewable energy technologies suggests that investors could profitably cater for investment needs in this sector. Thanks to technology innovation, the capital cost of utility-scale solar photovoltaic fell by 20% in 2016 alone. That of onshore wind has decreased by 20% since 2010. Yet, investments in renewable energy in the power sector are not scaling up fast enough to keep the well below 2°C goal within reach.

New research shows that misalignment in policies and electricity markets as well as cumbersome and unpredictable investment conditions are among the main factors holding back investment and innovation in renewable energy in advanced and emerging countries. For example, while public tenders generally attract renewable energy investments, they are less effective when independent power producers are forced to compete against a mostly state-controlled incumbent. In addition, research, development and deployment (RD&D) expenditures have played an important role in stimulating patenting in renewable energy technologies in the past. However, this innovation may soon taper off unless governments take action to increase spending in RD&D for low-carbon technologies, which is at historically low levels.

2.6.4.1 Global Renewable Energy Investment

It is nothing new to say that clean energy is better for the planet, than energy derived from fossil fuels. Its benefits in avoiding greenhouse gas emissions, delivering cleaner air and bringing energy to marginalized communities are essential to a better future for all. What is new is that the world has a unique opportunity to accelerate clean development by putting renewable energy at the heart of covid-19 economic recovery plans (UNEP & Bloomberg, 2020). Governments will inject huge amounts of money into their economies as they look to bounce back from covid-19 lockdowns, which have saved lives but stopped growth and cost jobs.

A new report published by a collaboration between UNEP and Bloomberg (UNEP & Bloomberg, 2020), shows that putting these money into renewable may help governments to deliver stronger climate actions under the Paris Agreement. The report shows that renewable energy capacity, excluding large hydro, grew by a record 184 gig watts (GW) in 2019. This was 20 GW or 12% more than new capacity added in 2018. Yet the 2019 dollar investment was only 1% higher, at 282.2 billion. Meanwhile, the cost of electricity continues to fall for wind and solar, thanks to technology improvements, economies of scale and fierce competition in auctions. Costs for electricity from new solar photovoltaic plants in the second half of 2019 were 83% lower than a decade earlier. This is great progress, but there is room to do much more. Nations and corporations have made clean energy commitments over the next decade. The report finds commitments for 826 GW of new non-hydro renewable energy capacity by 2030, at a likely cost of around 1 trillion USD.

However, these commitments fall far short of what is needed to limit the rise in global temperatures to less than 20 C under the Paris Agreement. It also falls short of last decade's achievements which brought around 1,200 GW of new capacity for 2.7 trillion USD. If governments take advantage of the ever-falling price tag of renewable to put clean energy at the heart of covid-19 economic recovery, instead of subsidizing the recovery of fossil fuel industries, they can take a big step towards clean energy and a healthy natural world, which is the best insurance policy against global pandemics. Table 4 shows global renewable energy investment in billion US dollars from the year 2004 to 2020.

Table 4: Global Renewable Energy Investment (2004-2020) (UNEP & Bloomberg, 2020)

Year	Amount (Billion USD)
2004	40.1
2005	60.4
2006	88.2
2007	120.2
2008	155.7
2009	146.5
2010	213.0
2011	264.7
2012	239.1
2013	211.7
2014	265.1
2015	300.3
2016	280.0
2017	315.1
2018	280.2
2019	282.2
2020	303.5

Looking at table 4 and Figure 6, one can observe that the amount of money being invested in renewable energy globally has been increasing for the past two decades, for instance, total global investment increased from USD 40.1 billion in 2004 to USD 265.1 billion in 2014, and to USD 303.5 billion in 2020. This is an important indication of how serious world governments are handling the global need to transition to low-carbon economies. China, the European Union and the United states of America holds a larger share of the global investments in renewable energy (Dailey, 2017).

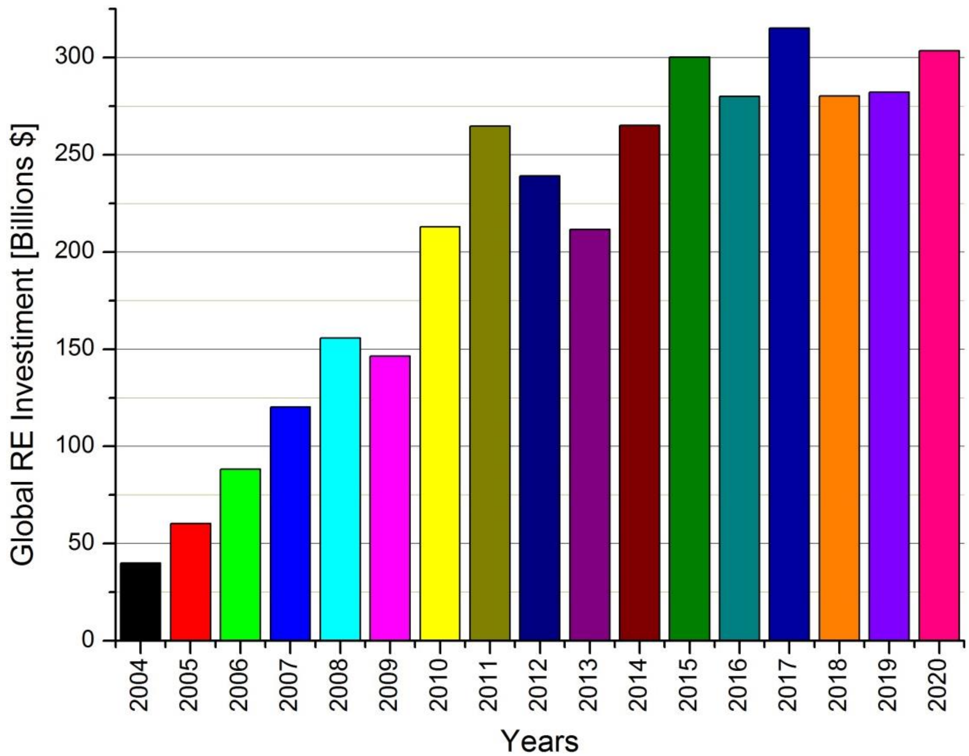

Figure 6: 15 years-long records on the Global investment in RE development

3. METHODOLOGY

3.1 Data Collection Method.

The data which was utilized in this study is secondary type of data. Therefore, data on the current and past levels of the indicators of a transition to a low-carbon economy which was used in this study, namely; low-carbon (renewable) energy share of total installed electricity capacity, access to clean energy for cooking, electric vehicles use and renewable energy investment, was collected from various institutions as explained below:

3.1.1 Low -Carbon Energy Share of Total Installed Electricity Capacity

Data on what has been the percentage share of low-carbon (renewable) energy in total installed electricity capacity both at present and in the past was obtained from the International Renewable Energy Agency (IRENA) website as well as from various publications of Rwanda Energy Group (REG), a company which generates and distributes electricity in the republic of Rwanda. Annual reports from REG provided useful data on this indicator.

3.1.2 Access to Clean Cooking Energy

Data on the trend of clean energy access in Rwanda was mainly obtained from the International Energy Agency (IEA) as well as from REG publications.

3.1.3 Electric vehicles use

Data on electric vehicles use which concerned this study was mainly the number of electric vehicles which were put on Rwanda's roads in the years from 2010 to 2020. This data was obtained from the Ministry of Infrastructure (MININFRA) as well as from Ampersand, a company assembling electric motorcycles in Rwanda.

3.1.4 Clean Energy Investment

Information regarding the past and current levels of investment in clean energy in Rwanda was supposed to be obtained from Rwanda Development Board (RDB), an authority which overlooks all investments being done in Rwanda. However, the data could not be provided timely.

3.2 Data Analysis Method.

The implementation of the ambitious target of Rwanda energy sector in transitioning to a low-carbon economy has been assessed within a timeframe of ten years. Obviously, the suitable method of data analysis to scrutinize such period-based comparative studies would be the “before-and-after data analysis” method. Therefore, in order to find out achievements within Rwanda’s energy sector, a before-and-after analysis was performed on selected indicators of a transition to a low-carbon economy: Renewable energy share of total installed electricity capacity, Access to clean energy for cooking, electric vehicles use, Renewable energy investments

Collected data regarding the trends of these indicators from 2010 (before) to 2020 (after), was analyzed to see what change has occurred in these indicators, as illustrated in Table 5. Further, this data was presented in the form of graphs and tables for information retrieval at glance.

Table 5: Analysis of low-carbon economy transition indicators

Indicator	2010 Level (before)	2020 Level (after)	Change 2020 level – 2010 level
Access to clean energy for cooking			
Low carbon energy share			
Electric Vehicles use.			
Clean energy investment			

3.2. Before-and- after Data Analysis Method

The before-and-after study measure the change in a given variable at two time points. The first time point is before the initiation of an intervention, and the second time point is after the intervention has begun. The main goal of this method is to determine if the variable in question has changed over time (Songer, 2013). In theory, this would be due to an intervention. The point in time when the first measure (before) and the second measure (after) are taken varies by study. There is no standard rule on which this time point should be. It is therefore not surprising to see time points that are six months to one year before and after an intervention. Before and after studies are very popular in research. They have been used in many scientific studies to evaluate the impacts of an intervention. Major advantages for the popularity behind the study designs of this investigation approach are the associated low cost, convenience and simplicity in conducting the studies.

3.2.2 Computer Software for Data Analysis

Two computer softwares were typically used in the analysis of data for this research work. The two computer softwares were Microsoft Excel and Origin Pro 8.0. The reason for choosing Microsoft Excel and Origin Pro 8.0 is because of their ability to produce outstanding graphs and histograms when relevant data can be easily detected for analytic interpretation. Moreover, using both softwares in data analysis proves cheaper and offers the simplest and most obtainable proceedings of data analysis. Microsoft excel was extensively used in producing histograms and pie charts, which gave a sufficiently good visual information about quantifiable trends of the selected indicators of a transition to a low-carbon economy. Origin Pro 8.0 was used for producing graphs visually depicting the information about what have been the trends of the indicators of a transition to a low-carbon economy on the global level and specifically on the country level for Rwanda, as well.

4.0 RESULTS AND DISCUSSSION.

This chapter presents the results of the study. The results are presented in the same order of the methodology explained in chapter 3. This means section 4.1 presents the findings on the trend of renewable energy share of total installed electricity capacity in Rwanda. Section 4.2 presents the trend of access to clean energy for cooking. Section 4.3 presents the trend of electric vehicles use in Rwanda. Section 4.4 presents the trend of investments in renewable energy in Rwanda.

4.1 Low-carbon (renewable) energy share in total installed electricity capacity in Rwanda.

Renewable energy often provides energy in four important areas: electricity generation, air and water heating/cooling, transportation and rural (off-grid) services. In 2018, the total installed generating capacity of Rwanda's power sector was recorded at 218 MW. Renewable sources of energy accounted for about 52.6% of that capacity (Hakizimana E. , Wall, Sandoval, & Venant, 2021). Renewable energy technologies have the potential to strengthen the nation's energy security, improve environmental quality and contribute to a strong energy economy.

Rwanda is in the African Great Lakes region and is highly elevated; its geography is dominated by mountains in the west and savanna to the east, with numerous lakes throughout the country. The climate is temperate to subtropical, with two rainy seasons and two dry seasons each year. This geographic location makes Rwanda the potential source of renewable energy. The potential especially for renewable such as hydro, biomass and solar energy are huge and play a major role in the energy mix of the country (Uwisengengeyimana, Teke, & Ibrikci, 2016). Hydropower is the dominant energy resource utilized for power generation in the country. The primary energy balance in Rwanda consists of biomass at 93.1%, petroleum fuels at 6% and electricity at 0.9%. In the biomass category, wood fuel consumption stands at 80.4% and charcoal at 1.9%, while agricultural waste and peat occupy 10.8%.

Historically, cheaper hydropower has dominated Rwanda's energy mix, accounting for 47% of its energy-generation capacity for more than a decade (SE4ALL, 2020). The country has utilized its abundant rivers and waterways to such an extent that the renewable energy share of total final energy consumption throughout Rwanda has increased more than 86% since 1995. This is a higher share than many OECD countries. However, some regions are increasingly relying on existing diesel fuel plants (currently 27% of the energy mix) to fill the peak demand gap created by hydropower plants failing due to the increasing intensity and length of dry seasons. At peak times, diesel use increases generation cost and relays this effect onto the electricity tariff, making electricity less affordable to consumers (SE4ALL, 2020).

Rwanda has also a high potential for solar energy generation. Rwanda has a high solar irradiance, 1890 kWh/m^2 in the eastern provinces. The eastern part of Rwanda is characterized by the savannah climate, and its geographical location gives it sufficient solar radiation intensity, approximately 5 kWh/m2/day, and approximately 5 hours of peak sunshine per day (Hakizimana E. , Wall, Sandoval, & Venant, 2021). In 2018, Rwanda's total on-grid installed solar energy generation capacity was 12.23 MW originating from 5 solar power plants namely; Jali power plant, generating 0.25 MW; Rwamagana Gigawatt, generating 8.5 MW; Ndera solar power plant, generating 0.15 MW and the Nasho solar power plant, generating 3.3 MW (REG, 2020).

The high potential of geothermal energy in Rwanda is also worth mentioning when discussing the country's renewable energy technologies. Rwanda is located in the East Africa Rift Valley, a region of intense volcanic and seismic activities. There is existence of geothermal fields in Rwanda that can be harnessed for energy generation purposes. Rwanda has an estimated potential of 700 MW of geothermal resources in the form of hot springs along the belt of Lake Kivu. However, the country is yet to harness this energy resource. Rwanda is still conducting exploration of economically viable geothermal sites. Geothermal energy exploration in Rwanda began as early as the 1980's when three sites at Cyangugu, Kibuye and Gisenyi were identified with geothermal energy potential of between 170 and 300 MW (Uhorakeye, 2010) (Ituze, Mwongereza, Abimana, Rwema, & Chisale, 2017) Further studies were conducted by Chevron in 2006, confirming two more sites with geothermal potential. However, to date, no investment has been made in this area as power generation using geothermal energy is considered an expensive process.

The government of Rwanda has a commitment to continue championing renewable energy as the major share of the generation mix. The GoR, through its energy sector strategic plan 2018-2024 and Least Cost Power Development Plan has set a target of having 60% of the generation mix to be powered by renewable resources by 2030 (REG, 2019) (Uwisengengeyimana, Teke, & Ibrikci, 2016). Table 6 shows percentage share of renewable energy in total installed electricity capacity in Rwanda from 2011 to 2018. This data was collected from the website of the International Renewable Energy Agency (IRENA).

Table 6: Percentage Renewable energy share in total installed electricity capacity in Rwanda (2011-2020) (IRENA, 2021)

Year	Renewable energy share (%)

2011	51.2
2012	51.8
2013	53.5
2014	58.9
2015	51.5
2016	53.5
2017	51.9
2018	52.6
2019	54.6
2020	54.6

Data in the above table was used to produce the graph below, which has shown the trend of renewable energy share in installed electricity capacity in Rwanda.

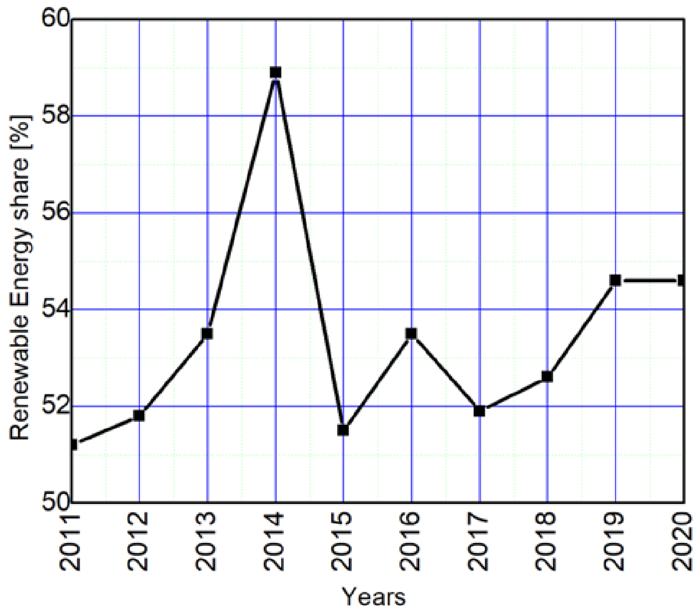

Figure 7: Trend of percentage renewable energy share in total installed electricity capacity in Rwanda from 2011 to 2020

In 2014, the percentage share of renewable power in total installed electricity capacity increased dramatically from 53.5% in 2013 to 58.9%. The main reason behind this increase was due to a number of hydro power plants, as well as one solar plant, that where commissioned in the year 2013 (REG, 2019). The installed capacities of these hydro power plants where reflected in the year 2014. The hydro power plants that where commissioned in the year 2013 included; Gashashi (0.2

MW), Musarara (0.45MW), Mukungwa II (2.5 MW) Rukarara (2.2MW), Nyirabuhombohombo (0.5 MW), Giciye (4MW) and one solar plant, Gigawatt (8.5MW) (REG, 2019).

The percentage share of renewable energy in total installed electricity capacity dropped from 58.9% in 2014 to 51.5% in 2015 due to the reason that three non-renewable energy power plants were completed in that year and there installed capacities were quickly added to the national electricity installed capacity. These three non-renewable energy power plants includes; Kivuwatt phase I methane power plant with an installed generating capacity of 26.4 MW, the Gishoma peat power plant which has an installed generating capacity of 15 MW and the Biomass (Rice Husk) power plant (0.07 MW) constructed in Nyagatare district. In 2017, the percentage of renewable power share in total installed electricity capacity dropped from 53.5% in 2016 to 51.9%. This drop was as a result of the addition of a 30 MW capacity So Energy diesel power plant. Then, in 2018, it increased slightly to 52.6% as a result of the commissioning of a 2.6 MW capacity Rwaza Muko hydro power plant. Again in 2019, the share increased slightly to 54.6% where it remained constant through 2020 (REG, 2019). A list of the existing electricity generating plants in Rwanda, as well as their dates of commissioning, is given in appendix II.

Table 7: Analysis of the indicator; renewable energy share in total installed electricity capacity

INDICATOR	2011 % LEVEL	2020 % LEVEL	% CHANGE (2020-2011 levels)
Renewable Energy share of total installed electricity capacity	51.2	54.6	3.4

The indicator; percentage of renewable energy share in total installed electricity capacity, was analyzed and results are shown in Table 7. Looking at Figure 7 and Table 7, some conclusions may be made that the trend of percentage renewable energy share in total installed electricity capacity from 2011 to 2020, in Rwanda, has been increasing and decreasing. But what is so special about this trend is that the percentage has been well maintained between 50% and 60%, which is good given the fact that the government of Rwanda has a commitment to have 60% of electricity generation capacity be from renewable sources by 2030 (REG, 2019).

The results of the analysis of the indicator, low-carbon (renewable) energy share in total installed electricity capacity, shows that Rwanda's energy sector has made an achievement or has increased renewable energy share in the power mix by 3.4% between the year 2011 and 2020. This is minor achievement in this indicator, but the country has a potential to decarbonize its electricity sector given its abundant renewable energy resources such as hydro, sun, geothermal and to a lesser extent wind. The nation can achieve its ambition of having 60% renewable energy in its energy mix without doubt; all what is needed to be done is to make sure that no more power plant utilizing fossil fuels for electricity generation is allowed to be developed in the country, instead any power plant to be developed in the country should use renewable sources as its main resource for energy generation.

The trend of percentage renewable energy share of total installed electricity capacity in Rwanda exhibit ups and downs kind of trend, this due to the reason that some fossil fuel-based power plants where commissioned and allowed to conduct operations in the country between 2011 and 2020. Whenever a fossil fuel-based power plant is commissioned, the percentage renewable energy share drops, and goes up when a renewable-based power plant is commissioned. Therefore, to ensure that percentage renewable energy share of total installed capacity remains up, every power plant to be commissioned in the country should be renewable-based power plant.

When compared to other East African countries (Uganda, Kenya, Burundi and Tanzania), Rwanda comes third in terms of the percentage renewable energy share in total installed electricity capacity. As shown in Figure 8, Uganda has the highest percentage share of renewable energy in total installed electricity capacity in the East Africa region followed by Kenya, Rwanda, Burundi and Tanzania hits the lowest level. Unlike Rwanda, Uganda and Kenya whose renewable energy share in total installed electricity capacity has been increasing over the years (from 51.2% to 54.6% between 2011 and 2020 for Rwanda, from 73.2% to 89.5% for Uganda and from 64.2% to 74.4% for Kenya between the same period), Burundi and Tanzania's renewable energy share in total installed electricity capacity has been decreasing over the years (from 78.2% to 53.2% for Burundi, and from 54.5% to 38.5% for Tanzania between the years 2011 to 2020).

For Burundi, this decrease can be attributed to the reason that a number of hydropower power plants, which are the most important technology for power generation in Burundi, are out of service or are in need for rehabilitation (Energypedia, 2018). This has led to the government of Burundi to decide to operate thermal power plants as a complement to the insufficient hydropower supply which the county is currently facing.

Table 8: Trends of percentage renewable energy share in total installed electricity capacity for East African countries from 2011 to 2020 (IRENA, 2021)

	Year									
Country	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Rwanda	51.2	51.8	53.5	58.9	51.5	53.5	51.9	52.6	54.6	54.6
Uganda	73.2	83.7	88.2	85.0	85.2	85.2	85.9	86.2	89.4	89.5
Kenya	64.2	65.3	65.5	65.6	65.6	65.9	67.1	71.6	74.5	74.4
Burundi	78.2	78.4	73.7	73.7	73.8	74.2	53.2	53.2	53.2	53.2
Tanzania	54.5	54.9	55.0	55.6	46.0	46.0	46.1	38.6	38.6	38.5

Stand alone diesel generator sets and inverters are also in use, but are mainly limited to hotels, lodges or public institutions (military camps, hospitals, schools) and rich individual households (Energypedia, 2018).

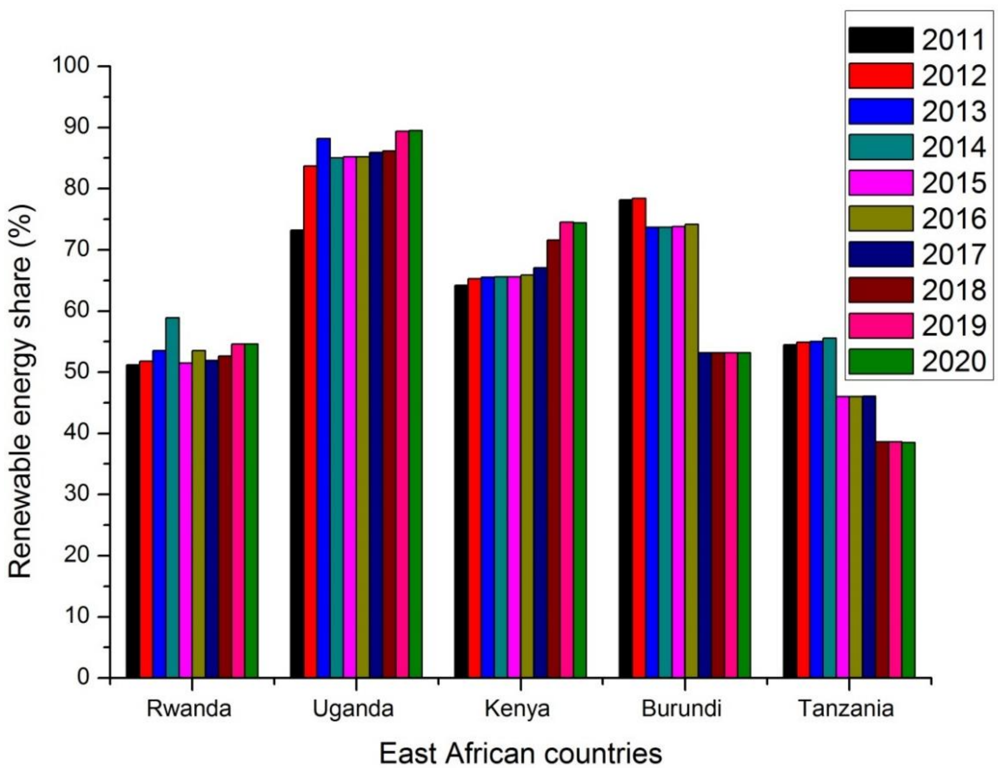

Figure 8: East African Renewable energy share rates

Tanzania has witnesses a drop in the percentage of renewable energy in total installed electricity capacity. This can be attributed to droughts which the country has experienced over the past few years. Over the years, the power sector of Tanzania has been dominated by hydropower. However, poor rains in the past few years resulted in a shortage of water to the turbines generating electricity. This was further aggravated by agricultural activities that were going on upstream around the hydropower stations (Energypedia, 2020). Over the past years, Tanzania experienced droughts. This led to Tanzania to replace hydropower with higher greenhouse gas-emitting and more costly alternatives such as coal and natural gas (Hellmuth, 2019). Due in part to hydropower variability, Tanzania has diversified its electricity supply over time, reducing dependence on hydropower from 96% in 2003 to 34% in 2015. Considering the overall achievement within 10 years, Uganda comes first, followed by Kenya, Burundi, Rwanda and Tanzania; as shown in Figure 9 LHS. The corresponding averaged illustration is shown in Figure 9 RHS.

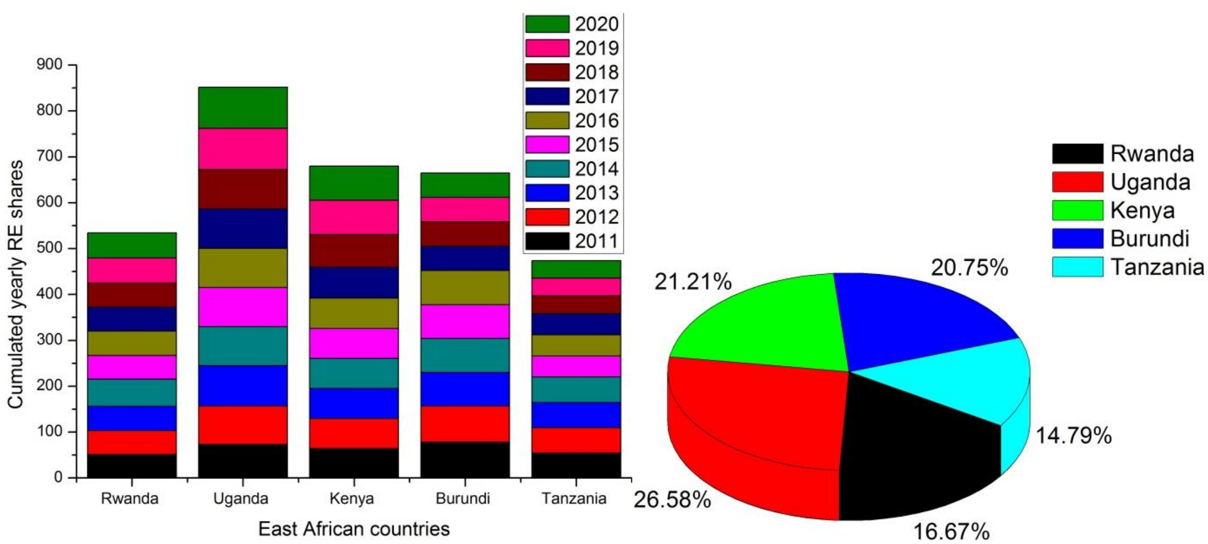

Figure 9: 10years-long cumulated and averaged share of East African RE

4.2 Access to Clean Cooking Energy in Rwanda

In Rwanda, the majority of the population lack access to clean cooking energy hence uses biomass energy. Biomass in the form of firewood, charcoal and agricultural residues play a significant part in Rwanda's economy. This accounted for 83 percent of Rwanda's energy consumption in 2020 (Hakizimana E. , Wall, Kayibanda, & Sandavoi, 2020). This overdependence on biomass has had negative impacts on the environment. There is significant deforestation taking place across the country. Furthermore, population growth is intensifying deforestation and causing more environmental degradation. Biomass consumption currently dominates primary energy supply. Although its share of energy will decline over time as other clean energy sources grow, biomass will remain a key pillar of Rwanda's energy system (MININFRA, 2014). Ensuring the sustainability of biomass supply in terms of the environmental and health impacts remains a major challenge for a densely populated country like Rwanda, especially in areas of the country where shortfalls are already evident. It is for this reason that in 2020 the government of Rwanda through the Ministry of Land and Forestry begun a campaign to reduce the use of firewood for cooking while promoting other technologies such as the use of gas and energy saving stoves to limit deforestation. The government also has a target to reduce the use of firewood and charcoal from 83.3% to 42% by 2024 to achieve a sustainable balance between supply and demand of biomass through the promotion of most energy efficient technologies (MININFRA, 2018). The government of Rwanda plans to partner with the private sector and facilitate a competition-based development of markets for clean-cooking products and technologies. The Ministry of Infrastructure (MININFRA) recently approved an ambitious new Biomass Energy Strategy (2019-2030) and an amendment to its Nationally Determined Contributions (NDC), with targets of reducing the percentage of households that use firewood for cooking from the baseline value of 79.9% in 2017 to 42% by 2024, and phasing out the use of charcoal in urban areas (BRD, 2021). The clean cooking agenda has been recently moved to MININFRA, and REG/EDCL has the mandate to implement it. The Rwanda Standards Board (RSB) is tasked with certifications and testing standards for cooking products and a testing laboratory is currently under development. The performance of eligible cooking technologies will need to be demonstrated through laboratory testing and/or field-based data. In May 2020, the Government updated its NDC under the Paris Agreements which includes promoting the use of efficient cook stoves as a mitigation measure since cooking accounts for 14% of the GHG emissions from the energy sector (BRD, 2021). This action by the government is a good step forward given that the government wishes to be carbon neutral by 2050.

Major drivers of households' lack of access to clean cooking energy include the lack of alternate solutions, low awareness and un-affordability; but awareness raising, behavior-change campaigns, and financing support for high-performing technologies that reduce fuel use can overcome these obstacles. Households in Rwanda have few available options for meeting their cooking needs, in terms of fuels and stove technologies. Self-built stoves and traditional charcoal stoves are commonly used. Efficient cook stoves account for only 13.5% of stoves nationwide. Clean fuel stoves, including liquefied petroleum gas (LPG) and biomass pellets are used by about 1% of households, mostly in urban areas (BRD, 2021). Affordability underscores the choices households make, especially in rural areas, where most households rely on firewood as their primary fuel. About 76% of households spend an average of 7 hours per week acquiring fuel (either by collecting or purchasing it) and prepare it for their stoves, with a disproportionate burden on households using firewood. Women and girls disproportionate spend more time engaging in cooking-related activities and bear the burden of drudgery. Households using charcoal tend to purchase it in small quantities at frequent intervals, especially if they are income constrained.

Access to clean energy for cooking is one of the indicators of a transition to a low-carbon economy, given the fact that using modern sources of energy for cooking reduces carbon dioxide emissions associated with the use of traditional sources of energy for cooking. Table 9 shows percentage of Rwanda's population with access to clean energy for cooking between the year 2000 and 2018. This data was obtained from the International Energy Agency (IEA) website.

Table 9: Percentage of the population with access to clean energy for cooking in Rwanda from 2000 to 2018 (IEA, 2020)

Year	Percentage of the population with access to clean energy for cooking
2000	0.4
2005	0.3
2010	1.2
2015	0.9
2018	2.1

The data in table 9 was used to produce the graph in Figure 10 using the computer software Origin Pro 8.0. The graph has shown that people's access to clean energy for cooking in Rwanda goes up, slightly drops, and then goes up again. The drop in access to clean cooking in Rwanda from 1.2% in 2010 to 0.9% in 2015 may be attributed to factors that were reported as causing decline in access to clean energy for cooking in the Sub-Sahara African region as a whole. These factors include; rapid population growth, escalating fuel costs, and fuel supply interruptions (World bank; AFREA

& ESMAP, 2014). These factors resulted in the rapid growth of biomass-dependent households. Therefore, it can be said that population growth rate was higher than the rate at which people were gaining access to clean energy for cooking between 2010 and 2015 in Rwanda. Also, between 2010 and 2015, Rwanda experienced a lot of electricity shortages (Alexander's OIL & GAS Connections, 2015) (Uhorakeye, 2010), this led to some households (already in small numbers) that were using electricity for cooking, switch to using charcoal or any other solid fuels in order to avoid being disturbed in carrying out there cooking activities whenever there was a power cut.

Table 9 shows that access to clean cooking in Rwanda is very low, which is currently at 2.1%. However, people's access to clean energy for cooking in Rwanda increased more than five times between 2000 and 2018. Looking at table 9 and Figure 10, access to clean cooking energy in Rwanda almost doubled between 2015 and 2018. This was caused by a number of factors, some of which are discussed after the analysis of this indicator.

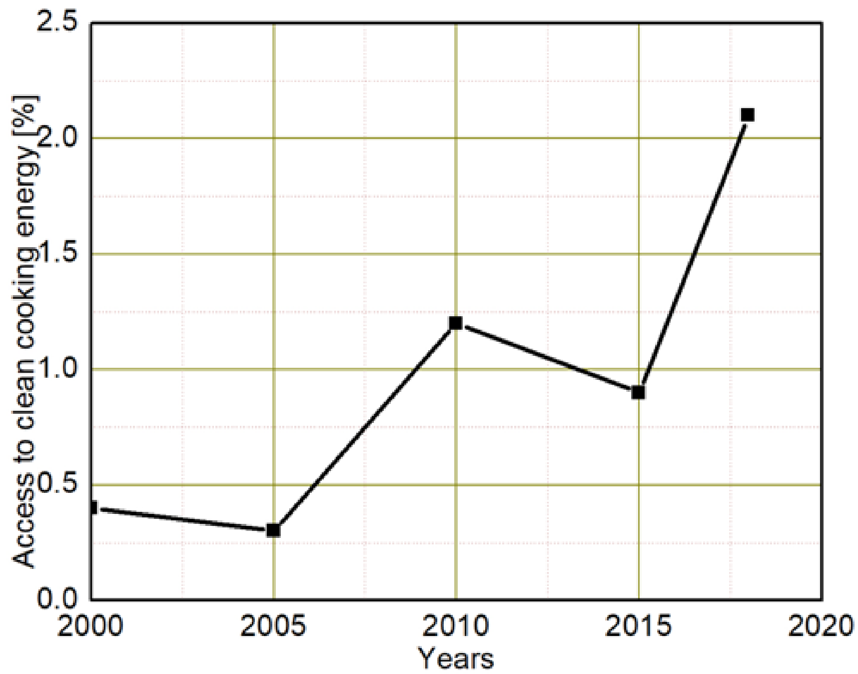

Figure 10: Trend of the percentage of the population with access to clean cooking energy in Rwanda from 2011 to 2020

The results from the analysis of the indicator; access to clean energy for cooking in Rwanda, shows that between 2010 and 2018, an achievement of 0.9% has been made in improving people's access to clean cooking energy in Rwanda. This is not a big achievement, but at the same time, this is an indication that the government of Rwanda is at least headed in the right direction with regard to improving people's access to clean energy for cooking.

Table 10: Analysis of the indicator; access to clean energy for cooking in Rwanda

Indicator	2010 level	2018 level	% Change $(2018level - 2010level)$
Access to clean energy for cooking	1.2	2.1	0.9

There are a number of factors which this small but important achievement can be attributed to. One factor concerns the government's support for the use of LPG as a cleaner alternative of charcoal in urban areas. There have been sensitization and awareness campaigns around the country on the availability and importance of transitioning to modern coking technologies including LPG and electricity (MININFRA, 2020). As a result, there was an increase in the use of cooking gas in Rwanda from 724.6 tons in 2010 to about 3,000 tons in 2017 according to government figures (Makoye, 2019) . There has also been promotion of the use of biogas in the country, through provision of household biogas digesters, especially for rural farmers (Paul, 2007) (FAO, 2021).

People's access to electricity in Rwanda has also increased drastically in recent years. The percentage Rwandan households with access to electricity increased from 10% in 2010 to 65% in 2021, including 47.2% connected to the national grid and 17.8% accessing through off-grid systems mainly solar (REG, 2021). This has led to more people start using electricity as a fuel source for cooking. And most importantly electricity shortage in major cities of Rwanda is now a thing of the past. There are no longer power outages in the country. Also electricity generation has increased over the years. This has encouraged people to use electric energy for cooking because they now cannot worry about power cuts.

Another area where the use of clean cooking technologies have been supported and applied in Rwanda is in correctional centers (prisons). Unlike in many correctional facilities of most sub-Sahara African nations, where mostly wood fuel is used for cooking, in Rwanda all correctional centers now use biogas for cooking. The Rwanda Correctional Service (RCS), with expertise from College of Science and Technology (formerly Kigali Institute of Science and Technology) of the University of Rwanda developed and installed large-scale biogas plants in all 13 prisons in Rwanda to treat toilet wastes and generate biogas for cooking. RCS established its biogas production facilities to alleviate current pressure on the environment, improve health and sanitation in prisons, and also reduce costs on firewood fuel consumption in prisons. Currently biogas is used for more than 60% of all cooking fuels and the government has a target of using biogas 100% for all cooking in correctional institutions (Kabeja, 2015). After the treatment, the bio-effluent is used as fertilizer for production of crops and fuel wood. In the past, sewage disposal from prisons was a major health hazard for both the prison and the surrounding area.

The prisons also used fuel wood for cooking, putting pressure on local wood supplies. Using biogas digesters to manage animal or human waste is not a new idea, but in Rwanda it has been applied on a large scale and with great success (Kimaro, 2005). Each prison is supplied with a linked system of underground digesters, so the sight and smell of the sewage are removed. Staff from the College of Science and Technology of the University of Rwanda manages the construction of the system and provides on-the-job training to both civilian technicians and prisoners (inmates). The biogas is piped to the prison kitchens, and halves the use of fuel wood. The fertilizer benefits both crop production and fuel wood plantation.

Before using biogas, the government spent about 1 billion Rwandan francs (USD 1.7 million) to buy firewood each year. After the start of using biogas, that amount has been reduced by 85% (Holliday, 2011) (Kabeja, 2015). While firewood is still used to provide a quarter of power needs in prisons, there are plans to phase out that with peat (abundant in Rwanda) in all Rwandan prisons in the near future. The efforts made by RCS in using biogas to combat degradation made them win a global award in 2015. Rwanda correctional services were awarded by the International Correctional and Prison Association (ICPA) for its efforts in using biogas to combat environmental degradation. The award 'ICPA Correctional Excellence Awards 2015- Correctional Healthcare Award – Rwanda Prison Service – Biogas Project' was handed over to RCS Deputy Commissioner General, during the 17th ICPA annual general meeting in Melbourne, Australia (New Times, 2015).

There has also been an effort to replace the use of charcoal and firewood for cooking with the use of biomass pellets and briquettes in Rwanda. The promotion of pellets and briquettes is one of the proposed interventions of biomass dependence reduction strategies from 83% to 42% by 2024 (REG, 2018). This is being done through:

- Training producers of pellets and briquettes to produce quality products.

- Providing technical support to pellets and briquettes producers.
- Attracting private sector to develop pellet and briquette- making factories.
- Facilitating factories to access raw materials (e.g. providing forest concessions to pellets makers).
- Carrying out extensive decentralized awareness campaigns.
- Promote the use of pellets and briquettes in households as a replacement to charcoal and firewood.
- Disseminate a business model that allows people in possession of raw biomass to exchange it with pellets or briquettes to support those who do not have monetary resources.

Currently there is one notable company dealing in biomass pellets and briquettes in Rwanda, the Inyenyeri Company Limited. Inyenyeri, a Rwandan Social Benefit Company which has been in operation since 2011, strives to provide a solution to the problems caused by traditional cooking methods in Rwanda and replicate that solution across sub-Saharan Africa (Clean Cooking Alliance, 2012). Inyenyeri distributes gasifying cook stoves free of charge and produces fuel pellets using locally sourced biomass. Inyenyeri is a for-profit renewable energy company, whose mission is to break the cycle of energy poverty through the provision of a fuel and Fan Gasifying cook stove solution, which can be sustainably scaled to serve more than 2 million Rwandan households (EEP, 2019).

Inyenyeri offers a holistic cooking system and uses an "energy utility" business model. Cook stoves are infrastructure, they require fuel for functionality. Fuel pellet are energy, they are purchased repeatedly and used every day: one is useless without the other. By creating a system that incorporates both the fuel and the stove, inyenyeri creates demand for their revenue-generating product while maximizing the health, environmental and social impacts of clean cooking. Inyenyeri engages rural and urban markets collectively to drive profitability and extend services to all Rwandans. Urban communities drive pellet purchases and the rural community trade collected biomass for pellets, which inyenyeri uses as the raw material for pellets. Through this approach, inyenyeri ensures that even the poorest households have access to clean cooking fuel. The business model developed by inyenyeri is novel and innovative. In addition to the sale of fuel pellets, inyenyeri is the first company in the world to prevent "stacking" of cook stoves.

Table 11: Trends of people's access to clean energy for cooking among East African countries (IEA, 2020)

					Year
Country	2000	2005	2010	2015	2018
Rwanda	0.4	0.3	1.2	0.9	2.1
Uganda	1.9	2.7	2.1	4.4	5.9
Kenya	3.3	4.5	8.0	13.8	15.0
Burundi	0.0	1.0	1.4	2.9	4.0
Tanzania	1.9	0.9	2.1	4.3	5.5

The concept of "stove stacking" is the use of more than one cook stove technology per household. Inyenyeri prevents stove stacking by completely replacing all traditional stoves in a household with the world's cleanest cook stoves (EEP, 2019). When we compare people's access to clean energy for cooking among East African countries (table 11), Rwanda has the lowest percentage of the population with access to clean energy for cooking.

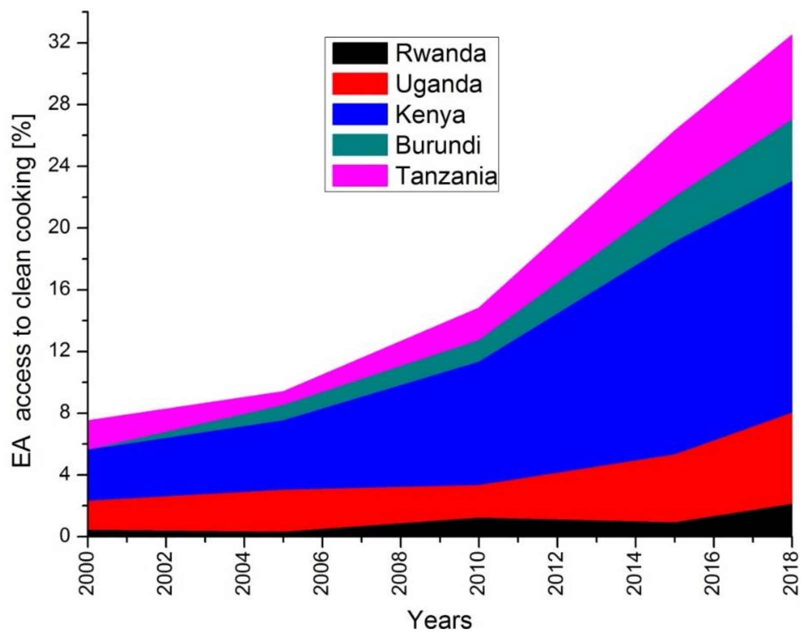

Figure 11: East African access to clean cooking by cumulated countries' rates

As depicted by Figure 11, Kenya has the highest percentage followed by Uganda, Tanzania, and Burundi while Rwanda hits the bottom line. But if the current measures which are put in place to increase access to clean cooking energy in Rwanda are maintained, the country may be able to surpass some of its East African counterparts, such as Burundi and Tanzania, in the years to come.

4.3 Electric Vehicles in Rwanda

A study conducted on air pollution in Rwanda back in 2011, found that transportation is the main source of air pollution in Rwanda (REMA, 2011). In the same year, the transport sector accounted for 52% of GHG emissions. From 2011 onwards, the government of Rwanda has been striving to find ways in which to limit air pollution emanating from transportation. The use of electric vehicles has been one of the ways found to limit air pollution from the transport sector. The Government of Rwanda has recognized the benefits of electric vehicles, especially in limiting air pollution.

Therefore, GoR aims to rapidly transition to electric motorbikes (e-motos), and eventually to electric buses and cars on Rwanda's roads. In august 2019, the President of Rwanda, Paul Kagame, announced his government's intention to replace internal combustion engines (ICE) motor bikes with electric motor bikes. On 28th November 2019, the Ministry of Infrastructure (MININFRA) briefed the Rwandan cabinet about its initiative to promote e-mobility. Subsequently, on 28th February 2020, MININFRA hosted a workshop where relevant stakeholders from public, private and development partners shared their views on how Rwanda may plan its e-mobility transition. During this workshop, a brief policy was developed that would act as a near-term road map for managing the EV transition in Rwanda, particularly for its capital city Kigali (Bower, 2020). These actions by top government officials and Ministries are a signs that the government remains committed to the Paris Agreement.

Rwanda is among the first countries in Africa to launch electric vehicles and it's charging points. Uganda, Rwanda's eastern neighbor, is another country in east Africa which has recognized the importance of electric mobility and is moving side-by-side with Rwanda in trying to electrify their transport sector (Obuya, 2021). Rwanda has set ambitious targets to become a green, climate-resilient and low-carbon economy by 2050 (Bower, 2020). Some of Rwanda's key strategies include: increasing energy efficiency, de-carbonizing the power sector, switching to electricity and other low and zero-carbon fuels, and adoption of e-mobility. In order to enhance this shift to electric bikes and vehicles, and also increase infrastructure, a number of companies have been launched in the country to bring about the electrification of motor vehicles in Rwanda. Currently, a few e-motos are now fully operating as taxis, their numbers is likely to increase because three private firms; Ampersand, Safi Universal Links and Rwanda Electric Mobility have entered the market and have plans for scaling up their operations.

Table 12: Companies currently dealing in electric vehicles in Rwanda (MININFRA, 2021)

Company Name	Number of Electric Vehicles + Comments
Ampersand	Ampersand has 35 operational electric motorcycles assembled locally with four swapping stations. There is a plan to add 40 more e-motorcycles.
Safi Universal Links (SUL) Ltd	Safi Universal Links Ltd has 30 e-motorcycles in operation with seven swapping stations. The company also has a training center for e-motorcyclists, where seven e-motors are used for training.
Rwanda Electric Motorcycle Company	Rwanda Electric Motorcycles Company (REM) has started assembling electric motorcycles and plans to retrofit existing ICE motorcycles into electric ones. Currently, 75 e-motorcycles are in operation and are fuelled by one charging station and three battery swapping stations.
Volkswagen	Volkswagen has 20 e-golfs fuelled by two charging stations operated by Siemens. One charging station is located in the Special Economic Zone (SEZ) while the other one is located at Kigali Convention Center.
Victoria motors	Victoria Motors Ltd has set up a company to exclusively focus on promotion of Plug-in-hybrid Electric Vehicles (PHEV) outlanders and electric buses in Rwanda. As of now, 20 PHEV were sold and are in

	operation with corresponding domestic charging units, while 60 PHEV are in stock waiting to be sold.
The International Finance Corporation	The International Finance Corporation, IFC/World Bank expressed interest to partner with Rwanda to introduce electric buses in the city of Kigali (CoK). In this context, IFC has dispatched a team of consultants to conduct the feasibility study of e-buses in the CoK.

Ampersand has already logged over 400,000 kilometers on its taxi bikes in Kigali. These firms are likely to compete, and over time, they aim to rapidly replace ICE-motorbike taxis. Volkswagen has also introduced electric cars (e-golfs) in the country and the International Finance Corporation (IFC) in conjunction with the World Bank is studying the possibility of introducing e-buses in Rwanda. Table 12 shows companies currently dealing in electric vehicles in Rwanda, and the number of EVs which each company has.

As of April 2020, Rwanda had 221,000 registered vehicles consisting of 52% motorcycles and 38% passenger vehicles, of which at least 30,000 were in the capital city Kigali. The number of vehicles is increasing rapidly (almost 12% per year) and the government is thus concerned about deteriorating air quality in Kigali and rising fuel imports bills (12% of total imports) (Bower, 2020). A recent EV study (Sweco, 2019) recommended that the government should aim to convert 30% of motorcycles, 8% of cars, 20% buses and 25% of mini and micro buses to electric power by 2030, but senior government officials and private sector firms have expressed their desire for a faster transition, especially in e-motorbikes. The Rwanda Environmental Management Authority (REMA) has called upon the public and private institutions as well as individuals to consider shifting to electric vehicles and join the effort to beat air pollution (Nkurunziza, 2021). Electric vehicles' adoption process in the country will also be facilitated by rent-free land for charging stations for land owned by the government, further reducing the cost of set up and maintenance.

According to (Mwai, 2021), to increase chances of Rwanda being a producer for electric vehicles, batteries and other inputs, the government has rolled out incentives in the investment code such as 15% Corporate Income Tax (CIT) cut and tax holiday for companies manufacturing and assembling electric vehicles. The e-mobility program plans for the phased adoption of electric buses, passenger vehicles (cars and motorcycles) from 2020 onwards and in the process reducing conventional vehicle sales, transport fuel imports and associated gas emissions. In an effort to reduce the cost of ownership and maintenance of electric vehicles, the strategy approved by cabinet exempted import and excise duties on electric vehicles, spare parts, batteries and charging station equipment. The incentives also zero-rated Value Added Tax for electric vehicles, spare parts, batteries and charging station equipment. Ordinarily vehicle imports have to settle a bill of 25% import duty, 18% VAT, 5-15% excise duty depending on the size of the engine (Obuya, 2021)

Table 13: Number of electirc vehicles reported in Rwanda from 2018 to 2020 (MININFRA, 2021)(REMA, 2021)

Year	Number of electric vehicles reported
2018	5
2019	24
2020	180
2021	436

Table 13 shows the number of electric vehicles reported in Rwanda between 2018 and 2020. The data in Table 13 was obtained from Rwanda's Ministry of Infrastructure (MININFRA), Rwanda Environment Management Authority (REMA), as well as from Ampersand, a company assembling electric motorcycles in Rwanda. The first electric vehicles in Rwanda were introduced by Ampersand in 2018, and these were electric motorcycles. In 2018 Ampersand had assembled 5 electric motorcycles, these were tested in Kigali: on the road, in the lab and with customers (https://www.ampersand.solar/about). The five e-motorcycles were not used commercially but were only used to test their performance in Kigali city. In the year which followed, 2019, the company assembled a total of 20 electric motorcycles. These were used commercially as moto-taxis in Kigali. In the same year (2019), four electric cars, of the Volkswagen golf model with one charging station, were launched in Rwanda as a partnership between Volkswagen and Siemens under a pilot project. During the launching ceremony which was attended by Rwanda's Prime Minister Edouard Ngirente, officials from Volkswagen Rwanda said that more cars were to join the market in the months to come In late 2020, MININFRA conducted a study on electric mobility in Rwanda, whose findings were reported in its strategic paper on electric mobility published in

April, 2021 (MININFRA, 2021). The study found that there were a total of 180 electric vehicles, 140 e-motorcycles and 40 e-cars, on Rwanda's roads (refer to Table 13). And according to the data obtained from Rwanda Environment Management Authority (REMA), as of September, 2021 the number of electric vehicles in Rwanda was standing at 436. This shows that the efforts being put in place to electrify the transport sector of Rwanda are actually working and this increase in the number of electric vehicles will continue in the years to come.

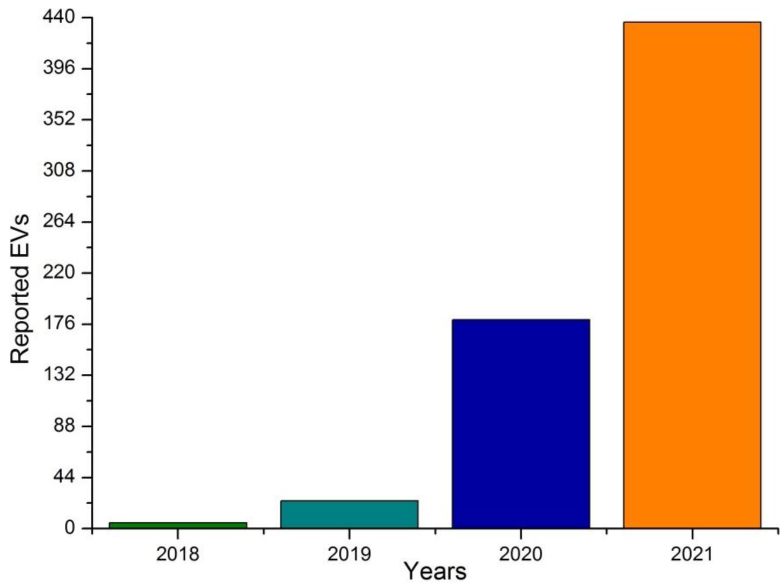

Figure 12: Trend of the number of electric vehicles reported in Rwanda from 2018 to 2021

The data in Table 13 was used to plot the histogram in Figure 12 using Microsoft Excel. The graph shows that there has been a sharp increase in the number of electric vehicles, especially electric motorcycles, in Rwanda ever since they were introduced in 2018. This sharp increase is as a result of the government's efforts in trying to electrify all electric motorcycles, which operates as taxis. Therefore, the increase in the number of electric vehicles, especially electric motorcycles is expected to continue in the coming years, given the fact that a number of companies are getting into the business of electrifying vehicles in Rwanda in particular, and in east Africa as a region.

Table 14: Analysis of the indicator; electric vehicles use in Rwanda

INDICATOR	2018 Number	2021 Number	Change $(2021\ \boldsymbol{number} - 2018\ \boldsymbol{number})$

Electric vehicles use	5	436	431	

From the analysis of our indicator; electric vehicles use in Rwanda, we can see that just over a period of 3 years the number of electric vehicles in Rwanda has increased from five EVs in 2018 to a record of 436 in 2021. Though this is only a scratch on the surface, given the huge number of ICE-vehicles present on Rwanda's roads (221,000 as of April, 2020), the country is on the right track to electrify its transport sector. The government is in full support of introducing electric vehicles, there are some tax exemptions for companies dealing in electric vehicles in the country, such as the preferential corporate income tax of 15% for investors operating in e-mobility. There are already several firms in the e-mobility space in Rwanda and the new incentives are expected to give them a major boost (MININFRA, 2021).

The government, through the ministries of environment and infrastructure, is encouraging public and private institutions as well as individuals to transition to electric vehicles by buying electric vehicles instead of internal combustion engine vehicles and join the efforts to beat air pollution (REMA, 2021). In this regard, in April 2021, the Ministry of Infrastructure together with Rwanda Environment Management Authority (REMA) organized the Inaugural E-mobility Technology Showcase at Kigali Convention Center (KCC) aimed to showcase the current and emerging technology options for e-mobility that are available in Rwanda. The event was an opportunity for participants to demonstrate the power and potential of sustainable transport to create jobs grow the economy and improve health outcomes for all. The event attracted different government institutions, private sector and different partners in e-mobility investment (MININFRA, 2021). With time, the population of Rwanda will come to realize the importance of electric vehicles; hence most will become comfortable with using electric vehicles instead of using ones that run on petroleum products. Therefore, the future of electric vehicles in Rwanda seems to be bright.

4.4 Renewable Energy Investments in Rwanda

Renewable energy technologies produce sustainable, clean energy from sources such as the sun, the wind, plants and water. In Rwanda, renewable energy often provides energy in four important areas: electricity generation, air and water heating/cooling, transportation and rural (off-grid) energy services. According to the Rwanda Energy Group, in 2018, the total installed capacity of Rwanda's power generating plants was recorded at 218 MW. Renewable sources of energy accounted for about 113.14 MW (52.4%) of total energy consumption in Rwanda (Eustache, Sandoval, & Venant, 2019). Renewable energy technologies have the potential to strengthen the nation's energy security, improve environmental quality and contribute to a strong energy economy. It is for this reason that Rwanda has made a lot of investments in renewable energy technologies in order to improve access to clean energy for its citizens.

In its public policy on access to energy, Rwanda has committed to electrifying 48% of households through off-grid by 2024. Off-grid energy refers to a stand-alone power system or mini-grids designed to provide electricity in small communities. It is used in areas where residential houses are far apart. Rwanda appears to be on the right track to achieve its objectives. The national electrification rate increased from 10 to 40 per cent between 2010 and 2017. By 2017, more than 185,000 solar home systems and nearly 300,000 solar lamps had been installed across the country. Rwanda invested $350 million in the energy sector in 2016 compared to less than $50 million in 2007 (Feukeng, 2019). The government's strategies through the Rwanda Energy Group, a national electricity distribution company, aim to ensure universal access to electricity throughout the country. Promotion of the use of biogas through provision of household biogas digesters, especially for rural farmers, is another area of renewable energy where the government has invested heavily in the past few years.

Data on what has been the yearly investment in renewable energy in Rwanda was lacking in the literature. The institution responsible for investments in the country; Rwanda Development Board (RDB) could not provide this data, requests were made to the board asking for the provision of this data, but were unable to do so until the completion of this research. Therefore this indicator was not analyzed due to the lack of data. But based on the little data obtained in the literature on this indicator, it can be said that Rwanda has been scaling up its investment in renewable energy in the period 2010 to 2020. For instance, it was found in the literature that in 2007, Rwanda invested a total of USD 50 million in its energy sector. The amount invested in the sector increased to USD 350 million in 2016 (Feukeng, 2019), which shows that the investment increased by USD 300 million. But it was hard to find out exactly what portions of those investments were allocated to renewable energy.

5. CONCLUSION

From the various literatures checked during this study, it can be said that a good number of countries around the world especially those that depend on imported fossil fuels, are taking the current energy transition more seriously. The Republic of Rwanda is among the countries in the world which has acknowledged the importance of having a low-carbon (green) economy. The current energy sector of Rwanda is well positioned to transition the economy of the country to a low-carbon one. Based on the indicators chosen to assess the achievements which the country has made in transitioning to a low-carbon economy namely; low-carbon (renewable) energy share in total installed electricity capacity, access to clean cooking energy, electric v ehicles use, and renewable energy investments, Rwanda is set to make tremendous achievements which will surprise the entire African continent in one of the indicators. And this indicator is electric vehicles use. The use of electric vehicles in Rwanda is expected to increase in the coming years at a higher rate than most countries on the continent. This is as a result of the government's ambitions to replace ICE-motorcycle, which is used as the main mode of transportation in the country, with e-motorcycles. Feasibility studies on introducing e-buses are also being conducted in the country by the government and private entities. A number of companies dealing in electric vehicles are now operating in the country. Electric motorcycles can now be spotted among motorcycle taxis drivers on the streets of Kigali. Signs of Rwanda's transition to a low-carbon economy have started to emerge. In the capital city Kigali, electric motorcycles are joining the moto-taxi fleet. Charging stations for electric vehicles are being installed on various key points in the city. And in rural parts of the country, mini to medium hydro and solar power plants dot the country side. Companies like Ampersand, Rwanda Electric Motorcycles as well as Volkswagen are helping support Rwanda's transition to a low-carbon economy by assembling electric vehicles in the country.

The indicator; renewable energy share in total installed electricity capacity also gave impressing results, where more than half of installed electricity capacity in the country is from renewable energy. This share has been going back and forth but the most interesting thing is that it has been maintained at above 50% which is recommendable. This shows hope of achieving the countries desire to have 60% of the installed electricity generating capacity be from renewable sources by 2024. What the government needs to do is to ensure that future electricity generation projects undertaken in the country should be based on renewable sources.

Based on literature searched and data obtained, the country has historically been fairing badly on the indicator; access to clean energy for cooking, the percentage of the population with access to clean cooking energy in Rwanda has stood at less than 5% since recorded history. However, outstanding strategies to increase people's access to clean energy have been put in place in the country, strategies such as awareness campaigns on the availability and importance of using modern forms of energy for cooking such as liquefied petroleum gas (LPG) and electricity. Also, the introduction of biogas digesters to produce biogas, which is a clean energy resource, in public institutions such as prisons; and among rural household especially rural farmers, is another strategy which the government is supporting to ensure access to clean cooking energy is increased in the country. These strategies seem to be working as access to clean cooking energy more than doubled between 2015 and 2018, from 0.9% to 2.1% respectively. Access to clean cooking energy is expected to increase in the country as clean cooking technologies are being promoted and made available among the population and people have shown interest in adopting these technologies.

Although data on renewable energy investments in Rwanda was lacking in the literature at the time of this study and that the institution mandated with overseeing investments being made in renewable energy in Rwanda which is the Rwanda Development Board (RDB) was unable to give any information on what has been the trend of this indicator, it can be said that investments in renewable energy are being made in the country. These investments are being manifested in the progress which the country has made in the other indicators of transition to a low-carbon economy namely; renewable energy share of total installed electricity capacity, electric vehicles use and access to clean energy for cooking. Without investments, no achievements can be made in these areas. Therefore, based on the indicators which were used in this study, Rwanda has made some achievements in transitioning to a low-carbon in the energy sector in the period 2010 to 2020. The country is set to make recommendable achievements in the years ahead, given that the government has acknowledged the benefits of having a low-carbon economy and has ambitions to fully transition to it by the year 2050 just like main countries around the world wishes to do so.

6 PROBLEMS FACED WHEN CONDUCTING THIS RESEARCH THESIS

The restrictions on movements imposed in Rwanda to control the spread of COVID-19 had some negative impacts on this study. Because I, the researcher, was unable to visit and conduct some discussions with key officials of the institutions were most of the data was obtained. For instance, discussions with key officials from companies dealing in electric vehicles in the country were not conducted due to the reason that the entire country was in lockdown at the time I was collecting information/data on electric mobility in Rwanda. Therefore the researcher relied on information obtained from the websites for these companies.

Financial constraints were another problem which the researcher faced when conducting this research work. Some websites, with information essential to this work, required that a certain amount in the range of USD 100-200 be paid in order for the requested vital information to be made available to me. But no funding was received for this work, therefore some important information which were required for this work were not obtained from these websites. Another problem which was faced when conducting this research is that some governmental institutions were unable to respond to requests made to them regarding the provision of information which can only be obtained from these institutions. Emails were sent as well as calls were made to these institutions, but they all went unanswered.

7. REFERENCE

Alexander's OIL & GAS Connections. (2015, August 05). *Rwanda: Water and electricity shortages worsen.* Retrieved September 17, 2021, from Alexander's OIL & GAS Connections: An Institute for Global Energy Research: http://www.gasandoil.com/oilaround/2015/08/rwanda-water-and-electricity-shortages-worsen

Azarian, R. (2011). Potentials and Limitations of the Comparative Method in Social Sciences. *International Journal of Humanities and Social Science* , 43-65.

Baranova, P., & Lynch, N. (2017). *The Low Carbon Economy: Understanding and Supporting a Sustainable Development.* Cham, Switzerland: Palgrave Macmillan.

Benjamin K. Sovacool; Marilyn A. Brown and Scott V. Valentine. (2016). *Fact and Fiction in Global Energy Policy: 15 Contentious Questions.* Baltimore: Johns Hopkins University Press.

Bimeyimana, S., & Li, G. A. (2018). The state of the power sector in Rwanda: A progressive sector with ambitious targets. *Frontiers in energy research* , 68-82.

Bonsu, N. O. (2020). Towards a Circular and Low-Carbon Economy: Insights from the Transitioning to Electric Vehicles and Net Zero Economy. *Journal of Cleaner Production* , 256-286.

Bower, J. B. (2020). *A road map for e-mobility in Rwanda.* Kigali: International Growth Center (IGC) Rwanda.

BRD. (2021). *Rwanda Energy Acess and Quality Improvement Project.* Kigali: Development Bank of Rwanda.

Capanna, S. (2020, August 24). *Four Reasons Why Investing in Clean Energy is Essential for Rebuilding the Economy*. Retrieved May 5, 2021, from Environmental Defense Fund: https://blogs.edf.org/climate411/2020/08/24/four-reasons-why-investing-in-clean-energy-is-essential-for-rebuilding-the-economy/

Clean Cooking Alliance. (2012, June 23). *Sector Directory.* Retrieved September 29, 2021, from Clean Cooking Alliance: https://cleancookingalliance.org/sector-directory/inyenyeri/

COSATU. (2017). *A Just Transition to a Low Carbon and Climate Resilient Economy: COSATU Policy on Climate Change.* Johannesburg: COSATU.

Dailey, M. (2017, June 17). *Five countries with the most invested in renewable energy.* Retrieved November 5, 2021, from Energy and Capital: https://www.energyandcapital.com/articles/5-countries-with-the-most-invested-in-renewable-energy/77063

DBSA. (2021, April 7). *Is Africa ready for a low-carbon economy?* Retrieved October 12, 2021, from Development Bank of Southern Africa: https://www.dbsa.org/article/africa-ready-low-carbon-economy

Dekelver, G., Ruzigana, S., & Lam, J. (2005). *Report on the Feasibility Study for a Biogas Support Programme in the Republic of Rwanda.* Kigali, Rwanda: Netherlands Development Organization.

EEP. (2019). *The Proof is in the Cooking: The Innovative Business Model of Inyenyeri.* Pretoria: Energy and Environment Partnership/South and East Africa.

Energypedia. (2018, July 18). *Burundi energy situation.* Retrieved October 5, 2021, from Energypedia: https://energypedia.info/wiki/Burundi_Energy_Situation#Introduction

Energypedia. (2020, May 04). *Rwanda Energy Situation.* Retrieved from energypedia: https://energypedia.info/wiki/Rwanda_Energy_Situation#toc

Energypedia. (2020, September 1). *Tanzania energy situation.* Retrieved October 5, 2021, from Energypedia: https://energypedia.info/wiki/Tanzania_Energy_Situation

Eustache, H., Sandoval, D., & Venant, U. G. (2019). Current Status of Renewable Energy Technologies for Electricity Generation in Rwanda and Their Estimated Potentials. *Energy and Environmental Engineering* , 8-15.

FAO. (2021). *Biogas Systems in Rwanda.* Rome: Food and Agriculture Organization of the United Nations.

Feukeng, L. (2019, October 1). *Rwanda: 5th Most Attractive Country for Investment in Green Energy*. Retrieved May 6, 2021, from Afrik 21: https://www.afrik21.africa/en/rwanda-country-becomes-worlds-fifth-largest-producer-of-green-energy/

Friedman, T. L. (2008). *Hot, Flat and Crowded: Why we need a green revolution and how it can renew America.* New York: Farrar, Straus and Giroux.

GoR. (2011). *Green Growth and Climate Resilience: National Stratedy for Climate Change and Low Carbon Development.* Kigali: Government of Rwanda (GoR).

Hakizimana, E., Wall, U. G., Kayibanda, V., & Sandavoi, D. (2020). Environmental Impacts of Biomass Energy Sources in Rwanda. *Energy and Environmental Engineering* , 62-71.

Hakizimana, E., Wall, U., Sandoval, D., & Venant, K. (2021). Importance of Renewable Electricity Generation for Sustainable Development, Case study: Rwanda. *International Journal of Scientific and Technology Research* , 98-102.

Hellmuth, M. (2019, August 14). *Hydropower in Tanzania.* Retrieved October 05, 2021, from Climate Links: https://www.climatelinks.org/blog/hydropower-tanzania

Holliday, G. (2011, November 21). *Prison waste cuts costs in Rwanda.* Retrieved September 22, 2021, from REUTERS: https://www.reuters.com/article/us-rwanda-biogas-idUSTRE7AK0IN20111121

IBEC. (2018). *Building a Low Carbon Economy: A Roadmap for a Sustainable Ireland.* Belfast, Ireland: IBEC.

IEA. (2020). *Access to clean cooking.* Paris: IEA.

IEA. (2019). *World Energy Outlook-2019.* Paris: International Energy Agency.

IRENA. (2021). *Renewable Capacity Statistics 2021.* Abu Dhabi: IRENA.

Ituze, G., Mwongereza, J. d., Abimana, C., Rwema, M., & Chisale, P. (2017). Rwanda Energy Landscape. *Foundations of Future Energy Policy* , 15-26.

Kabeja, B. B. (2015, December 01). *Rwanda: Biogas in prisons saves millions of dollars.* Retrieved September 22, 2021, from Clean leap: https://cleanleap.com/rwanda-biogas-prisons-saves-millions-dollars

Kimaro, A. (2005). Biogas plants providing sanitation and cooking fuel in Rwanda. *Ashden awards seminars* (pp. 50-54). London: The Ashden awards for sustainable energy.

Makomere, K. M. (2020). Climate Action and Low carbon Economy. *ResearchGate* , 87-97.

Makoye, K. (2019, August 16). *New initiative helps tackling clean cooking crisis in Rwanda.* Retrieved September 10, 2021, from SDGs for All: https://www.sdgsforall.net/index.php/goal-7/1102-new-initiative-helps-tackling-clean-cooking-crisis-in-rwanda

MININFRA. *Energy Sector Strategic Plan.*

MININFRA. (2018). *Energy Sector Strategic Plan: 2018/19-2023/24.* Kigali: GoR.

MININFRA. (2018). *Energy Sector Strategic Plan: 2018/2019-2023/24.* Kigali: Government of Rwanda.

MININFRA. (2020). *Infrastructure Sector Annual Report.* Kigali: GoR.

MININFRA. (2015). *Rwanda Energy Sector Strategic Plan.* Kigali: Rwanda Ministry of Infrastructure.

MININFRA. (2021, April 27). *Rwanda has awesome new incetives for electric vehicles.* Retrieved September 21, 2021, from MININFRA: https://www.mininfra.gov.rw/updates/news-details/rwanda-has-awesome-new-incentives-for-electric-vehicles

MININFRA. (2021). *Strategic Paper on Electric Mobility Adaptation in Rwanda.* Kigali: GoR.

MININFRA. (2014). *Sustainable Energy for All: Rapid Assessment and Gap Analysis Rwanda.* Kigali: Government of Rwanda (GoR).

MININFRA. (2014). *Sustainable Energy for All: Rapid Assessment and Gap Analysis Rwanda.* Kigali: GoR.

MININFRA. (2014). *Sustainable Energy for All: Rapid Assessment Gap Analysis Rwanda.* Kigali: Government of Rwanda (GoR).

Moss, D. H. (1983). Biomass for energy in developing countries. *Geojournal* , 5-14.

Mwai, C. (2021, April 16). *Rwanda Unveils New Incetives to Drive Electric Vehicle Uptake.* Retrieved July 14, 2021, from AllAfrica: http://www.allafrica.com

Nalule, V. R. (2020). Transitioning to a Low Carbon Economy: Is Africa ready to bid farewell to Fossil Fuels? In G. Wood, & K. Baker, *The Palgrave Handbook of managing fossil fuels and Energy Transition.* (pp. 261-286). Cham: Palgrave Macmillan.

Nash, E., & Ngabitsinze, J. C. (2014). *Low-Carbon resilient Development in Rwanda.* London: IIED.

New Times. (2015, October 29). *RCS wins global award for bio gas technology.* Retrieved September 22, 2021, from The New Times Rwanda: https://www.newtimes.co.rw/section/read/193911

Nkurunziza, M. (2021, January 19). *Rwanda Moves to Stimulate Transition to Electric Vehicles on the Local Market.* Retrieved July 12, 2021, from The New Times Rwanda: http://www.newtimes.co.rw

Obuya, J. (2021, July 8). *EV Plugin Launches its first Public and Multi EV Charging Station Project in Kigali-Rwanda.* Retrieved July 13, 2021, from Cue Africa: http://www.cueafrica.net

Odhiambo, E. (2021, May 3). *Africa should develop its own electric vehicle agenda.* Retrieved June 21, 2021, from Aljazeera Opinions: https://www.aljazeera.com/opinions/2021/5/3/africa-should-develop-its-own-electric-vehicle-agenda

OECD. (2015). *Monitoring the Transition to a Low Carbon Economy: a strategic approach to development.* Paris: OECD.

Paul, E.-M. H. (2007). *National Domestic Biogas Programme Rwanda: Baseline Study Report.* Kgali: MININFRA.

Rajpoot, M. (2017, March 1). *Data Analysis wit MS Excel.* Retrieved from Code Project: https://www.codeproject.com

REG. (2018, June 05). *Biomass.* Retrieved September 28, 2021, from Rwanda Energy Group: https://www.reg.rw/what-we-do/biomass/

REG. (2021, August 31). *Electricity access.* Retrieved September 19, 2021, from Rwanda Energy Group: http://www.reg.rw/what-we-do/access/#:~:text=To%20date%2C%2063%25%20of%20Rwandan%20households%20have%20access,63%25%20of%20Rwandan%20households%20have%20access%20to%20electricity.

REG. (2019). *Rwanda Least Cost Power Development Plan (LCPDP) 2019-2040.* Kigali: Rwanda Energy Group.

REG. (2020, December 20). *Solar Energy Generation.* Retrieved September 26, 2021, from Rwanda Energy Group: https://www.reg.rw/what-we-do/generation/solar/

REMA. (2011). *A study on air pollution in Rwanda with reference to Kigali city and vehicular emissions.* Kigali: Rwanda Environment Management Authority.

REMA. (2021, January 18). *Electric Vehicle to Support Rwanda's Environmental Protection Efforts.* Retrieved September 21, 2021, from Rwanda Environment Management Authority (REMA): https://www.rema.gov.rw/index.php?id=77&L=0&tx_news_pi1%5Bnews%5D=103&tx_news_pi1%5Bday%5D=18&tx_news_pi1%5Bmonth%5D=1&tx_news_pi1%5Byear%5D=2021&cHash=98ecdba4e095ded9af7b72535bed20bf#:~:text=Electric%20Vehicle%20to%20Support%20Rwanda%27s%20Environmental

Rottgers, D. (2017). *The Government Role in Mobilising Investment and Innovation in Renewable Energy.* Montclair: OECD Investment Insights.

Scott, S. B. (2016). *Fact and Fiction in Global Energy Policy: 15 Contentious Questions.* Baltimore: Johns Hopkins University Press.

SE4ALL. (2020). *Impact of Policies on Electricity Financing: A Look at Rwanda.* Vienna: Sustainable Energy for All (SE4ALL).

Sikora, S. (2020). *Electric vehicles: Setting a course for 2030.* London: Deloitte Insights.

Songer, T. (2013, July 20). *Before and After Studies in Injury Research.* Retrieved from slide serve: http://www.slideserve.com

Sovacool, B. K., Brown, M. A., & Valentine, S. V. (2016). *Fact and Fiction in Global Energy Policy: 15 Contentious Questions.* Baltimore: Johns Hopkins University Press.

Sovacool, B. K., Brown, M. A., & Valentine, S. V. (2016). *Fact and Fictions in Global Energy Policy: 15 Contentious Questions.* Baltimore: Johns Hopkins University Press.

Sugarman, D., & McDougall, J. (2021, March 2). *Climate Risk and the Transition to a Low Carbon Economy.* Retrieved from BlackRock: www.blackrock.com/corporate/literature/publication/blk-commentary-climate-risk-and-energy-transition.pdf

Sweco. (2019). *Electric Mobility in Rwanda: Background and feasibility report.* Kigali: FONERWA.

Uhorakeye, U. R. (2010). Geothermal Development in Rwanda: An alternative to the energy crisis. *World Geothermal Congress 2010* (pp. 1-6). Bali, Indonesia: MININFRA.

UN. (2015). *The Paris Agreement.* Paris: United Nations.

UN-DESA, UNCTAD, & UNEP. (2011). *The Transition to a Green Economy: Benefits, Challenges and Risks from a Sustainable Development Perspective.* New York: UN.

UNEP & Bloomberg. (2020). *Global Trends in Renewable Energy Investment 2020.* Frankfurt: Frankfurt School of Finance and Management.

UNEP. (2018). *Green Energy Choices: The Benefits, Risks and Trade-offs of Low-carbon Technology for Electricity Production.* Nairobi: UNEP.

UNEP, UNCTAD, & UN-OHRLLS. (2011). *The Transition to a Green Economy: Benefits, Challenges and Risks from a Sustainable Development Perspective.* Nairobi: United Nations Environment Programme.

UNGA. (2015). *Resolution Adopted by the General Assembly on 25 September 2015.* New York: United Nations General Assembly.

USAID. (2021, April 05). *RWANDA.* Retrieved from USAID: https://www.usaid.gov/rwanda

Uwisengengeyimana, J. D., Teke, A., & Ibrikci, T. (2016). Current Overview of Renewable Energy Resources in Rwanda. *Journal of Energy and Natural Resources* , 92-97.

Virta. (2021, February 15). *THE GLOBAL ELECTRIC VEHICLE MARKET IN 2021: STATISTICS & FORECASTS.* Retrieved June 21, 2021, from Virta: https://www.virta.global/global-electric-vehicle-market

Wang, H. C. (2017). Coproducts Generated from Biomass Conversion Processes. *Technologies for Biochemical Conversion of Biomass* , 219-264.

Wikipedia. (2021, April 24). *Low-Carbon Power.* Retrieved May 4, 2021, from Wikipedia: https://en.wikipedia.org/wiki/Low-carbon_power

World Bank. (2020, January 05). *Access to electricity (%of the population)- Rwanda.* Retrieved September 17, 2021, from The World Bank: https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=RW

World Bank. (2019, November 4). *Clean Cooking: Why it matters*. Retrieved May 4, 2021, from The World Bank Group: https://www.worldbank.org/en/news/feature/2019/11/04/why-clean-cooking-matters

World bank; AFREA & ESMAP. (2014). *Clean and Improved Cooking in Sub-Saharan Africa.* Washington, DC: The World Bank Group.

World Population Review. (2021, April 28). *Rwanda Population 2021 (Live)*. Retrieved May 3, 2021, from World Population Review: https://worldpopulationreview.com/countries/rwanda-population

APPENDIX

Appendix I: Thesis work plan

TASK	MONTH						
	March	April	May	June	July	August	September
Proposal writing	✓	✓	✓				
Literature review	✓	✓	✓	✓	✓	✓	✓
Proposal presentation			✓	✓			
Data collection			✓	✓	✓		
Data analysis					✓		
Presentation of research findings						✓	✓

Appendix II: List of the existing electricity generation plants within Rwanda, as well as their associated characteristics and date of their commissioning.

No	Plant Name	Installed Capacity (MW)	Capacity Factor (%)	Available Capacity (MW)	Owner	COD	Type of Technology
1	Ntaruka	11.25	23	2.5875	GoR	1995	Hydro

2	Mukungwa I	12.00	50	6	GoR	1982	Hydro
3	Nyabarongo I	28.00	48	13.44	GoR	2014	Hydro
4	Gisenyi	1.20	65	0.78	Prime Energy	1957	Hydro
5	Gihira	1.80	70	1.26	RMT	1984	Hydro
6	Murunda	0.1	45	0.045	Repro	2010	Hydro
7	Rukarara I	9.5	40	3.8	Ngali Energy	2010	Hydro
8	Rugezi	2.6	50	1.3	RMT	2011	Hydro
9	Keya	2.2	50	1.1	Adre Hydro & Energicotel	2011	Hydro
10	Nyamyotsi I	0.1	60	0.06	Adre Hydro&Energicotel	2011	Hydro
11	Nyamyotsi II	0.1	60	0.06	Adre Hydro & Energicotel	2011	Hydro
12	Agatobwe	0.2	35	0.07	Carera-Ederer	2010	Hydro
13	Mutobo	0.2	45	0.09	Repro	2009	Hydro
14	Nkora	0.68	50	0.34	Adre Hydro & Energicotel	2011	Hydro
15	Cyimbili	0.3	50	0.15	Adre Hydro & Energicotel	2011	Hydro

16	Gaseke	0.582	90	0.5238	Novel Energy	2017	Hydro
17	Mazimeru	0.5	49	0.245	Carera-Ederer	2012	Hydro
18	Janja	0.2	80	0.16	RGE Energy UK ltd	2012	Hydro
19	Gashashi	0.2	40	0.08	Prime Energy	2013	Hydro
20	Nyabahanga I	0.2	55	0.11	GoR	2012	Hydro
21	Nshili I	0.4	60	0.24	GoR	2012	Hydro
22	Rwaza Muko	2.6	60	1.56	Rwaza HydroPower Ltd	2018	Hydro
23	Musarara	0.45	49	0.2205	Amahoro Energy	2013	Hydro
24	Mukungwa II	2.5	73	1.825	Prime Energy	2013	Hydro
25	Rukarara II	2.2	52.5	1.155	Prime Energy	2013	Hydro
26	Nyirabuhomboho mbo	0.5	35	0.175	RGE Energy UK ltd	2013	Hydro
27	Giciye I	4	40	1.6	RMT	2013	Hydro
28	Giciye II	4	40	1.6	RMT	2016	Hydro
29	Ruzizi II	12.00	89	10.68	GoR	1984	Hydro
S-total		**103.16**		**51.26**		**Hydro**	

30	Jabana 1	7.8	95	7.41	GoR	2004	Diesel
31	Jabana 2	21	95	19.95	GoR	2009	HFO-Diesel
32	So Energy	30	95	28.5	So Energy & SP	2017	Diesel
S-total		**58.8**		**55.86**		**Diesel**	
33	Gishoma	15	95	14.25	GoR	2016	Peat
S-total		**15**		**14.25**		**Peat**	
34	Biomass (Rice Husk)	0.07	95	0.0665	Novel Energy	2016	Biomass
S-total		**0.07**		**0.0665**		**Biomass**	
35	Kivuwatt Phase I	26.4	100	26.4	Contour Global	2016	Methane
S-total		**26.4**		**26.4**		**Methane**	
36	Jali	0.25	14	0.04	Mainz Stadwerke/Local Agency	2007	Solar
37	GigaWatt	8.50	14	1.19	Gigawatt Global	2013	Solar
38	Nyamata Solar	0.03	35	0.01	NMEC Nyamata	2009	Solar
39	Nasho solar PP	3.30	20	0.66	GoR	2017	solar
	s-total	21.08		1.90			Solar
40	Rusizi I	3.50	100	3.50	Snel sarl	1957	Imports
41	UETCL	2.00	100	2.00	UETCL	2006	Imports

	S-total	5.50		3.5			Imports
	Grand total	221.0		154.1			

Appendix III: Draft of emails used to collect data from governmental institutions

UNIVERSITY of RWANDA COLLEGE OF SCIENCE AND TECHNOLOGY ACE-ESD AFRICAN CENTER OF EXCELLENCE IN ENERGY FOR SUSTAINABLE DEVELOPMENT

The Chief Executive Officer,

Rwanda Development Board

Kigali, Rwanda

2nd September, 2021.

Dear Sir/Madam,

Re: <u>Student request for information regarding renewable energy investments in Rwanda.</u>

I am a student at the University of Rwanda-College of Science and Technology; I am doing a Master's degree in Energy Economics. My name is Chikonkolo Mwaba.

I write to your institution, pleading with you to provide me with information regarding Investments (monetary values), which the government of Rwanda has made year by year from 2010 to 2020, in promoting Renewable Energy integration in the energy sector of Rwanda. The information which I am requesting for is of importance to my research which I am currently working on.

I am kindly asking you to provide me with this needed information which can help me fill the table below this letter.

Your positive response to my request will be highly appreciated.

Yours faithfully,

CHIKONKOLO MWABA

UR-Student

Phone: +250789381931

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Renewable Energy investment (USD or FRW)											