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An Overview of Hydropower and Biomass Use in Mozambique

Shylet Tsoca

Environmental Sciences at European University of Lefke, Lefke, Cyprus
Email: shyletsoca@gmail.com

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Abstract

Mozambique is doing well in its implementation of renewable energies (green energies), and this is a positive move as it sees to the protection of the environment, reduction of the emission of greenhouse gases, and the reduction of the country's reliance on foreign fuels which are expensive and an economic burden on a country with an extremely high poverty index in Africa. Green energies like hydropower, solar energy and biomass are already in use with biomass leading, followed by hydropower. This paper explores and analyses the use of hydropower and biomass in Mozambique with the focus being on the extent of their use in the country and the impacts associated with their use. It also aims to look at policies that have been implemented to promote the use of these renewable sources of energy, and it discusses the success of the implementation of these policies and if they have helped in making the use of biomass and hydropower sustainable. The environmental impact of the use of green energies is minimum if compared to fossil fuels but this paper aims to show that there is concern in their use, especially the use of Biomass as there is little consideration being given to its environmental footprint. Mozambique has great potential for hydropower and bioenergy, but potential does not depict the reality as there are several issues to consider before the implementation of such in a developing country like Mozambique and this work explores the existence of issues that affect or hinder the growth and the sustainability of the use Biomass and Hydropower, and this is crucial in policy revision and implementation.

Keywords

Renewable Energies, Green Energies, Hydropower, Solar Energy, Biomass, Greenhouse Gases, Environmental Impacts, Environmental Footprint, Fossil Fuels, Developing Country, Sustainability Policy Implementation

1. Introduction

Mozambique, a former Portuguese colony located in the South-East of Africa shares borders with Tanzania, South Africa, Eswatini, Zimbabwe, Zambia, and Malawi. It has a 2500 km Indian Ocean coastline that is to the east of Madagascar [1]. Mozambique has a lot of economic potential as it boasts of large areas of arable land, water, energy as well as minerals. These minerals include the newly discovered natural gas, coal, graphite, and iron ore. It has an estimated population of 31 million people, about two-thirds of the population work in rural areas, and as of 2021, 40% of the population (36% on grid and 4% off grid) had access to electricity. The government has set a milestone of having new installations of about 2300 MW set by 2030, and about five million new connections both on and off grid [2] [3].

This paper will give a critical look at the use of biomass especially in its traditional form (charcoal and firewood), and hydropower in Mozambique. It gives a brief overview of Mozambique's energy sector, and it goes on to look in detail at biomass and Hydropower. Focus is given on the factors driving the use of these sources of energy, the limitations in their use which include environmental, social, and economic impacts. Further, the paper looks at strategies, policies, and laws that govern the use of biomass and Hydropower in the country. It also focuses on how climate change will impact hydropower production and use in Mozambique.

2. Mozambique's Power Sector

Mozambique's power sector has mostly been state controlled but there have been recent changes which have seen to the inclusion of the private sector. Since 60% of the country still does not have access to electricity, the country has embarked on a campaign for universal energy access by 2030 [2] [3]. Mozambique has the largest power generating potential in Southern Africa (187 gigawatts). This is from the untapped coal, hydro, gas, wind, and solar resources. Currently, it has an installed capacity of 2.7 GW, and this is from hydropower (79%), gas (16%), solar (1%), and other (4%) as indicated in **Figure 1** below.

From the data shown in **Figure 1** below, Mozambique gets most of its electric power supply from Hydropower, a renewable energy source, followed by gas which is a non-renewable source. Mozambique is the greenest country in the African continent and according to a report done by Energy and power [4], Mozambique is the greenest country in the world with hydropower accounting for the large part of its installed capacity as indicated in **Figure 1** below. With a growing population, economy, and industry, demand for energy will increase by 7% to 8% annually and this means that there is a need to extend the capacity of energy production.

With an estimated hydropower potential of 12,500 MW, it has one of the largest hydroelectric potentials in Southern Africa. This figure regarding hydropower potential in Mozambique is highly attractive, although only roughly 2200

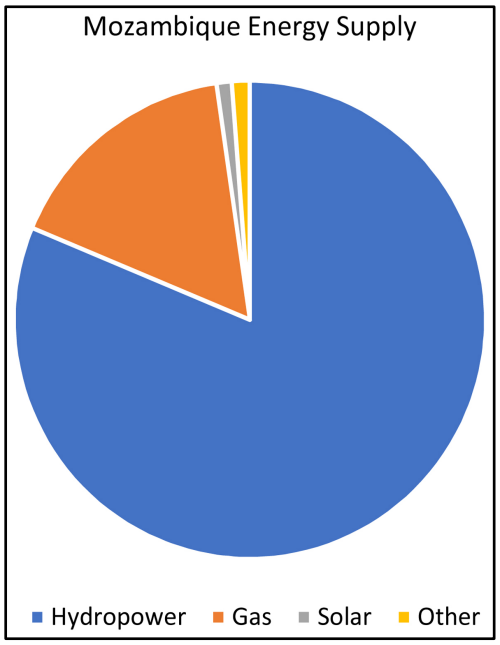

Figure 1. Energy supply in Mozambique.

MW of it has been developed in a manner providing it access to the national grid. Since a large part of the population still does not have access to electricity, the Mozambican government promoted solar PV solutions in rural areas and around 700 schools and 800 public buildings now use solar energy [5]. Use of solar energy is therefore at a small scale (household or institutional and it mostly not accounted for). Mozambique has one solar power plant which is in Mocuba (Zambezia Province). This plant which was established in 2016 has increased Mozambique's energy capacity by 40 MW.

Green energies should play a major role in increasing Mozambique's energy production. Green Energies are those that are used and are continually replaced by nature and come directly or indirectly from the sun. These include solar energy, hydropower, biomass energy, wind energy, and geothermal energy. Renewable energy does not include energy resources derived from fossil fuels, waste products from fossil sources, or waste products from inorganic materials [6]. It has become viable to use renewable energies more than fossil fuels because of the excessive costs and limited sources of fossil fuels in a world where the energy consumption is growing daily. Renewable resources are the viable solution to improve the environmental condition of our planet by mitigating the number of emissions while not affecting the countries economically.

3. Hydropower in Mozambique

As noted above electricity supply from green energies in Mozambique is from hydropower and solar. Hydropower is a very attractive form of electrical power generation for several reasons: it is one of largest sources of electricity in the world, the electrical power output takes only a short time to produce, it is always

available since it represents renewable energy, and it is dependent upon water being available in large amounts [7]. The largest amount of electrical energy consumed in Mozambique (79%) is from Hydropower (**Figure 1**). It is estimated at about 2200 MW (with 80% of this located in the Zambezi valley). This includes the existing Cahora Bassa power station (2075 MW). Cahora Bassa is an independent power producer and exports most of its power to Southern Africa (73%), and only 500 MW is supplied to Electricidade de Moçambique (EDM), the national energy company. Mozambique has a total of six hydropower stations, the Cahora Bassa Hydropower plant (2.075 MW), Mavuzi (52 MW), Chicamba (38.4 MW), Corumana (16.6), Lichinga (0.73 MW) and Cuamba (1.9 MW). Half of the hydropower stations are found in the Central part of the country (Manica and Tete Provinces). Cahora Bassa is a private entity, with the rest belonging to EDM Mavuzi and Chicamba (built on Rovue River) are EDM's largest stations. The two have recently benefitted from a rehabilitation program from the Norwegian and French Government [8] which extended their lifetime to 30 years and increased their capacity to 86 MW (combined). Mozambique has several hydropower projects which are still under development. One of these projects is the Mpanda Nkuwa, a 1.500 MW project which will make it the second largest hydropower station in the country. Also, 70% of the estimated hydropower potential is concentrated in the Zambezi Valley, which is mostly on the Zambezi River. Below is a table of Hydropower Projects which are in plan:

There are several hydropower projects under development in Mozambique as noted in **Figure 2**, and the development of hydropower is now being done using the National Climate Change Adaptation and Mitigation Strategy (NCCAMS), which includes a strategic action to improve the capacity for integrated water resources management including building climate resilient hydraulic infrastructures. This entitles to the protection of floodplains and water for all uses, agriculture, livestock, and fisheries. This guarantees the availability of water for other uses, for example, agriculture and see to the protection of the resource (water).

The functioning hydropower and other renewable power stations still fail to

Name of Project	Location	Size	Status
Mpanda Nkuwa	Tete	1500 MW	Commercial Agreements
Cahora Bassa North Bank	Tete		Pre-feasibility
Lupata	Sofala		Feasibility
Boroma	Tete		Feasibility
Lurio	Cabo Delgado		Feasibility
Ruo	Zambezia		-
Mavuzi 2 & 3	Manica		Conceptual
Malema	Nampula		Pre-feasibility
Massingir	Gaza		Pre-feasibility

Figure 2. Hydropower projects in development in Mozambique [9].

supply energy to rural areas and a large part of Mozambique's population is found in rural areas. In Mozambique, FUNAE (National Fund for Rural Electrification), an entity that is held up by donor funds is responsible for rural off-grid electrification and is seeing to the installation of solar PV systems as well as Diesel generators in district headquarters, clinics, hospitals, schools, etc.

3.1. Policies and Regulations Governing Hydropower in Mozambique

Unlike the case of Biomass, there is no specific policy that governs the use of Hydropower in Mozambique. The policies that function include, New and Renewable Energy Development Strategy for 2011-2025 (2011), National Determined Contribution, National Electrification Strategy (2017) Electrical Infrastructure Integrated Master Plan 2018-2043 [1] [10]. Since 1999, The Government liberalized the energy sector of the country and an influx of direct foreign investments into hydro-projects within Mozambique to meet the government's rural electrification program.

On the 17th of October 2014, the Government of Mozambique approved a regulation for renewable energy feed-in tariffs (REFIT). The REFIT scheme targets generation plants of 10 MW or less, connected to the main grid and using any of the four types of renewable technology: hydropower, solar, biomass and wind. The feed-in tariffs vary by plant size and technology, ranging between 4.06 - 5.74 MT/kWh (12.23 - 17.29 USc/kWh) for biomass, 4.12 - 8.00 MT/kWh (12.41 - 24.09 USc/kWh) for wind, 2.29 - 4.81 MT/kWh (6.90 - 14.49 USc/kWh) for hydropower and 7.91 - 13.02 MT/kWh (23.82 - 39.21 USc/kWh) for solar, although the tariffs could be changed after three years [11]. Another measure the Government took was to provide subsidised financing for renewable energy projects through public funds and low-interests or government loans, exemption of duty and VAT payment for equipment used in plants generating renewable energies, and the reduction of cooperate income tax on these projects [12].

Hydropower plants are governed by the Environmental Law Act No. 20/97 Environment Act which is not specifically for hydropower projects but for every project which interacts with the natural environment or involves the exploitation of natural resources. According to Chisompola [13] this Act establishes protective requirements to be satisfied to exploit the environmental sector and impact assessment conditions to avoid environmental disasters. It focuses on environmental management principles, based on rational use and management, enhancement of local knowledge, awareness, integrated vision of the environment, participation wide, equal access, accountability, and national and international cooperation. Further, Environmental Impact Assessment Regulation (Decree 45/2004) regulates the environmental licensing in Mozambique. It requires that all large-scale projects such as the construction hydropower plants as well as all activities conducted in the protected areas are subject to a detailed Environmental and Social Impact Study (ESIA).

3.2. Impacts of Using Hydropower and in Mozambique

The implementation of green energies in Mozambique is to a large extent moving in the right direction. Hydropower is an attractive energy source since there is no burning of fuel, thus minimal pollution, water is a free renewable natural resource which produces green energy with reduced greenhouse emissions. Further, hydropower technology is dependable as it has the best conversion efficiencies of all known energy sources (about 90% efficiency, water to wire), and has been proven over time. Although it requires high initial investment, it has a long lifespan with extremely low operation and maintenance costs [14], which is a great advantage for low-income countries like Mozambique.

Further, the water that drives the turbines in hydropower plants is not consumed but is available for various other essential uses. In fact, a significant proportion of hydropower projects are designed for multiple purposes. Not only do the dams prevent or mitigate floods and droughts, but they also provide water for irrigation, domestic, municipal, and industrial use, and can improve conditions for navigation, fishing, tourism, or leisure. A good example of such a dam is the Chicamba Dam in Manica Province in Mozambique where we find a hydropower plant, fishing, tourism, irrigation, and water supply for domestic use to the nearby towns and cities (Chimoio, Manica and Gondola).

There are however challenges that Mozambique might face, and these include geographical, financial, political, and social. Seeing that Mozambique depends mostly on hydro power for electricity production, this comes with its own disadvantages. The major disadvantage is the seasonal droughts that the country experiences and these may be exacerbated by climate change. Also, the high costs associated with the initial setup of a hydropower station are a setback. Mozambique's largest hydropower plant, Cahora Bassa was under the control of the Portuguese for many years and the Mozambican government managed to get total control of it a few years back. The power produced at this station is mostly imported and the larger part of the Mozambique population still does not have access to electricity.

Hydropower stations are also geographically restricted, but they have a small environmental footprint. They however have their own negative impacts on the environment like the occurrence of floods, for example, the 1978 Cahora Bassa floods and the 2007 Mozambique floods. The 1978 floods caused deaths, displacement of people and vast economic damage. In the 2007 floods, Cahora Bassa overflowed and caused the displacement of many people. Cahora Bassa is located on the Zambezi River and downstream and transboundary impacts also must be considered, and it will be important to implement an Integrated Water Management (IWM) system on the Zambezi River or in the Zambezi Valley since it is a transboundary river. Further, hydropower stations are a threat to endemic species, including endangered ones due to the modification of the natural habitats or inundation.

Apart from direct contact, there can also be wildlife impacts both within the

dammed reservoirs and downstream from the facility. Water in the reservoir is more stagnant than river water. This causes the reservoir to have higher than normal amounts of sediments and nutrients, which can lead to the growth of excess algae and other aquatic weeds. These weeds can choke other river animal and plant-life, unless they are manually harvested or controlled by introducing fish that feed on them. Also, water is lost at a faster rate through evaporation in dammed reservoirs than in flowing rivers [14]. Floodplains can be lost or degraded leading to the disturbances in habitats and livelihoods. A hydropower plant can alter the hydrological and morphological conditions downstream of the hydropower plant which further affects the availability and the quality of water for other uses. In some cases, there can be reservoir impairment, sedimentation, eutrophication ad the accumulation of upstream pollutants.

The occurrence of cyclones especially along the coastal lines also affects power infrastructures and this impact on investments as there is the risk of losing everything. The Chicamba and Mavuzi hydropower stations in Manica province suffered some damages due to Cyclone Idai (2019). These had to go through restorations, and these restorations were mostly donor funded. The restorations included reconstruction of access roads, restructuring and fortification of riverbanks, repair of flood gates and transmission lines, and the replacement of the roof over Mavuzi power plant.

3.3. The Future of Hydropower Production in the Face of Climate Change

Rainfall and topography offer the greatest hydropower potential in Mozambique within the Zambezi Valley where we find the Cahora Bassa in Tete and Mavuzi and Chicamba hydroelectric plants on the Revue River in Manica with 80 MW of power output. Together these plants have a generating capacity of about 2200 MW, of which Cahora Bassa provides 95% of the total hydropower produced in Mozambique. The variability of climate in Mozambique already affecting negatively in the water resources sector due to climate variations. Studies have shown evidence that temperatures have increased by 0.6˚C from 1960 to 2006 and by, 0.13˚C per decade and precipitation has decreased by 2.5 mm per decade. The rain season is starting late, and the dry period has become longer. There has been an increase in the occurrence of extreme weather events (since the late 90s). These include droughts, heavy flooding events, tropical storms, and tropical cyclones [15]. Water supply is low in Africa and the governments especially in Mozambique are having difficulties in delivering the resource to the population. According to Uamusse *et al.* [7], climate change will further complicate future management of water systems. The southern African countries where Mozambique is located, are expected to experience a decrease in annual discharge which will affect the amount of surface water in this part of the continent by the end of the century. Hydropower depends on a predictably steady precipitation pattern. The use of hydropower in Mozambique is therefore faced with potential risks due to its geographical location. Mozambique is identified as a country which is

vulnerable to climate change. Located along the coast of the Indian Ocean, Mozambique is semi-arid, subtropical in the south, and tropical in the north, and it is usually affected by seasonal air circulation of the Indian Ocean. Being a downstream country and being a country with low technology, high poverty and a low capacity to adapt to societal changes, hydropower use in Mozambique is expected to be negatively affected by climate change in the future.

The Zambezi hydropower system (Cahora Bassa, Mavuzi, and Chicamba) is likely to be affected negatively because of future climate changes. Increasing air temperature leading to increased evaporation, and reduced rainfall, both contribute to a decrease in river flows and increased reservoir evaporation. Climate change is projected to alter the frequency of precipitation, floods, and drought events in Mozambique. Further, regional studies have been made for the Zambezi River, which has the largest river basin, where it is estimated that the output from major Zambezi hydropower plants will decline by 10% - 20% under a drying climate [7]. To mediate this potential reduction, there is a need for the application of an Integrated Water management system and cooperation with other governments in the management of shared water resources in the entire southern African region. Consequently, the decrease in water resources is expected to cause a decrease in hydropower production potential, by 9% in the 2020s, 18% in the 2050s and 28% in the 2080s, for a medium emission scenario [16]. This decrease in hydropower production will affect electricity supply in the country since most of the electricity is from hydropower.

4. Use of Biomassin Its Traditional Forms in Mozambique

Mozambique is a country rich in natural resources with 50% of it still covered in Forest and because of its large availability of land and favourable environmental conditions for agricultural production, it is a promising country for sustainable biomass production. Since only 40% of the population has access to electricity, and major part of the population (80%) still relies on biomass, and biomass makes up 75% of the total energy consumption in the country. The charcoal market is at an estimated value of 250 million USD, and about 15% of the population participates in the charcoal market.

The population is growing at a rapid pace, and this is putting pressure on the biomass resources available. Mozambique is therefore losing parts of its forests and thus a future low-cost energy resource. The country still heavily relies on traditional, non-standardised and non-sustainable biomass energy [17] mostly based on plants feedstocks (firewood and charcoal). Mozambique has different biomass sources, although forest (tree harvesting) biomass is mostly used. There are woody residues from conventional logging or from dedicated plantations, biomass from industrial and agro industrial wastes, waste materials from manufacturing industries of wood and plant materials, waste materials from the wood firing process referred to as “black liquor”, and residues sugarcane processing. Sugar cane foliage could also be used for power generation [18].

In Mozambique, biomass energy in the form of charcoal or firewood is used by over 85% of urban households in Mozambique [17] [19]. Although the country has vast areas still covered in forest, most of the surplus biomass is inaccessible to the main zones of consumption, and the wood resource base is also diminishing, principally because woodlands and trees in agricultural areas are being cleared to open new land for farming. It is estimated that 80% of urban and peri-urban households use charcoal in the urban market and most rural households use firewood with traditional stoves [20]. The charcoal industry generates millions of dollars, with a value chain that includes the producers of charcoal, transporters, and retailers. Firewood on the other hand is commonly used in rural parts of Mozambique, and all the bakeries in the country use firewood in their production of bread. In a study done in Mabale District in Gaza [21], firewood was commonly used in all villages, with 86% - 100% of households using firewood as their primary source of fuel. Two-thirds of these collected firewood from woodlands while the remaining one-third collected firewood from agricultural fields or fallows. This shows that a greater part of the population clears forest for their firewood, which is a great environmental concern as the study does not give any existence of sustainable management of these woodlands or attempts at reforestation in the area.

It is estimated that charcoal users in Maputo and Matola use an equivalent of 1.8 million tonnes of wood per year, and this translates to 141,985 ha of forest cleared annually to produce charcoal to feed just these two cities. About 12 045 hectares of forest are removed each year in Sofala and Manica provinces. In Nampula, 722,518 tonnes of wood are consumed per year. This translates to an annual deforestation rate of 23,360 hectares. There are however no noticeable efforts of reforestation or any sustainable forestry [22]. There are various reasons why charcoal continues to be extensively used in Mozambican households. These reasons are economic, social and in some cases lack of awareness. Most of the population is not aware of the fact that it is more economical to use gas for cooking compared to using charcoal. The price of a 50 kg·s of charcoal in Chimoio, Manica Province is around MZN 650, which is equivalent to about 10.17 USD. While the price of a 10 kg LPG is around MZN 1100, which translates to 17.22 USD. Although the gas seems expensive to purchase and especially since it just comes in these large containers only and not available in smaller containers, it is still more economical and cleaner to use. The unavailability of smaller container of LPG makes it difficult for parts of the population to afford using it for cooking, and a significant part of the population cannot afford to use electricity for cooking and heating and the use of biomass is therefore going to continue for a long time still.

There is a need to move towards modern and sustainable biomass use, for example the use of organic waste in generating heat and energy for cooking to promote sustainability and to avoid overexploitation of natural resources. The sector however continues to be mostly informal which makes it difficult for poli-

cies and strategies to be applicable in making it sustainable.

4.1. The Use of Biofuels

Modern biofuels are a renewable energy source that has a long the potential to address both environmental impacts and security issues associated by the global dependence on fossil fuels. Energy crops are the largest potential source of bioenergy feedstocks but land availability and other priorities like food security must be considered first before allocating land or crops to the production of biofuels. Based on global bioenergy production potential assessments, Mozambique was identified as one of the promising biomass production regions in tropical Africa, with the capacity of producing up to 6.7 EJ (all energy values for fuels in HHV) of bioenergy annually with moderate introduction of agricultural technology and use and the guarantee of forestry protection and meeting growing food demand [23]. They assume that Mozambique can achieve full energy independence and supply international markets with surplus production. These predictions are often based on the country's favourable climate and environmental conditions, availability of arable land and water for potential biofuel crop production, large rural population for cheap labour in intensive biomass production, government that supports (foreign) investment, integrating biofuel production and use in its poverty reduction strategy and is concerned with energy security and lastly due to its trade relationships with EU and other SADC countries [24].

Mozambique has been producing biofuels from jatropha (oil plant) since the 2000s. The government promoted the planting of the oil plant as a means of reducing the country's dependency on foreign fossil fuels which are expensive to obtain. The country received a large amount of funding towards the project of the production of biofuels from jatropha, sugarcane and sorghum. Jatropha is a crop that can be grown throughout Mozambique. In 2008, Mozambique officially received 17 biofuel-related investment proposals. However, the areas identified during the agro-ecological zoning exercise were not popular amongst biofuel investors. Biofuel developments were situated around areas with existing good infrastructure such as processing facilities, roads and harbours, availability of labour, (tele-)communication, and access to goods and services (e.g., health care and financial services). This went against the Government's initial objective of adoption of biofuel production to alleviate poverty by including remote rural areas. Most biofuel projects had no interest in locating themselves inor near remote rural areas in Mozambique and therefore failed to contribute to this objective. Moreover, employment creation was lower than the government's expectations.

Since 2008, biodiesel was produced in Mozambique using coconut oil, and occasionally palm oil as feedstock [25]. An increase in the price of coconut oil went up significantly which made it difficult to use it as feedstock as it was more valuable to sale on the international market. The most prominent biodiesel pro-

ject is Ecomoz, in which Mozambique's oil company PetroMoc has a 30% share. Ecomoz started operating in 2007, using coconut oil as feedstock. The product was refined in Matola, Maputo province. The refinery had a capacity of 100,000 l day, but limited quantity and quality of feedstock prevented this potential from being achieved. Ecomoz sold its biodiesel to PetroMoc and used it in their company's cars while awaiting approval of the blending license to sell to the market since the Government's initial idea was to mix the biofuel from jatropha with the fossil fuels. This was however at a time when the cost of fuels was high but in 2017, the Government decided that it was economically non-viable to continue with the production and mixing of biofuels with fossil fuels as there was a fall in the price of fossil fuels. The other issue is that of priorities since some of these crops are food crops, there is that question whether it should be biofuel production or food production. Although it can be argued that Mozambique has potential in the production of biofuels because of the availability of land for massive production of feedstocks, water, and labour, this argument falls short as it fails to address the complexity of the agricultural sector of Mozambique, a developing country with a high index of poverty with about 54 percent of the population being below the poverty line despite the economic growth experienced in the past years [26]. Social, and economic factors therefore are to be considered.

Economically, Mozambique cannot sustain the production of a substantive amount of biofuel that will have a noticeable economic impact as it is still grappling crippling poverty in most parts of the country. This makes it difficult to argue to produce feedstocks for biofuel manufacturing. It has been noted that in some parts of the country, land that had been designated to produce feedstocks has by now been turned into residential areas, or subsistent farmlands. A good example is the land which contained jatropha trees along the National highway N6 (Estrada Nacional N6) which links the Beira Port with the Zimbabwean Border. The fields had been lying unattended for several years and have since been converted to residential areas. With the expansion of the city of Chimoio, it became a necessity to reassign the land to a different use.

4.2. Policy and Regulations to Promote Sustainable Use of Biomass in Mozambique

Mozambique boasts of extensive biomass resources, with 50% of the country still under forest cover. 80% of the energy used in the country is in the form of traditional biomass and the value of the charcoal market alone is an estimated 250 million USD. If Mozambique loses its forest cover, it risks losing a major domestic resource and a constant supply of low-cost renewable energy. Studies show that rural poor households in sub-Saharan Africa are expected to become more dependent on biomass energy [27]. There is a need for the development of a sustainable wood fuel supply chain to guarantee the availability of sustainable and affordable energy. This however is being hindered by a lack of commercial interest in improving local energy supply chains due to the low prices of wood, and the lack of information at all levels [28].

The Mozambican energy policy approved by Resolution No. 05/98 of March 3rd aims to ensure the reliable supply of energy, at the lowest cost, to meet consumption needs and socio-economic development. Natural gas has been recently discovered in Mozambique with two reserves, one in Inhambane Province and the other in Cabo Delgado Province being currently explored. However, the growth in the use of fossil energy sources is not available to low-income households, which puts at risk the intended reduction in the demand for firewood and charcoal. In 2009, the new Energy Strategy came into force, and highlighted the importance of energy security, efficiency improvement, energy waste reduction, research, and technological innovations. It is believed that timely investment in the production of electricity from the available sources can reduce the cost of electricity and reduce the negative impacts of forest resources exploitation and thus promote sustainable use of biomass.

The strategy for the conservation and sustainable use of biomass energy was approved in November 2013, with the aim of promoting the production and sustainable use of woody biomass energy through the adoption of alternative energy sources, thus guaranteeing energy security in the domestic and industrial sector. This strategy established two approaches, which is the definition of measures to conserve wood fuel consumption, through the improvement of carbonisation and combustion techniques, and the introduction and promotion of efficient technologies for the use of biomass, such as improved stoves. However, the level of adoption of improved stoves is still low within the country [29].

This strategy constitutes one of the instruments for the materialisation of the New and Renewable Energy Development Policy [30]. The New and Renewable Energy Development Policy (NREDP) was approved on October 14th of 2009 [31]. This policy aims to promote the provision of good quality green energies at low prices that are affordable to the poor population of the country especially those in rural areas. Further, it aims to promote the use of new and renewable energy sources which will be combined with non-renewable energies for a hybrid system which was thought to improve access to energy in the country and reduce the cost of energy. The policy also promoted the use of renewable energies to strengthen energy security at local and national levels, and to reduce negative environmental impacts at local and global levels.

This policy however regulated the prices of all energy source except the prices of biomass (wood and charcoal). It is only the charcoal producers that must pay some fees to get a licence for harvesting wood, and it is not all the producers that work with a license as most of the wood in Mozambique is harvested illegally. The prices of charcoal are extremely high in other parts of the country in comparison to the minimum wage. A 50 kg of charcoal was sold at MZN 900 in urban parts of Maputo [32], and this was equivalent to 20% of the minimum monthly wage in the country. Although NREDP's objective is to guarantee affordable prices, the cost of energy in the country continues to be high for most consumers.

So far, only biomass has a specific regulatory platform; specific strategies for other sources (solar, wind, small-scale, oceanic, among others) are yet to be developed. In 2009, another policy was put in place, The National Biofuels policy [33]. The policy was approved by the Council of Ministers with the intention of contributing to energy security and sustainable socio-economic development by exploiting agro-energetic resources through stimulating the diversification of the energy matrix, contributing to the welfare of the population, and promoting socio-economic development, particularly in rural areas. It promotes inclusiveness in the establishment of business opportunities for the private investors and rural community, transparency in pricing mechanism so that the overall management of the National Biofuels Program includes the participation of all stakeholders, environmental and social protection to enhance the environmental and social benefits of biofuels production and use while avoiding or mitigating any negative impacts [24].

The government however is making efforts in protecting the natural resources and promote sustainability. A lot of effort has been put in place to promote forest conservation. In 2020, it suspended logging licences issuance for two years (the logging licences has been approved by the 2002 regulation of the forestry and wildlife law). This however may not be effective if it is not accompanied by other measures, such as regulating biomass energy sector to look at fuelwood production as part of sustainable development. Efforts have been made in regulating the biomass energy sector in Mozambique, but the policies and strategies are new and still present challenges. The biggest challenge is the fact that they do not establish restrictions on the type of raw materials or the type of technology suitable for charcoal production [34].

The supply and demand of forest resources in Mozambique are regulated by the Forest and Wildlife Law and the Land Law, and the energy sector is guided by the Energy Policies and Strategies. However, the effectiveness and implications of these policies are still not clear, and they are still falling short in the development of biomass energy so that it has a positive environmental and climate impact, guarantee security of energy supply, economically efficient as well comply with health and safety standards. Each province should have solutions that are a true depiction of the supply balance. There are three biomass energy supply scenarios in Mozambique. The first one is areas where there is surplus, that is the case of Cabo Delgado, Manica, Niassa, and Zambezia. The second scenario is of areas with an approximate balance between supply and demands as in the case of Gaza, Inhambane and Sofala. Lastly, there are areas with shortages of biomass energy supply like the case of Maputo and Nampula. There is a need for strategic actions to bring changes in the biomass sector in Mozambique. These include regulatory changes which will see to the application of the decentralisation principle of wood resources and the implementation of fiscal measures. The fiscal measures will increase income from wood resources thus stimulating companies, villages, and individuals to use the resource sustainably. It will also see to the in-

crease of efficiency in the use of wood, and it will also provide the government with funds to enforce regulations and improve supply chain sustainability.

The regulations and policies however still leave a grey area on the differentiation between fuelwood production for household consumption and production for commercial purposes, and this vagueness, in addition to the current regulation on taxation mechanisms, favours illegal logging. In general, it is much cheaper to produce biomass illegally than legally and sustainably. Therefore, while strategies are being created to reduce the consumption of this energy source, there must also be efforts for greater regulation, inspection, and control of the biomass energy market, to avoid the large physical and financial losses that occur along the chain of value. In the case of charcoal, mechanisms should be created to discourage illegal production and promote efficient production with improved techniques that can reduce wood consumption. Most producers engaged in charcoal production do not adhere to existing government regulation, since the current regulations see biomass production as an environmental problem and not as a rural livelihood activity, and therefore the formal licensing of charcoal is currently unlikely, especially to small producers, who are often overlooked [34]. Some of these policies are failing because they are not adapted to the people's needs. Thus, biomass energy should be considered as an economic opportunity to local communities and not only as a threat to forests, to facilitate the formalisation of biomass energy production.

4.3. Issues Associated with the Use of Biomass in Mozambique

The bigger part of the country's population also relies on primary biomass for cooking and heating, and surprisingly Mozambique continues to have the lowest levels of access to electricity for its population compared to other neighbouring African countries. Use of primary biomass wastes much of the energy found in biomass [35], and it comes with high environmental and health problems. The major environmental concern is on charcoal production and not on the firewood consumption because firewood is usually collected from dead trees or residues. Charcoal production on the other hand involves the cutting down of healthy trees and this may lead to high levels of deforestation, loss, or the modification of ecosystems, and might lead to the extinction of certain flora. On the health side, a lot of people die especially in the cold season due to suffocation from the use of firewood or charcoal stoves indoors where ventilation will be poor.

The use of biomass in its primary form causes emissions of greenhouse gases, thus contributing to global warming and climate change. There is therefore a need to modernise the biomass sector in Mozambique as it has environmental and health benefits for the population. Modernization of the biomass sector will result in reduced carbon dioxide emissions from the energy efficiency improvements in end-user equipment, and reduced deforestation and degradation. Less charcoal will be produced with more efficient methods, leading to less green-

house gas emissions, and improved stoves using less fuel and better combustion will cause less emissions. It can also help in maintaining existing forestry resources or even lead to an increase. The resources will therefore be preserved for the future, and the population also gets economic benefits when sustainable management practices are applied. At the household level indoor air pollution will be less, from the use of stoves with better combustion characteristics, and the reduction of indoor air pollution will ultimately result in better health and sanitary conditions for households. The inside of the house will be less polluted which will positively impact on the health conditions, especially of women, children, and the elderly who are indoors most of the time. The sanitary conditions of the kitchen and the whole household will also improve [19].

Further, there are serious cases of deforestation due to the harvesting of trees from forests for charcoal production which is on high demand in the urban areas. In Maputo for example, charcoal has become so expensive as the city is now being supplied by towns and cities which are hundreds of kilometres away (Inhambane and Sofala) because the forests in Maputo's radius have all been cleared and there are no mature trees to harvest for charcoal production. Most of the wood harvested for charcoal product is harvested illegally, and although Mozambique is still made up of vast and dense forests mostly, the clearing of trees is still a concern as trees are effectives carbon dioxide sinkers, and thus help in the mitigation of global anthropogenic climate change.

Also, the stoves which are used around the country are mostly low-efficient ones and they consume a lot of charcoal or wood for cooking, which further put pressure on the forest resources. Below is a picture of a typical charcoal stove:

The stove depicted in the picture above was an attempt at making it economical by making the plates smaller so that they do not need a lot of charcoal to fill them up, but they still consume a lot of charcoal. The government however has started to promote the use of more economic charcoal stoves that do not use a lot of charcoal for cooking in a move towards sustainable harvest of forest resources. The use of these stoves however is still low due to a few reasons that can be social, cultural, or economical [34]. The design of these improved stoves can either favour or restrain their adoption, depending on the characteristics of the community [29]. For example, in rural areas, the height of the raised stove (**Figure 3**), is an impediment, given that the women usually conduct their activities seated for greater comfort and for cultural reasons. On the other hand, height favours adoption among urban population as cooking is mostly done standing. Below is a picture of an efficient charcoal stove (**Figure 4**).

The stove above is smaller compared to the previous one and it is made of pottery which makes it able to preserve some heat and thus makes it an economical charcoal stove. From experience, it is possible to cook a meal for two or three people on this stove using just one load of charcoal. This however is not possible with the charcoal stove made from scrap iron in **Figure 1**. The charcoal stoves made from scrap iron sheets however are more widely used because

Figure 3. Two-plate scrap metal charcoal stove. (Source: Author).

Figure 4. Economic charcoal stove. (Source: Author).

of durability and they allow smarter cooking (while standing) which is an attractive aspect for the young and the urban population. A few households use the clay ones because of their fragility, difficulty in handling (they are difficult to move when they are loaded with hot charcoal), and the fact that one must cook while seated.

5. Conclusions

The renewable energy sector in Mozambique is still growing and it can be argued that it has seen tremendous growth with the country having put in place policies that promote green energies. It is clear however that Mozambique has been more successful in developing its hydropower system as compared to other

green energy sources, and there is still lack of the involvement of the locals in the implementation of renewable energies. Also, it is commendable that the country relies mostly on electricity generated from hydropower. However, hydropower generation will be influenced by the temperature increase due to the climate change effects thus negatively affecting the potential of hydropower production. Therefore, it is expected that Mozambique hydropower production will face a challenging future which makes it important for the country to invest in other renewable sources of energy like solar and wind. The access to electricity in Mozambique is one of the lowest in Africa and in the world even though the country is rich in different natural energy resources such as gas, coal, and hydro energy. Over 80% of the rural population depends on traditional biomass energy sources such as charcoal and firewood. The biggest challenge to hydropower is the climate change and its effects. Currently, Mozambique is selling the energy from its different hydropower stations. A decline in the production will negatively affect not just Mozambique but these countries' economies [15].

Although hydropower has its advantages and disadvantages as noted above, the advantages outweigh the disadvantages as they reduce the country's carbon emissions and make it one of the African countries with the least carbon footprint. If we are to consider all the advantages of using renewable energies, we can say that they have the potential to improve Mozambique's economy as they reduce its dependency on foreign energy sources which cost a lot of money and are a liability to the environment. It is therefore important for poor countries, especially the poor African countries like Mozambique to invest in renewable energies to reduce production cost and emissions which are a major concern to global climate change. These poor nations are the most vulnerable to climate change as their economies are based on agriculture which is highly susceptible to climate change [36].

The use of biomass in its primary form is going to continue in Mozambique for an unforeseeable future as the economic situation of the country makes it difficult for the greater part of the population to afford cleaner stoves and forms of energy. The bigger part of the Mozambican population is found in the rural areas where on-grid electrification is still low. There is therefore a need to move towards sustainable forms of bioenergy. Also, the population needs to be aware of the importance of the sustainable use of natural resources and renewable energy sources, in this case, biomass [37]. Even though biomass is termed renewable, there is a need for sustainable use to avoid over-exploitation of the resources which in turn will cause extreme deforestation and land use changes. This in turn has serious environmental repercussions like global warming as it destroys a natural carbon sink, destruction of ecosystems and extinction of species due to the destruction of their habitats.

The use of renewable energies is clearly still under development and there is need for proper structure and mechanisms to guarantee its continued growth. Most of these renewable energies are still not being exploited to their maximum

potential. Although it has a lot of potential in adopting renewable energies, Mozambique is still a long way from exploring the full potential of renewable energy sources, given that the policy still has a hybrid approach, that is combining renewable energy sources with non-renewable ones. Considering the vast resources at its disposal, Mozambique should aim at developing an energy industry that is solely based on renewable sources like biomass, hydro power, solar energy, and wind energy.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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