

CLIMATE CHANGE IMPACTS AND MITIGATION STRATEGIES IN THE ENERGY SECTOR OF AFRICAN COUNTRIES

ABSTRACT

Many of the Sustainable Development Goals (SDGs) require access to dependable, affordable, and sustainable energy, as it has a substantial impact on health, climate, and other sectors. *This study focus on Creating an understanding of Climate Change Impacts, Identifying Mitigation Strategies as well as bringing the spot light on the Energy Sector in African Nations.* Modern energy services are also required for agricultural transformation, the creation of productive firms, and the support of revenue-generating activities. As a result of energy consumption, combustion, and greenhouse impacts from emissions of environmental pollutants such as carbon monoxide, hydrocarbon compounds, sulfur oxides, nitrogen oxides, methane, and particulates are examined. *Among the many pollutants that contribute to climate change, CO₂ emissions have received a lot of attention as the primary cause of climate change. Special attention should be given to investments and policies that promote all three goals or at the very least, those that improve one or both without worsening the other.* This report provides a (non-exhaustive) synthesis and assessment of energy consumption rates, supply, and access challenges in Africa, focusing on the connections, synergies, and conflicts with climate mitigation and adaptation strategies. Additionally, the ladder of the utilization of energy and its variety switches as income levels of individuals rise has been considered. Access to energy and its impact on the well-being of the people including the use of biomass and electricity has been expanded. Africa's energy portfolios will need to be properly calibrated to suit adequate supply, access, mitigation, and adaptation goals.

Key words: Climate change; energy; environmental pollution; mitigations; sustainable developmental goals.

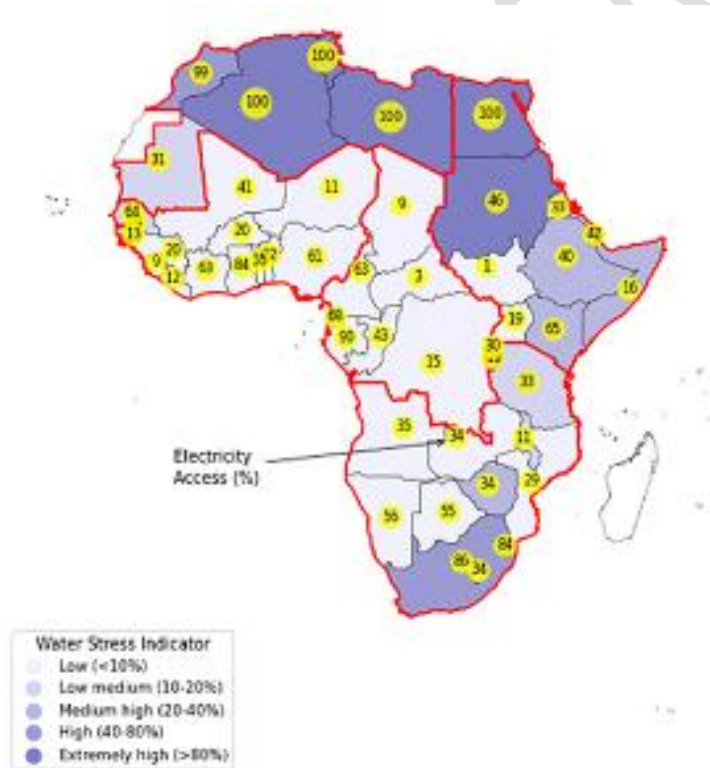
1. Introduction

Overview of Climate Change

Worldwide observed and anticipated climatic changes for the twenty-first century and global warming are significant global changes that have been encountered during the past 65 years.

Climate change is an inter-governmental complex challenge globally with its influence over various components of the ecological, environmental, socio-political, and socio-economic disciplines (Sambo, 2016). Climate change involves heightened temperatures across numerous worlds (Schwerhoff and Sy, 2016). With the onset of the industrial revolution, the problem of earth climate was amplified manifold. It is reported that immediate attention and due steps might increase the probability of overcoming its devastating impacts. It is not plausible to interpret the exact consequences of climate change on a sectoral basis (IEA, 2016a), which is evident by the emerging level of recognition plus the inclusion of climatic uncertainties at both local and national levels of policymaking (Sambo, 2016).

Africa is facing severe water and energy challenges (Welsch et al. 2013). Population increase, together with rapid urbanization and economic growth, are expected to increase water and energy needs in Africa. The interdependency of these two resources is important for Africa, which is vulnerable to climate change (IEA, 2016b). The continent hosts economically diverse countries (figure 1) with unevenly distributed energy and water resources.



Energy is used most commonly among four economic sectors: buildings (residential & tertiary), agriculture, transportation, and industrial as shown in Figure 2.

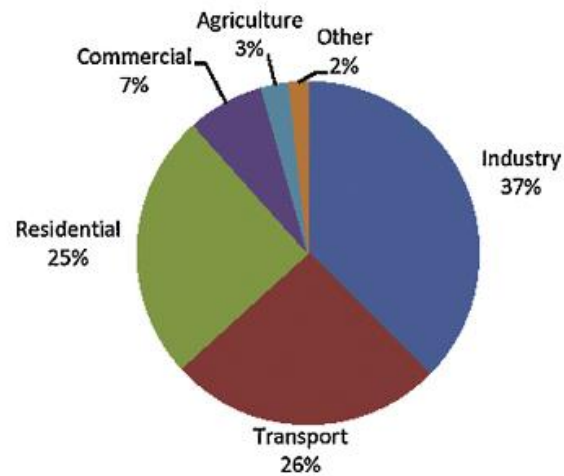


Figure 2: Distribution of energy consumption in South Africa per sector

Nevertheless, many nations' exploitation of energy to drive their growth processes comes with a growing cost in terms of pollution. The most major environmental problem in the previous decade is the influence of global change in weather, often known as **climate change** or the **greenhouse effect** (Power Africa, 2016).

Importance of Studying Climate Change in the Energy Sector

To stay informed about climate change, its effects, and ways to counteract it, such as lowering our dependency on fossil fuels like coal and oil, reducing deforestation, and implementing sustainable agriculture methods, it is imperative that we acquire knowledge about it. A global average temperature increase of two degrees could have disastrous effects, according to NASA: up to 270 million more people would face water shortages, 61 million more people would be exposed to severe drought, the frequency of deadly heat waves and extreme weather events would significantly increase, and nearly all coral reefs would perish.

Climate change endangers animals.

Unfortunately, human development, shifting weather patterns, and rising global temperatures can all have a devastating effect on animals. Animals including African elephants, giant pandas, monarch butterflies, sea turtles, tigers, polar bears, and dolphins may suffer significant habitat

losses as a result of the rising temperatures, which also have an impact on vegetation, food sources, and water availability (Welsch et al. 2013).

Devastating losses of animal habitat and life have also resulted from the dramatic rise in climate change and weather-related natural disasters including storms, droughts, and wildfires. For instance, three billion kangaroos, koalas, and other species are thought to have been killed or relocated by the Australian bushfires of 2019–20.

Conflict between humans and wildlife, including jaguars, increases when ecosystems shift and people and animals have to venture farther in quest of food, resulting in more congested areas. All of these problems ultimately run the risk of extinction if they are not properly resolved. For example, the impacts of warming ocean temperatures and an increase in conflicts with fishers and their nets and vessels are making it difficult for North Atlantic whales to live (Fay, 2009).

Climate change threatens important ecosystems.

Significant biomes and ecosystems, such as rainforests, coral reefs, and polar ice caps, are also becoming more and more devastated by climate change. One in ten of all known species on Earth and half of the world's surviving rainforest can be found in the 1.4 billion acres of dense forest that make up the Amazon. Not only is over one-third of this valuable habitat at risk from climate change, but deforestation also contributes to the emission of more greenhouse gases.

Six of the seven marine turtle species in the world, over 2,000 species of reef fish, and approximately 600 different species of reef-building coral may all be found in the Coral Triangle. This important marine habitat is under danger due to rising ocean and air temperatures, coral bleaching, and ocean acidification brought on by more carbon dioxide in the atmosphere (Welsch et al. 2013).

Polar bears and other endangered species of animals can be found in the polar regions of Earth, which are home to a variety of landscapes including tundra, polar ice caps, and the sea. Regrettably, NASA reports that Greenland is losing 280 billion tons of ice annually and Antarctica is losing 150 billion tons annually, both of which contribute to rising sea levels and the loss of habitat for the creatures who live in these regions.

Climate change damages human health and infrastructure.

The truth is that, in the absence of mitigation, climate change has the potential to harm infrastructure and natural ecosystems, increase the frequency of natural catastrophes, and present serious health hazards due to rising temperatures, pollution, and food shortages. For instance, the

devastation of coral reefs has an effect on coastal communities' food sources in addition to the marine ecosystem.

According to the U.S global change research programme, the consequences of unchecked climate change include:

- Increasing risks to human health and safety, quality of life, and economic growth;
- Agricultural productivity in the US will be disrupted by rising temperatures, droughts, flooding, and wildfires;
- Disease transmission through insects, pests, food, and water, endangering people's health;
- Crop declines and livestock health issues, endangering rural livelihoods, food security, and price stability;
- Chronic high-tide flooding in coastal communities, posing serious financial risks to homeowners and businesses; and
- Issues with aging infrastructure from heavy rain, flooding, extreme heat, and other events that will deteriorate performance and potentially pose a threat to national security, vital services, and human health.

Climate change will affect future generations.

The simple fact is that you cannot avoid the effects of climate change, regardless of who you are or where you live. Future generations will also be more negatively impacted by human activity, air pollution, ocean acidification, global warming, and devastating weather. But it is feasible to inform people about the threats posed by climate change, including the personal actions each of us can take to lessen its effects. We can also assist companies, elected officials, and environmental organizations that are prepared to take action by endorsing environmental laws that have a significant impact (Godsday et al., 2023). We can clear the path for a more secure and sustainable future for everybody by raising awareness, supporting sustainable habits, and building resilience in the face of climate challenges.

The objectives of this research are:

1. Create an understanding of Climate Change Impacts
2. Identify Mitigation Strategies
3. Bringing the spot light on the Energy Sector in African Nations

The significance of the study is that the gap in knowledge will be addressed and the impact of climate change will be ascertained as well as possible ways for sustainability.

Methodology

All of the possible studies that the search approach turned up were evaluated. Data from the chosen studies were extracted.

Statistics on Energy Consumption for Some African Countries

The statistics on energy will concern the twenty home countries, the energy group. These countries are Benin, Botswana, Cameroon, Ethiopia, Ghana, Kenya, Lesotho, Liberia, Malawi, Mali, Morocco, Mozambique, Nigeria, Rwanda, Sierra Leone, South Africa, Swaziland, Uganda, Zambia, and Zimbabwe. The energy sources considered in the current study are coal, diesel, kerosene, LPG, and petrol. The data used are collected from The UN energy statistics review for 2019. These data cover an eleven-year timeframe (2009-2019). The energy consumption of Nigeria and South Africa will be highlighted in this section (Tables 1 and 2 as well as Figs 3 and 4). The trends of energy consumption for other countries are shown by the figures in the Appendix 1.

Table 1: Fossil energy consumption for Nigeria (thousand metric tons)

| Product | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|-----------------|----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Diesel | 509 | 500 | 589 | 556 | 830 | 1307 | 770 | 1264 | 965 | 1006 | 1002 |
| kerosene | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Coal | 10 | 10 | 52 | 16 | 15 | 338 | 246 | 21 | 10 | 26 | 19 |
| LPG | 15 | 14 | 15 | 17 | 13 | 23 | 19 | 19 | 33 | 32 | 37 |
| Petrol | 95 | 155 | 168 | 177 | 179 | 434 | 294 | 457 | 302 | 297 | 289 |
| Total | 629 | 679 | 824 | 766 | 1037 | 2102 | 1329 | 1761 | 1310 | 1361 | 1347 |
| Product | Percentage (%) | | | | | | | | | | |
| Diesel | 80.92 | 73.64 | 71.48 | 72.58 | 80.04 | 62.18 | 57.94 | 71.78 | 73.66 | 73.92 | 74.39 |
| kerosene | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Coal | 1.59 | 1.47 | 6.31 | 2.09 | 1.45 | 16.08 | 18.51 | 1.19 | 0.76 | 1.91 | 1.41 |
| LPG | 2.38 | 2.06 | 1.82 | 2.22 | 1.25 | 1.09 | 1.43 | 1.08 | 2.52 | 2.35 | 2.75 |
| Petrol | 15.1 | 22.83 | 20.39 | 23.11 | 17.26 | 20.65 | 22.12 | 25.95 | 23.05 | 21.82 | 21.46 |

Table 2: Fossil energy consumption for South Africa (thousand metric tons)

| Product | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|----------|----------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Diesel | 6646 | 7081 | 7828 | 7882 | 8446 | 8509 | 8264 | 8491 | 8811 | 7815 | 10769 |
| kerosene | 394 | 338 | 382 | 352 | 423 | 445 | 458 | 520 | 581 | 568 | 559 |
| Coal | 192164 | 190235 | 186340 | 185157 | 181879 | 192856 | 183878 | 178600 | 171626 | 164415 | 182832 |
| LPG | 245 | 274 | 315 | 350 | 286 | 207 | 334 | 484 | 450 | 304 | 247 |
| Petrol | 6898 | 7068 | 7443 | 6038 | 5952 | 5935 | 6187 | 7868 | 6784 | 6313 | 5015 |
| Total | 208356 | 207006 | 204319 | 201791 | 198999 | 209966 | 201136 | 197979 | 190269 | 181433 | 201441 |
| Product | Percentage (%) | | | | | | | | | | |
| Diesel | 3.19 | 3.42 | 3.83 | 3.91 | 4.24 | 4.05 | 4.11 | 4.29 | 4.63 | 4.31 | 5.35 |
| kerosene | 0.19 | 0.16 | 0.19 | 0.17 | 0.21 | 0.21 | 0.23 | 0.26 | 0.31 | 0.31 | 0.28 |
| Coal | 92.23 | 91.9 | 91.2 | 91.76 | 91.4 | 91.85 | 91.42 | 90.21 | 90.2 | 90.62 | 90.76 |
| LPG | 0.12 | 0.13 | 0.15 | 0.17 | 0.14 | 0.1 | 0.17 | 0.24 | 0.24 | 0.17 | 0.12 |
| Petrol | 3.31 | 3.41 | 3.64 | 2.99 | 2.99 | 2.83 | 3.08 | 3.97 | 3.57 | 3.48 | 2.49 |

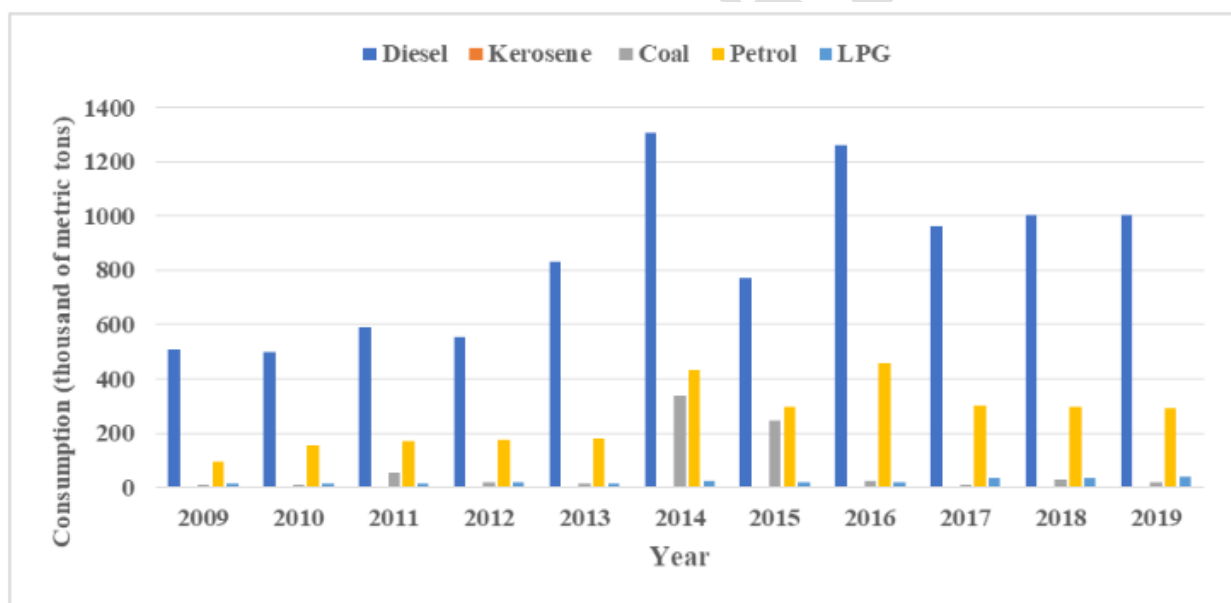


Fig 3: Fossil energy consumption for Nigeria (thousand metric tons)

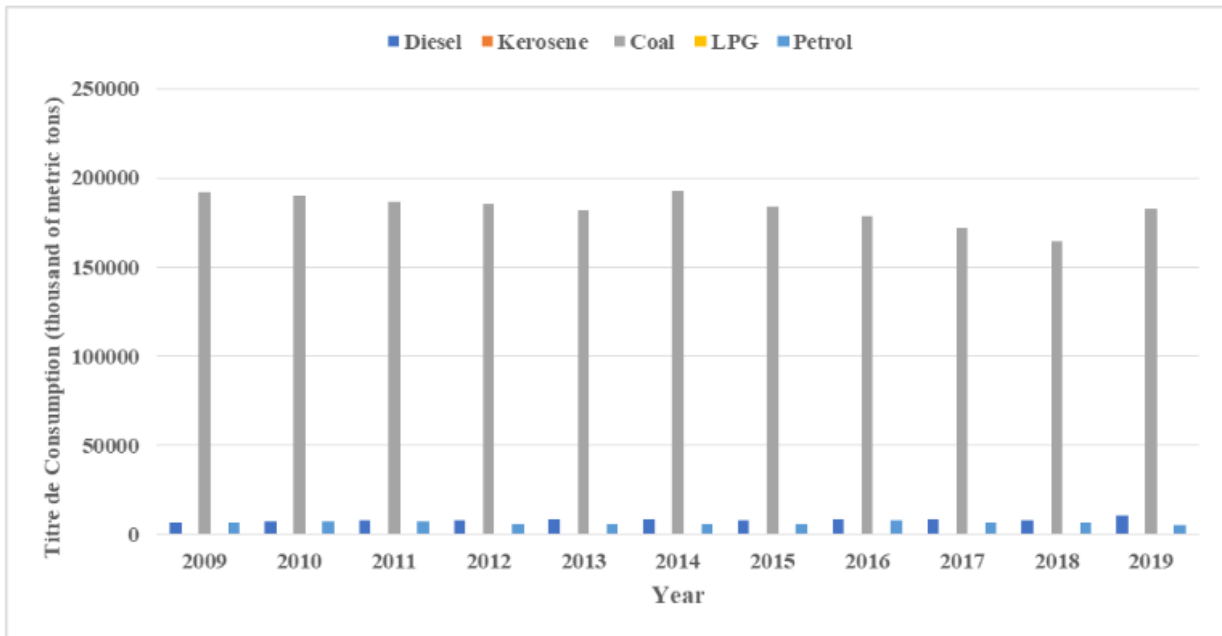


Fig 4: Fossil energy consumption for South Africa (thousand metric tons)

These statistics show that the main energy consumption of Nigeria is diesel followed by petrol while coal is for South Africa and greatly ahead of diesel. Similar conclusions can be reached for the other countries.

Results and Discussion

Climate Change Impacts on the Energy Sector

The climate change effects are becoming more perceptible in some African countries even though its manifestation is not negligible in the remaining countries. The following are some of the climate change effects observed in some of the countries concerned by this study.

Climate change is already having an impact on Botswana's energy sector. Droughts are becoming more frequent and intense, leading to reduced river flows and power generation. In response, Botswana has been investing in thermal power plants to diversify its energy mix (Fay, 2009). However, these plants are also vulnerable to climate change, as they rely on water for cooling. With rising temperatures and more frequent droughts, the country's energy sector is under increasing strain. Botswana can partly provide itself with self-produced energy. The total production of all-electric energy-producing facilities is 3 bn kWh. That is 69% of the country's

usage (IEA, 2015). The rest of the needed energy is imported from foreign countries. Along with pure consumption production, imports, and exports play an important role. Other energy sources such as natural gas or crude oil are also used.

Climate change is already having an impact on the energy sector in Cameroon. For example, hydropower production – which accounts for around 80% of the country’s electricity – has been affected by changes in rainfall patterns. This has led to increased costs and reduced output from hydropower plants (Adger et al., 2007). In the future, climate change is likely to have an even greater impact on the energy sector. Extreme weather events such as floods and droughts are expected to become more frequent and intense, affecting energy infrastructure and operations. This will have knock-on effects on the availability and affordability of energy for households and businesses. Action must be taken to mitigate the effects of climate change on the energy sector (Smit and Wandel, 2006). This includes investing in climate-resilient infrastructure and diversifying the energy mix. For example, the use of renewable energy sources such as solar and wind power can help to reduce the sector’s reliance on hydropower. By acting now, Cameroon can safeguard its energy sector against the worst impacts of climate change and ensure a secure and affordable supply of energy for years to come (Ebinger and Vergara, 2011).

The Ethiopian energy sector is highly vulnerable to climate change. The country is heavily reliant on hydropower, which is particularly susceptible to changes in precipitation and temperature. Climate change is already causing reductions in river flows and water availability in Ethiopia, with a projected decrease of up to 20% by the end of the century (Smit and Wandel, 2006). This will have a major impact on the country's ability to generate electricity and meet the growing energy demand. In addition to hydropower, Ethiopia also relies on biomass for energy. Climate change is likely to reduce the productivity of agricultural land, which will in turn reduce the availability of biomass for fuel. This will have a significant impact on the rural population who rely on biomass for cooking and heating (Ebinger and Vergara, 2011). Ethiopia is one of the most vulnerable countries to climate change and its impacts are already being felt. The country must take urgent action to adapt its energy sector to the changing climate (Fay, 2009).

Climate change is already affecting the energy sector in Ghana. The most visible impact is on hydropower generation, which is highly dependent on rainfall (African Development Bank, 2014). Decreased rainfall due to climate change has led to lower water levels in reservoirs,

resulting in reduced electricity generation. This has caused blackouts and power rationing in Ghana. Climate change is also affecting the oil and gas sector in Ghana (Ebinger and Vergara, 2011). Rising sea levels are threatening coastal oil and gas infrastructure, and extreme weather events are disrupting production. These impacts are likely to increase in the future, as climate change continues to affect Ghana. The effects of climate change on the energy sector are likely to have far-reaching consequences for Ghana. The sector is a major contributor to the country's economy, and any disruptions could have a significant impact on economic growth and development. In addition, the energy sector is critical for meeting Ghana's development goals, and any setbacks could jeopardize progress towards these goals. The government of Ghana is aware of the risks posed by climate change to the energy sector and is taking steps to mitigate these risks. For example, the government is investing in renewable energy sources, such as solar and wind power, to diversify the country's energy mix and reduce its reliance on hydropower. The government is also working to improve the resilience of the energy sector to climate change, through measures such as strengthening early warning systems for extreme weather events (Smit and Wandel, 2006). Despite these efforts, the effects of climate change on the energy sector are likely to continue to be a major challenge for Ghana in the years ahead.

Climate change is already having an impact on the energy sector in Kenya. The most obvious impact is on hydropower, which is the country's main source of electricity. Changes in rainfall patterns are reducing the amount of water available for hydropower generation, and this is likely to become more pronounced in the future as the climate continues to change. This is likely to lead to higher electricity prices and, potentially, power shortages. Other forms of renewable energy, such as solar and wind, are also likely to be affected by climate change. Changes in temperature and rainfall patterns will affect the amount of solar radiation and wind available for power generation. Again, this is likely to lead to higher prices and potential power shortages. The impact of climate change on the energy sector is likely to be negative, leading to higher prices and potential power shortages (Ebinger and Vergara, 2011). This will have knock-on effects on the Kenyan economy as a whole and could lead to increased poverty and social inequality. It is therefore essential that the Kenyan government takes action to mitigate the effects of climate change, and to adapt the energy sector to the new reality.

The climate in Lesotho is changing, and this is affecting the energy sector. The main source of energy in Lesotho is hydropower, which is generated by the country's rivers. These rivers are fed by rainfall, and as the climate changes, the amount of rainfall is becoming less predictable. This is causing problems for the hydropower plants, as they are not able to generate as much electricity as they need to. This is leading to power cuts and blackouts, which are harming the economy. The government is working on plans to diversify the country's energy sources, but in the meantime, the climate change is having a real impact on the people of Lesotho.

The climate change is already affecting the energy sector in Liberia. The main source of energy in Liberia is hydropower, which is generated by waterfalls. The waterfalls are fed by rivers, which in turn are fed by rain. As the climate changes and the rains become more erratic, the waterfalls become less reliable as a source of energy. This is particularly true in the dry season when the waterfalls are at their lowest. The hydropower plants must rely on backup generators, which are powered by diesel. This is not only more expensive but also generates more pollution. In addition, climate change is affecting the agricultural sector, which is a major source of income for many people in Liberia. The changing rains are making it difficult to predict when the planting and harvesting seasons will be, which makes it difficult for farmers to plan their activities. The lack of reliable information about the weather also makes it difficult for farmers to get the right seeds and other inputs for their crops (Smit and Wandel, 2006). As a result, many farmers are struggling to produce enough food to feed their families. The effects of climate change are already being felt in Liberia and are likely to become more severe in the future. The energy and agricultural sectors are particularly vulnerable to the effects of climate change. If the trend continues, it will hurt the economy and the people of Liberia.

Climate change is already having an impact on the energy sector in Malawi. The country is highly dependent on hydropower, which is being affected by changes in rainfall patterns. Droughts are becoming more frequent and intense, leading to reduced river flows and lower water levels in reservoirs (Ebinger and Vergara, 2011). This has led to power outages and increased costs for the energy sector. In addition, climate change is expected to increase temperatures and reduce rainfall in Malawi. This will lead to more evaporation and lower water levels in lakes and rivers. This will further reduce the country's hydropower potential and increase the need for thermal power generation, which is more expensive. The impacts of climate

change are already being felt in the energy sector in Malawi and are expected to become more severe in the future. This will have major implications for the country's economy and development.

Climate change is already having an impact on the energy sector in Mozambique. The main source of energy in the country is hydropower, which is generated by the Cahora Bassa dam on the Zambezi River. The dam provides about 95% of the country's electricity, but it is now at risk due to climate change. The Zambezi River is highly variable, and its flow is determined by the amount of rainfall in the catchment area. In recent years, there has been less rainfall in the catchment area, and this has led to lower water levels in the dam. As a result, the dam has had to reduce its electricity output. The reduced output from the dam has had a knock-on effect on the country's economy. Businesses have had to cut back on production, and this has led to job losses. The government has also had to ration electricity, which has led to blackouts and power cuts. Climate change is also having an impact on the country's agriculture. The main crop in Mozambique is maize, and the yield has been declining in recent years because of climate change. The decline in maize production has led to higher food prices, and this has hit the poorest people in the country the hardest. Climate change is expected to have several other impacts on the energy sector in Mozambique in the future. The reduced flow of the Zambezi River is likely to lead to more frequent and severe droughts, which will put even more pressure on the country's hydropower supply. The impact of climate change on agriculture is also expected to continue, and this will put upward pressure on food prices. The government of Mozambique is aware of the risks posed by climate change, and it is taking steps to try and mitigate the impacts. The country has signed up to the Paris Agreement, and it is working on many projects to increase its resilience to climate change. However, the country is already feeling the effects of climate change, and this is likely to continue in the future.

Climate change is already affecting the energy sector in Nigeria. For example, changes in precipitation patterns are affecting hydropower generation, while higher temperatures are affecting thermal power generation (IEA, 2014). In the future, climate change is expected to cause even more disruptions to Nigeria's energy sector (Lemaire, 2011). For example, sea level rise could damage coastal power plants, while more extreme weather events could damage infrastructure and disrupt power generation. Climate change is expected to have several impacts

on Nigeria's energy sector (Masera et al., 2015). These impacts will be felt in both the short- and long-term and will have serious implications for the country's economic development. In the short term, climate change is expected to cause disruptions to power generation, as well as damage to infrastructure. In the long term, climate change is expected to exacerbate existing problems in the energy sector and could lead to even more serious disruptions (Smeets et al., 2012).

The Rwandan government has been working hard to mitigate the effects of climate change on the country's energy sector. In recent years, the country has experienced an increase in droughts and floods, which has led to a decrease in hydropower production. The government has responded by investing in renewable energy sources, such as solar and wind power. These investments have helped to offset the effects of climate change on the energy sector and have ensured that Rwanda has a reliable source of energy.

4. Climate Change Mitigation Strategies in Energy Sector

This section will address the mitigation strategies in energy sector in African countries in which clear strategies have been set down. Moreover, a summary of the proposed set of strategies for all countries concerned by the current study is highlighted in the Appendix 2.

Mitigation options for Rwanda. Although agriculture is currently by far the largest source of GHG emissions in Rwanda (Smit and Wandel, 2006) in the future, emissions from other sectors will need to grow to meet development and energy access goals. Being a small country with low electricity use and many renewable sources, the current energy supply from thermal power plants only contributed 69 tons of CO₂eq. Biomass energy demand for cooking and heating contributed to an estimated 23% of total national emissions and is projected to increase significantly in 2030 (Smit and Wandel, 2006). According to GoR (2015), priority implementation in the energy sector includes:

- a) Establishment of new grid-connected renewable electricity generation in the form of large hydropower plants and solar photovoltaic systems.
- b) Installation of solar PV mini-grids in rural areas targeting 100 mini-grids.

- c) Increase energy efficiency through demand-side measures including bulk procurement and distribution of CFLs; D4.4.3 Energy Access.
- d) Environmentally sustainable use of biomass including 100% adoption of improved cookstoves by 2030, installation of 35,000 biogas plants, efficient charcoal production, and increased adoption of LPG.
- e) To reduce fossil fuel imports the country will develop efficient transport networks, including Bus Rapid Transit (BRT) in Kigali.
- f) Enhancement of industrial energy consumption by promoting efficient equipment and energy management.

Mitigation options for Ethiopia ratified the Paris Agreement in January 2017 and its NDC, if fully implemented, will lead to an estimated 64% emission reduction below the BAU by 2030 (Irish Aid, 2016). The full implementation is, however, dependent on the availability of finance, technology transfer, and capacity building, as highlighted by Ethiopia's Climate Resilient Green Economy plans (CRGE, 2012). The BAU estimation projects an increase in emission from 150MT CO₂eq to 400MT CO₂eq by 2030, with the key emission sources being agriculture, industry, and forestry (Climate Action Tracker, 2017; Irish Aid, 2016). One of its major projects is the 6000 MW Grand Ethiopia Renaissance hydropower station that will not only serve the country but will be a major source of power export to Eastern African countries. The climate action tracker rates the implementation of mitigation implementation options as sufficient to achieve its NDCs. Although not obligated to reduce its GHG emissions, Ethiopia has invested unilaterally (Ministry of Environment and Forestry, 2015). Ethiopia is considered one of the most significant countries in Africa in terms of its vast potential for renewable energy that can transform many sectors of the economy, particularly its 45 GW of hydro potential and 7 GW of geothermal (Smit and Wandel, 2006).

Kenya's climate change mitigation plans under their Nationally Determined Contribution (NDC) include a variety of options and measures: expansion in geothermal and other renewable energy options, enhancement of resource efficiency, ensuring 10% tree cover of total national land area, reduced reliance on wood fuel, efficient transport, climate-smart agriculture, and sustainable waste management. The national climate change action plan projects a reference scenario in

which emissions from electricity grow from 2.2Mt CO₂ equivalent in 2010 to 18.5Mt CO₂eq by 2030. The agriculture and forestry sector, which contributes 71% of GHG emissions in 2010, is estimated to reduce to 65% in 2030 as emissions from other sectors grow significantly. On the demand side, nine mitigation options were analyzed. Replacing and or improving biomass energy as a source of cooking fuel is considered to have high mitigation potential. Improved cook stoves are estimated to have the potential to mitigate 5.6Mt CO₂ eq by 2030. Standards and labeling for energy-efficient appliances in Kenya are also expected to yield emissions benefits. Other options at the household level include fuel-switching by replacing kerosene lamps with solar lanterns and using LPG instead of charcoal and fuel wood for cooking. In other sectors, the cogeneration of heat and power in the agriculture sector using residues and agro-energy options has significant abatement potential (Godsday et al., 2023). In the transport sector, seven options were analyzed including bus rapid transport (BRT) corridors complemented by light rail transit (LRT). These have an abatement potential of 2.8 Mt CO₂ eq annually. The introduction of biodiesel (B10) in the transport fuel has a potential of approximately 1.2 Mt CO₂ eq in 2030. (Johnson et al., 2017).

There are different climate change options in different African countries for instance there are 2 major ways to minimize emissions in the transport sector in Botswana: Reducing the number of on-road vehicles and introducing mass transportation.

5. Ways to Encourage Sustainability in the Energy Sector

In the future, it is aimed that the main energy sources become renewable and sustainable energies. Sustainability can be achieved by using energy derived from resources that can maintain current operations without jeopardizing the energy needs or climate of future generations (Letcher, 2013). The most popular sources of sustainable energy, including solar, wind, and hydropower, are also renewable. Generally, wind and solar power are considered the most sustainable because wind turbines and solar panels can be used almost anywhere in the world without significantly altering the natural landscape. The use of hydropower is significant, but it has consequences for aquatic ecosystems. New technologies related to renewable energy help to reduce environmental costs, and thus the energy systems will be operated securely and

economically without any environmental problems (Godsday et al., 2023). Enabling technologies is a major driver in sustainability and encourages the following:

1. Addressing global challenges such as low-carbon energy or resource efficiency
2. Supporting the development of new products
3. Stimulating economic growth and providing jobs

Key recommendations have been put across the globe to promote energy sustainability. Smit and Wandel, (2006) outline some of the recommendations that have been forwarded as

1. Phasing out of fossil fuel technologies and subsidies
2. Redirecting fossil fuel subsidies to energy efficiency, renewable energy, and/or essential public services
3. Declaring a climate emergency
4. Ensure all nations provide revised nationally determined contributions (NDCs) that are submitted and consistent with achieving long-term low greenhouse gas (GHG) emission development strategies
5. Investing in modernized and increased energy efficiency (e.g. buildings, equipment, and appliances), renewable energy, the electrification of industrial processes, heating and transport, energy storage, the greening of gas networks, education and training, and low-carbon research and development (Wang et al., 2021).
6. Reforming energy markets-Ensure energy markets are open, competitive, transparent, and flexible, so that they optimize the use of modern energy services and energy efficiency, allow the entry of new innovative technologies
7. Implement immediate, short-term, and long-term measures for energy transitions from gas extraction and power plants, and nuclear power plants (for example) Nigeria and South Africa) consistent with their nationally Determined Contributions (NDCs) under the Paris Agreement.

6. Conclusion

There has been growing global interest in renewable energy technology, such as solar, wind and wave energy, hydroelectricity, and biofuels, which have low or no emissions (Uziabulu et al., 2022). The technology for these systems is improving and the cost (particularly for solar) has dropped dramatically in the last five years. However, developing ways to store energy during times when, for example, the sun is not shining or there is no wind, is proving to be a major obstacle. The technology for energy-efficient batteries is improving and it is hoped that solar, wind, and wave energy sources will soon become widely available and viable. In 2013, renewable energy sources, notably wind power, contributed 44% to new electricity generation capacity, showing a pleasing growth in this sector. However, coal-burning power stations, which account for the largest greenhouse gas emissions of all energy production processes, are still the fastest-growing means of power generation.

Changes in temperature, precipitation, sea level, and the frequency and severity of extreme events will affect how much energy is produced, delivered, and consumed in Africa.

Energy plays an important role in many aspects of our lives. For example, we use electricity for lighting and cooling. We use fuel for transportation, heating, and cooking. Our energy production and use are interconnected with many other aspects of modern life, such as water consumption, use of goods and services, transportation, economic growth, land use, and population growth. Our production and use of energy also contribute to climate change.

Reducing the impacts of climate change will require substantial investments in energy sources especially renewable energies. But climate change itself could affect those renewable alternatives: changing yields for biomass crops, reduced stream flow for hydropower, diminished sunlight and increasing temperatures for solar, and altered air density and wind speed patterns for wind power.

Climate change's consequences on the energy industry will almost certainly prove disastrous for African countries. These nations must take steps to reduce the consequences of climate change and adjust their energy systems to accommodate the predicted changes.

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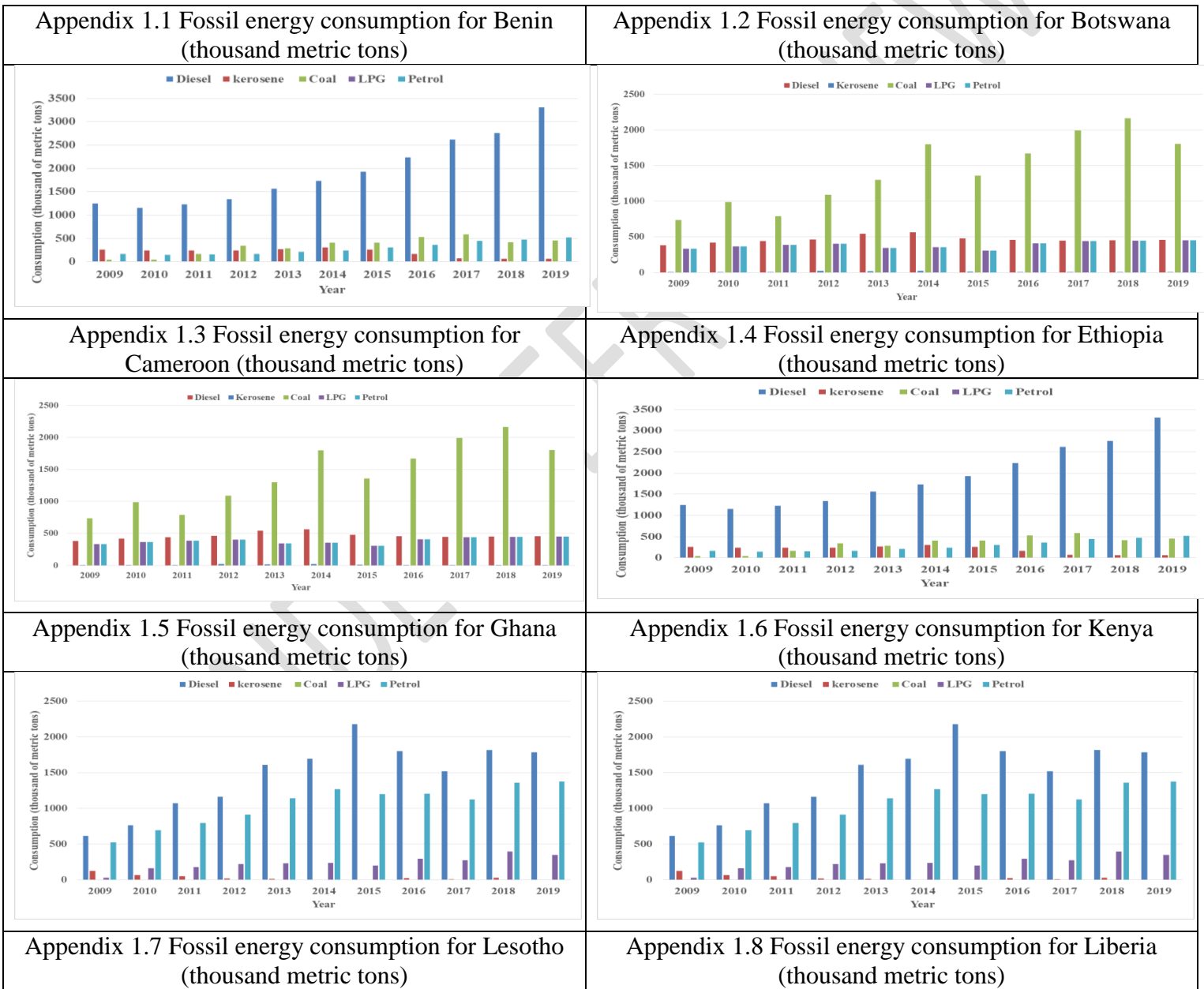
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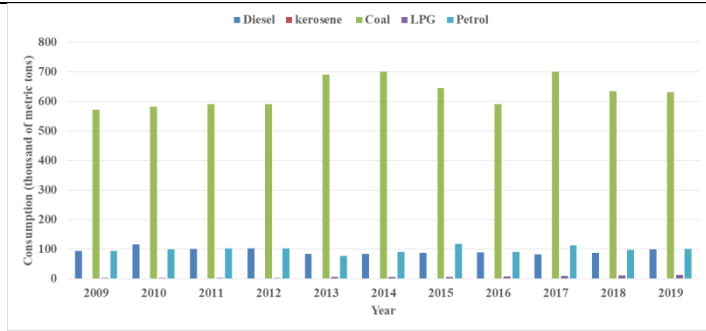
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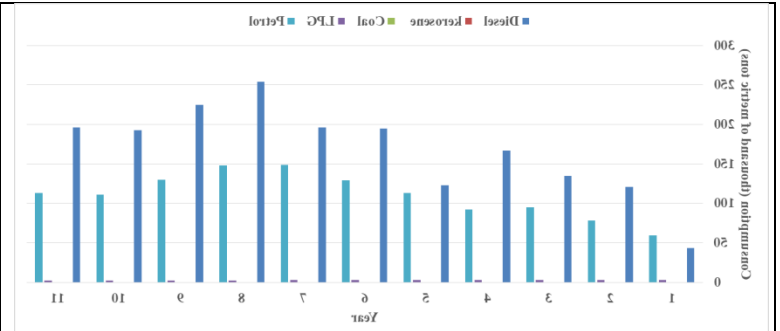
Appendix

Appendix 1 – Trend of energy consumption in African countries

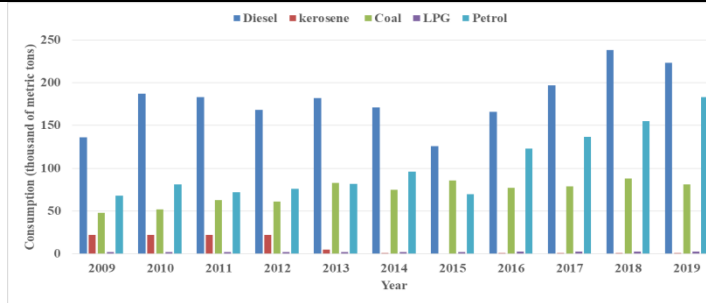




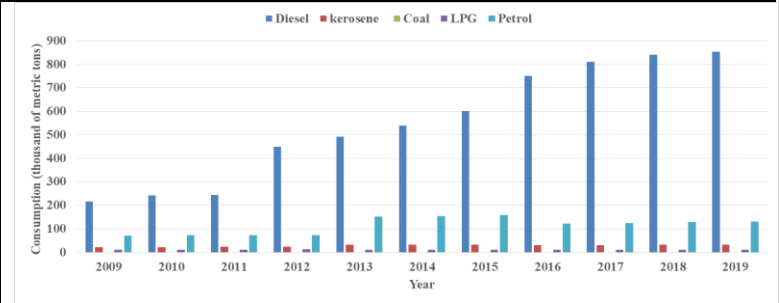
Appendix 1.9 Fossil energy consumption for Malawi (thousand metric tons)



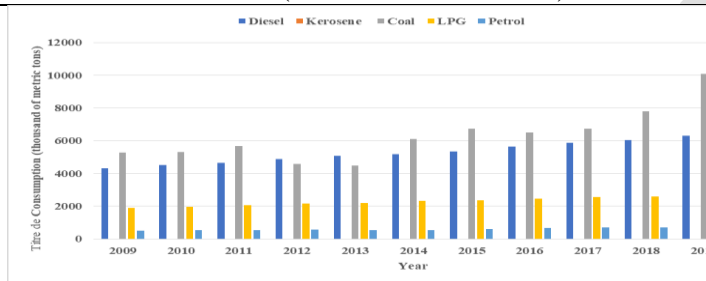
Appendix 1.10 Fossil energy consumption for Mali (thousand metric tons)



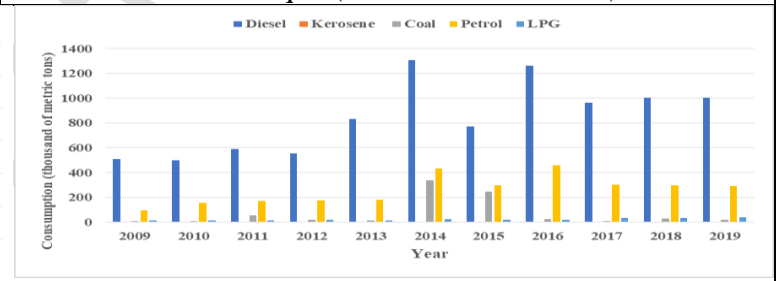
Appendix 1.11 Fossil energy consumption for Morocco (thousand metric tons)



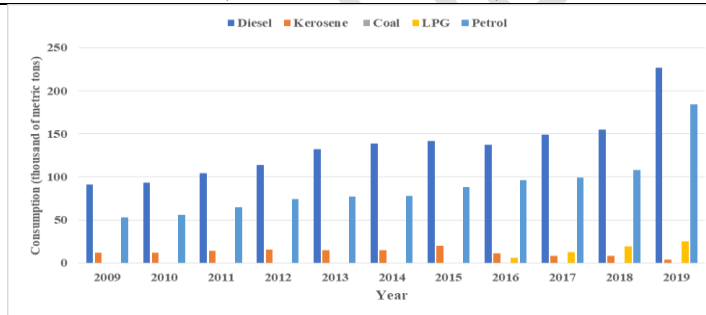
Appendix 1.12 Fossil energy consumption for Mozambique (thousand metric tons)



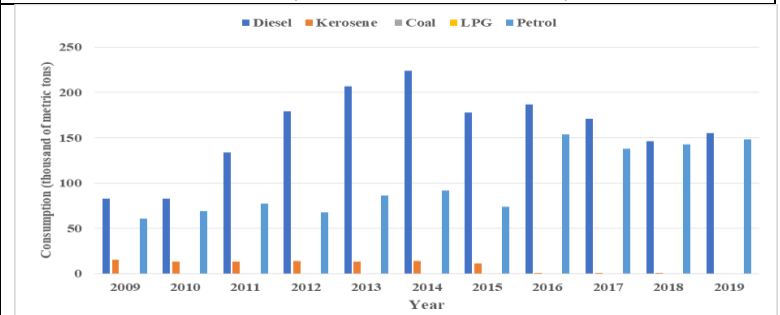
Appendix 1.13 Fossil energy consumption for Rwanda (thousand metric tons)



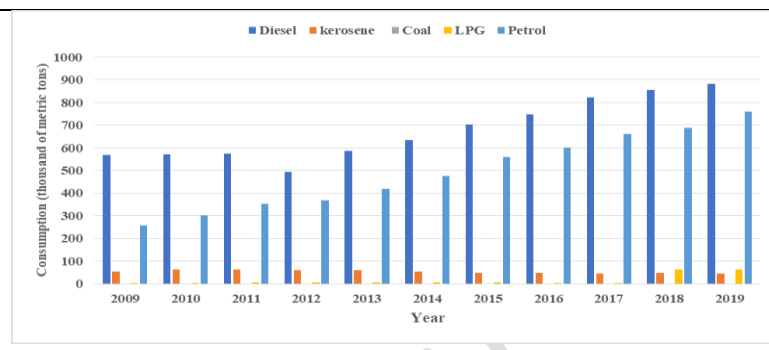
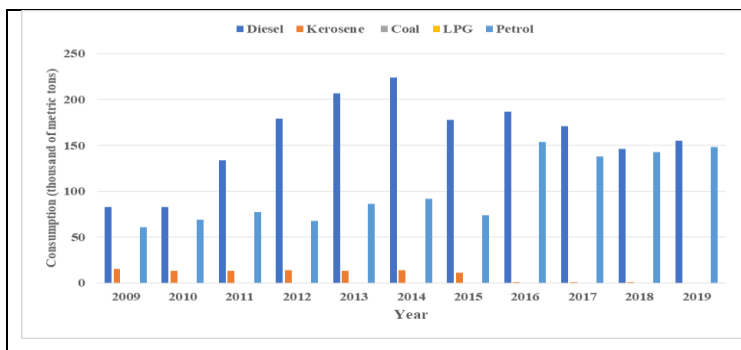
Appendix 1.14 Fossil energy consumption for Sierra Leone (thousand metric tons)



Appendix 1.15 Fossil energy consumption for Swaziland (thousand metric tons)

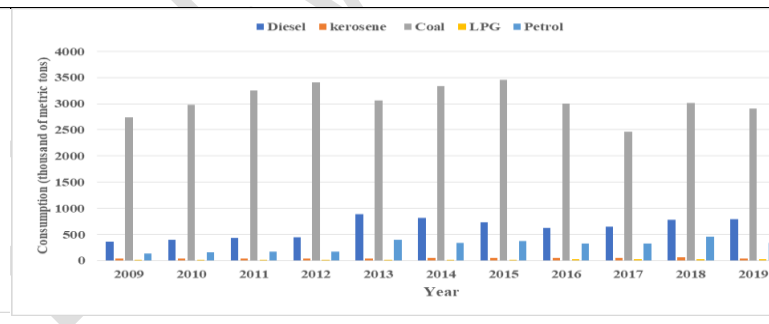
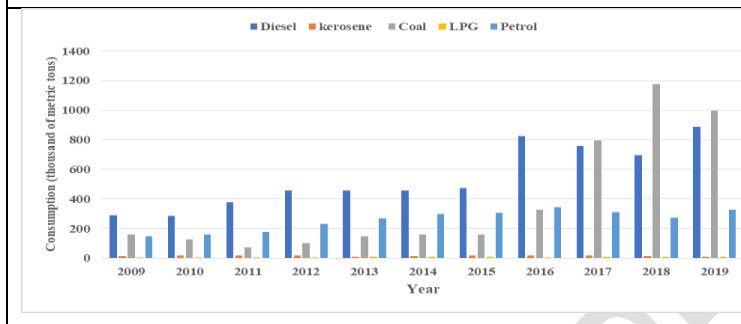


Appendix 1.16 Fossil energy consumption for Uganda (thousand metric tons)



Appendix 1.17 Fossil energy consumption for Zambia (thousand metric tons)

Appendix 1.18 Fossil energy consumption for Zimbabwe (thousand metric tons)



Appendix 2 – Recommendations for energy transition in African countries

| Country | Main energy source | Domain | Recommendations |
|----------|--|------------------------|--|
| Benin | (1) Diesel, (2) Petrol, (3) Kerosene | Transport | Adapt gas power engines and used LPG instead of petrol and Diesel |
| | | Cooking | Promote the use of LPG stove to reduce the use of kerosene in rural area |
| | | Domestic Electricity | Promote the use of solar energy to replace kerosene in rural area |
| | | | Raise the number of hydraulic power generators |
| | | Industrial Electricity | Raise the number of hydraulic power generators Raise the number of natural gas power generators |
| Botswana | (1) Coal, (2) Petrol, (3) | Transport | Adapt gas power engines and used LPG instead of petrol and Diesel |
| | | Cooking | Promote the use of LPG stove to reduce the use of kerosene |
| | | Domestic | Promote the use of solar energy to replace kerosene |

| | | | |
|---|--|------------------------|--|
| | Diesel | Electricity | Promote the use of gas power generators to reduce the use of petrol |
| | | Industrial Electricity | Raise the number of hydraulic power generators Promote natural gas power generators to move from coal |
| Cameroon | (1) Diesel, (2) Petrol, (3) LPG | Transport | Promote gas power engines for cars to reduce petrol consumption |
| | | Cooking | Raise the use of LPG |
| | | Domestic Electricity | Promote the use of solar energy to replace kerosene |
| | | | Raise the number of hydraulic power generators to reduce the use of diesel |
| Industrial Electricity | Raise the number of hydraulic power generators | | |
| | Promote natural gas power generators to move from coal | | |
| Ethiopia | (1) Diesel, (2) Petrol, (3) Coal | Transport | Promote gas power engines for cars to reduce petrol consumption |
| | | Cooking | Promote the use of LPG |
| | | Domestic Electricity | Promote the use of solar energy |
| | | | Raise the number of hydraulic power generators to reduce the use of diesel |
| Industrial Electricity | Raise the number of hydraulic power generators to reduce the use of diesel | | |
| | Promote natural gas power generators to move from coal | | |
| Country | Main energy source | Domain | Recommendations |
| Ghana | (1) Diesel, (2) Petrol, (3) LPG | Transport | Promote gas power engines for cars to reduce petrol consumption |
| | | Cooking | Raise the use of LPG |
| | | Domestic Electricity | Promote the use of solar energy to replace kerosene |
| | | | Raise the number of hydraulic power generators to reduce the use of diesel |
| Industrial Electricity | Raise the number of hydraulic power generators | | |
| | Promote natural gas power generators to move from coal | | |
| Kenya | (1) Diesel, (2) Petrol, (3) Kerosene | Transport | Raise the use of LPG |
| | | Cooking | Promote the use of solar energy to replace kerosene |
| | | Domestic Electricity | Raise the number of hydraulic power generators to reduce the use of diesel |
| | | | Raise the number of hydraulic power generators |
| Industrial Electricity | Promote natural gas power generators to move from coal | | |
| | Raise the number of natural gas power generators | | |
| Lesotho | (1) Coal, (2) Petrol, (3) Diesel | Transport | Adapt gas power engines and used LPG instead of petrol and Diesel |
| | | Cooking | Promote the use of LPG stove to reduce the use of kerosene |
| | | Domestic Electricity | Promote the use of solar energy to replace kerosene |
| Promote the use of gas power generators to reduce the use of petrol | | | |

| | | | |
|------------------------|--|------------------------|--|
| | | Industrial Electricity | Raise the number of hydraulic power generators Promote natural gas power generators to move from coal |
| Liberia | (1) Diesel, (2) Petrol, (3) LPG | Transport | Promote gas power engines for cars to reduce petrol consumption |
| | | Cooking | Raise the use of LPG |
| | | Domestic Electricity | Promote the use of solar energy to replace kerosene |
| | | | Raise the number of hydraulic power generators to reduce the use of diesel |
| Malawi | (1) Diesel, (2) Petrol, (3) Coal | Transport | Promote gas power engines for cars to reduce petrol consumption |
| | | Cooking | Promote the use of LPG |
| | | Domestic Electricity | Promote the use of solar energy |
| | | | Raise the number of hydraulic power generators to reduce the use of diesel |
| Mali | (1) Diesel, (2) Petrol, (3) Kerosene | Transport | Raise the use of LPG |
| | | Cooking | Promote the use of solar energy to replace kerosene |
| | | Domestic Electricity | Raise the number of hydraulic power generators to reduce the use of diesel |
| | | | Raise the number of hydraulic power generators |
| Industrial Electricity | Promote natural gas power generators to move from coal | | |
| | Raise the number of natural gas power generators | | |

| Country | Main energy source | Domain | Recommendations |
|-------------------|--|----------------------|--|
| Mozambique | (1) Diesel, (2) Petrol, (3) LPG | Transport | Promote gas power engines for cars to reduce petrol consumption |
| | | Cooking | Raise the use of LPG |
| | | Domestic Electricity | Promote the use of solar energy to replace kerosene |
| | | | Raise the number of hydraulic power generators to reduce the use of diesel |
| Nigeria | (1) Diesel, (2) Petrol, (3) LPG | Transport | Promote gas power engines for cars to reduce petrol consumption |
| | | Cooking | Raise the use of LPG |
| | | Domestic Electricity | Promote the use of solar energy to replace kerosene |
| | | | Raise the number of hydraulic power generators to reduce the use of diesel |
| Industrial | Raise the number of hydraulic power generators | | |

| | | | |
|--|--|---------------------------|--|
| | | Electricity | Promote natural gas power generators to move from coal |
| Rwanda | (1) Diesel, (2) Petrol, (3) LPG | Transport | Promote gas power engines for cars to reduce petrol consumption |
| | | Cooking | Raise the use of LPG |
| | | Domestic Electricity | Promote the use of solar energy to replace kerosene |
| | | | Raise the number of hydraulic power generators to reduce the use of diesel |
| | | Industrial Electricity | Raise the number of hydraulic power generators |
| Promote natural gas power generators to move from coal | | | |
| Sierra Leone | (1) Diesel, (2) Petrol | Transport | Promote gas power engines for cars to reduce petrol consumption |
| | | Cooking | Promote the use of LPG |
| | | Domestic Electricity | Promote the use of solar energy to replace petrol |
| | | | Raise the number of hydraulic power generators to reduce the use of diesel |
| | | Industrial Electricity | Raise the number of hydraulic power generators |
| Promote natural gas power generators to move from diesel | | | |
| Morocco | (1) Coal, (2) Diesel, (3) LPG | Transport | Adapt gas power engines and use LPG instead of petrol and Diesel |
| | | Cooking | Raise the use of LPG |
| | | Domestic Electricity | Promote the use of solar energy to replace kerosene |
| | | | Raise the use of gas power generators to reduce the use of petrol |
| | | Industrial Electricity | Raise the number of hydraulic power generators |
| Promote natural gas power generators to move from coal | | | |

| Country | Main energy source | Domain | Recommendations |
|--|---|---------------------------|---|
| South Africa | (1) Coal, (2) Diesel, (3) Petrol | Transport | Adapt gas power engines and use LPG instead of petrol and Diesel |
| | | Cooking | Promote the use of LPG |
| | | Domestic Electricity | Promote the use of solar energy to replace kerosene |
| | | | Promote the use of gas power generators to reduce the use of petrol |
| | | Industrial Electricity | Promote the use of hydraulic power generators to move from coal |
| Promote natural gas power generators to move from coal | | | |
| Swaziland | (1) Diesel, (2) Petrol | Transport | Promote gas power engines for cars to reduce petrol consumption |
| | | Cooking | Promote the use of LPG |
| | | Domestic | Promote the use of solar energy to replace petrol |

| | | | |
|--|--|------------------------|--|
| | | Electricity | Raise the number of hydraulic power generators to reduce the use of diesel |
| | | Industrial Electricity | Raise the number of hydraulic power generators |
| | | | Promote natural gas power generators to move from diesel |
| Uganda | (1) Diesel, (2) Petrol, (3) Kerosene | Transport | Adapt gas power engines and used LPG instead of petrol and Diesel |
| | | Cooking | Promote the use of LPG stove to reduce the use of kerosene in rural area |
| | | Domestic Electricity | Promote the use of solar energy to replace kerosene in rural area |
| | | | Raise the number of hydraulic power generators |
| Industrial Electricity | Raise the number of hydraulic power generators | | |
| | Raise the number of natural gas power generators | | |
| Zambia | (1) Coal, (2) Diesel, (3) Petrol | Transport | Adapt gas power engines and used LPG instead of petrol and Diesel |
| | | Cooking | Promote the use of LPG stove to reduce the use of kerosene |
| | | Domestic Electricity | Promote the use of solar energy to replace kerosene |
| | | | Promote the use of gas power generators to reduce the use of petrol |
| | | Industrial Electricity | Raise the number of hydraulic power generators |
| Promote natural gas power generators to move from coal | | | |
| Zimbabwe | (1) Coal, (2) Diesel, (3) Petrol | Transport | Adapt gas power engines and use LPG instead of petrol and Diesel |
| | | Cooking | Promote the use of LPG |
| | | Domestic Electricity | Promote the use of solar energy to replace kerosene |
| | | | Promote the use of gas power generators to reduce the use of petrol |
| | | Industrial Electricity | Promote the use of hydraulic power generators to move from coal |
| | | | Promote natural gas power generators to move from coal |