International Journal of Renewable Energy Technology Research
Vol.2, No.2, February 2013, PP: 44 - 52, ISSN: 2325-3924 (Online)
Available online www.ijretr.org

Research article

Development of Renewable Energy Technologies in Malawi

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Abstract

This paper presents efforts, opportunities and challenges in the development of renewable energy technologies in Malawi. Renewable energy technologies are not effectively contributing to the national energy sector hence not effectively contributing to economic development of the country because energy supply is generally unreliable and insufficient hence not able to meet the energy demand. About 83% of Malawi's population live in rural areas and rely on fuel wood for energy supply. High reliance on biomass has had negative environmental impacts through indoor pollution, deforestation, soil erosion leading to high soil sediment loads to water bodies resulting in poor water quality in rivers and lakes. Current electricity supply is much less than demand resulting in deficient and undependable supply. Malawi is endowed with a number of renewable energy resources yet utilization of these resources is still a major challenge. Little progress has been made in improving renewable energy supply and utilization due to a number of reasons, main ones being poverty, lack of political will, lack of information on renewable energy technologies and wrong approaches in addressing the problem. A number of programs and projects have been implemented with varying degrees of success but the overall picture is still negligible use of renewable energy technologies. The rural population would benefit a lot from renewable energy technologies since they are generally facing energy supply challenges. Just about 1% of the rural population has access to the national electricity grid and this will remain the case for the foreseeable future. Availability of renewable energy resources in remote and most rural areas provides potential for electrical energy supply to the people living in such areas who cannot be supplied with energy from the national electricity grid.

Keywords: Energy mix, rural areas, renewable energy resources, electrical energy

Introduction

Malawi is a land locked country located in Southern Africa, between latitudes 9^{O} 22' S and 17^{O} 3' S and longitudes 33^{O} 40' E and 35^{O} 55' E. The country is about 900 km long and 80-161 km wide, with a total area of 118,484 km^2 of which 80% is land. The remaining 20% is covered by water, mainly comprising Lake Malawi, which is about 586

km long and 16-80 km wide. The rest of the water area is made up of the following lakes: Lake Chilwa, Lake Malombe and Lake Chiuta and there are also rivers a majority of them flowing into Lake Malawi. The country is divided into three administrative regions namely Northern Region, Central Region and Southern Region with population distribution, population density and energy resources as shown in table 1. Malawi is one of the poorest countries in the world with gross domestic product based on purchasing-power-parity (PPP) per capita GDP of about USD 900 in 2010.[1] GDP composition by sector is 35.5% agriculture, 19.9% industry and 44.6% services. The population of Malawi is currently about 15 million and recently, it has been increasing at a rate of about 2.8% per annum. About 83% of the population live in rural areas and about 75% of the population carries out farming as smallholders on fragmented customary land.[2] Crops that contribute significantly to the economy of the country are tobacco, tea, sugarcane and cotton with these crops accounting for about 75% of total exports for the country and tobacco alone contributing about 52%.Urban growth is increasing at a rate of about 6.7%, of this, 60-70% live in traditional housing areas and unplanned settlement areas. Poor planning has resulted in extreme urban squalor and deprivation, poor sanitation, and the rapid spread of communicable waterborne diseases. There is little environmental impact from mining and industries due to the minor economic contribution from these sectors. There is an increase in extraction of construction materials like sand and clay for bricks (with a high demand for fuel wood for curing of the bricks), lime for cement and quarry stones for concrete. Sand and gravel extraction leave large holes, which provide breeding environments for disease vectors and waterborne pathogens. Another important mining industry activity is making of cement, which is the second greatest contributor to greenhouse gases in Malawi, after agricultural-related processes. The industry sector is a great contributor to creation of noise, dust, air pollution from furnaces and effluent by-products, however, these impacts are currently quite low.

Energy Situation in General

One of the challenges the country faces is being able to meet the energy needs of the various sectors in the country. Energy supply deficiencies are common which result in interruptions to processes that require energy as an input. From 2008 statistics, about 90% of Malawi's population use wood for fuel and charcoal production, accounting for about 88.5% of the country's energy requirements, 6.4% comes from petroleum, 2.8% from electricity and 2.4% from coal. Households account for 83% of all energy consumption, with industry taking 12%, transport taking 4% and the service sector taking 1%. Statistics show that 85.7% of the population use paraffin in hurricane and pressure lamps for lighting, 7.2% use electricity, 2.2 use candles, 2.6% use firewood and 1.4% use other means of alternatives for lighting. For cooking, 88% of the population use firewood, 8% use charcoal, 2% use electricity, 1% use paraffin and 1% use other means such as crop residues, animal dung and those not mentioned above.[3] Looking more closely at the various energy sources for lighting and cooking for both rural and urban areas gives us results as summarized in table 1. Renewable energy technologies can play an important role in both cooking and lighting applications

Table 1: Population distribution by source of energy for lighting and cooking (*Source: Malawi Census Main Report, 2009*)

	Cooking (% of population)			*Lighting(% of population)*		
Source of	National	Rural	Urban	National	Rural	Urban
Charcoal	8	1.7	43.4	0	0	0
Electricity	2	0.4	13.6	7.2	1.9	37.5
Firewood	88	95.7	41.8	2.6	2.9	0.4
Gas	0	0	0.1	0	0	0
Paraffin	1	1.2	0.7	85.7	92.5	46.5
Others	1	1	0.5	1.3	1.6	0.3
Candles	0	0	0	3.2	1.1	15.3

The Government of Malawi has embarked on quite a number of programs and projects to improve the standard of living for the rural masses which should be able to eventually result in energy utilization switch. Even with such programs being carried out, only about 1% of the rural population has access to electricity. In 2004, four energy laws were created to help operations in the energy sector in Malawi. These are four Energy Acts aimed at addressing various aspects of the energy sector which are: Act 20, the Energy Regulation Act which established Malawi Energy Regulatory Authority (MERA); Act 21, the Rural Electrification Act which laid the foundation for the formation of Rural Electrification Management Committee and Rural Electrification Fund; Act 22, the Electricity Act which deals with electricity issues in terms of licensing, tariffs, generation, transmission, distribution, sales contracts and related issues; Act 23, the Liquid Fuels and Gas (Production and Supply) Act which handles issues related to liquid fuels and gas production in terms of licensing, safety, pricing, taxation, strategic reserves and any other related issues.

Generally, it is known that as the environment degrades, there are consequences that are observed in energy systems, whether it be the supply, transportation or utilization aspects. A simple example of rural communities depending on biomass as their main source of energy will face energy challenges because of deforestation. Population growth and the pressures associated with it have resulted in most of the hills being laid bare in most of the catchment areas of the rivers. People have been opening up gardens in areas previously protected and use a lot of fertilizers to compensate for low yields and in addition the use of firewood and charcoal both as a household energy source and for business has depleted the forests. This has resulted in more soils being prone to erosion. When raining, a lot of soils are eroded into the river tributaries and later to the Shire River, which is the biggest river in Malawi and where electrical generation is mainly being done. The soils being eroded are full of nutrients from the use of artificial fertilizers and so when these soils and their nutrients are deposited into the river they provide necessary nutrients to the aquatic plants and they then grow and multiply.[4] Also the soil being eroded into the river cause problems at the intakes of the water which goes into the power stations.

Elements of achieving national energy security are included in other government's key policy and strategy documents such as the Vision 2020, the Millennium Development Goals and the National Energy Policy. There is a need for periodic policy and strategic reviews to ensure realization of energy sufficiency for the country. The National Energy Policy being the framework for the development of the energy sector in Malawi sets out policy goals, objectives, strategies and priority actions. The policy also sets out target energy mix for the future as shown in table 2 aimed at achieving a shift from an energy sector that heavily relies on biomass to one that better distribution among the various energy sources in the country. [5]

Table 2: Energy mix: projections, targets and actual from National Energy Policy and Malawi Energy Regulatory Authority

Energy source	2000 (Actual)	2010	2010 (Actual)	2020	2050
Biomass	93.0	75.0	80	50.0	30.0
Coal	1.0	4.0	4.0	6.0	6.0
Electricity	2.3	10.0	8.0	30.0	40.0
Liquid fuels	3.5	5.5	5.5	7.0	10.0
Nuclear	0.0	0.0	0.0	0.0	4.0
Renewable	0.2	5.5	2.5	7.0	10.0
TOTAL (%)	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Looking at table 2, it is clear that the targets are far from being met using the current approaches in developing the energy sector and this is having serious impacts on the economy of the country. Renewable energy is below half of the projected target in the energy policy document but it is increasing. The energy sector is still in the infancy stage where energy consumption is relatively low with inefficient energy conversion methods being dominant. The energy supply sector comprises five key components namely electricity, liquid fuels and gas, coal, biomass and other renewable sources of energy.[5] Three of the five supply sectors have a good potential of using renewable energy technologies and these are electricity, biomass and other renewable sources of energy sectors. Liquid fuels and gas sector and the coal sector have the most negative environmental impacts due to the emission of pollutants during combustion of the fuels in form of carbon monoxide, carbon dioxide, sulfur dioxide, nitrate oxides and particulates. There have been a number of programs and projects that have been implemented with the intention of achieving the already mentioned goals but there has been little progress so far. A closer look at the components with renewable energy potential reveals the following:

Biomass Supply

The availability of biomass energy in Malawi can be made sustainable which currently it is not. Wood resource base is diminishing mainly because woodlands and trees in agricultural areas are being cleared up to start new farming land. Statistics show that between 1991 and 2008 about 669,000 hectares of woodlands were converted to farmland.[6] Diminishing standing stock is leading into gradual reduction of biomass that can be harvested. From the information already given, Malawi is heavily dependent on biomass fuels yet the national energy policy has little information on biomass energy supply. Looking at the biomass side of energy supply, a similar situation exists to that of electricity generation in that very little is being done to address issues concerned with improving the supply and efficiency of biomass, although it is the major energy source for the country. Household sector consumes about 92% of biomass energy and the rest is distributed among the other sectors as shown in table 3. About 76% of firewood is used for cooking, 21.5% for heating water, 2% for space heating and the remainder for other uses.

Table 3: Consumption of biomass energy by sector and fuel type in 2008 (*Adapted from National Biomass Energy Strategy document, 2009)*

Sector	Type of biomass energy (TJ)			
	Charcoal	Firewood and sawdust	Residues (crop and wood)	**Total**
Household	8,703	115,879	2,992	**127,574 (92.2%)**
Industry	31	4,092	5,562	**9,685 (7%)**
Transport	0	0	589	**589 (0.43%)**
Service	102	350	0	**452 (0.33%)**
Total	**8,836 (6.4%)**	**120,321 (87%)**	**9,143 (6.6%)**	**138,300 (100%)**

The national energy policy is focused on shifting energy use away from the current heavy reliance on traditional biomass to modern sources of energy like electricity, liquid fuels and renewable sources but little progress has been achieved so far. High dependence on biomass means that it should be a priority to find means and ways of improving utilization of energy from biomass alongside the issues of fuel switching. There are some policy contradictions that exist concerning this sector that continue to hinder progress for biomass fuel supply. Agricultural activities are diminishing resources for the supply of biomass in that as the population is increasing, more land is converted from forests to farming land. Although there are regulations to safeguard the affected forests, there are no mechanisms to ensure that the regulations are adhered to. Another example is that of charcoal in which its production from indigenous trees is deemed illegal unless it can be proven that it has been produced from a sustainably managed forest for which a production license has been applied for and received (article 81 of the Forestry Act, 1997). Charcoal is therefore continually being confiscated by government authorities yet nearly 40% of the urban households use charcoal for cooking.[7] Existence of such contradictions in various sectors hinders investments or efforts towards modernization in more sustainable alternatives of biomass fuels production. Another challenge is existence of different aspects of the biomass sector under different government departments. The supply side of biomass energy supply is covered under the National Forest Policy (1997), the Forestry Act (1997) and the

Land Policy Act (2002) while general issues of energy supply fall under the Energy Policy (2003). While the energy policy envisages an ambitious transition from wood fuels to electricity, liquid fuels, coal and renewable energies, little is written concerning modernization, development or sustainability of the wood fuel sector.[8] To fill this gap a Biomass Energy Strategy was formulated and the document was produced in 2009. This strategy makes a pro-active approach towards managing and developing the biomass energy sector instead of just tolerating biomass fuels as an interim solution while waiting for alternative energy supply sources (which has been the case for some time). The Forest Policy recognizes the importance of wood fuels for livelihood of producers in the rural areas and promotes sustainable wood fuel production.[9] The total consumption of biomass in 2008 was estimated at about 9 million tons of wood equivalent. Rural households accounted for about 80% of total consumption while urban households consumed about 12.2% and the remainder was distributed among the remaining sectors as already shown in table 6.

Malawi has a potential to produce bio-fuels for its local markets which can result in reduction of fuel importation bill. This can be accomplished by blending bio-fuels with petrol or diesel as the case has been of blending ethanol and petrol which has been done for over 30 years now. There are two ethanol plants in Malawi, one in Salima and another one in Chikhwawa both plants being connected to sugar factories. Malawi has no refineries for petroleum products because it has been proven to be uneconomical due to the small national market. Malawi therefore imports about 97% of its refined petroleum products; the balance is contributed by locally-produced ethanol which is sold directly to the oil companies for blending with petrol on a maximum 20:80 ratio of ethanol-petrol. In practice, the mixing ratio is usually 12:88 because ethanol production is inadequate and also because there is no legislation to make the blending mandatory resulting some petrol being unblended. Apart from blending with petrol, ethanol has also been converted to gel and liquid fuels for both domestic and industrial use but on a small scale because the products have been deemed not economically viable or not suited to the local cooking practices. The country is capable of producing different non-food feed-stocks by converting unutilized land for bio-fuels crop production. Malawi needs to take the necessary steps to manage risks associated with bio-fuels crop production and increase opportunities for bio-fuel development through locally-suited but regionally and internationally aligned good practices in bio-energy production. Malawi's focus should be on emerging trade and investment opportunities for the country, implications for poverty reduction, supply-side constraints to expanding production, use and trade in bio-fuels and promotion of new investment mechanisms.

In the field of biomass and biogas, the country has favorable conditions for the application of a majority of technologies in these fields. So far there have been some initiatives for improved wood cook stoves both at domestic and institutional levels. Biogas digesters have been constructed in a number of areas as pilot projects for the rural communities with variable success levels but uptake of the technology remains a challenge to date. In an attempt to minimize the use of biomass fuels and provide the communities in rural and urban areas with alternative source of energy, the government undertook a number of initiatives. Some of these are: the program for biomass energy conservation (ProBEC) which seeks to use more energy efficient technologies like improved stoves; introducing more efficient firewood management through drying and splitting wood among other ways; improved kitchen management through better ventilation at the cooking place, at domestic and institutional levels and use of alternative renewable energy sources such as solar and gel fuel.[10] Another one is the Promotion of Alternative Energy Sources Project (PAESP) which seeks to promote non-traditional fuels for cooking and heating to reduce effects of environmental degradation.

Electricity Supply

This sector generates electricity mainly from hydro potential but thermal (mainly diesel and gas based) and photovoltaic systems are also in use. A significant number of commercial and industrial enterprises have installed their own diesel and petrol operated generators due to unreliable energy supply from the national energy supply utility company, but it is still a challenge to determine the capacity of such due to gaps in regulations. Electricity Supply Corporation of Malawi (ESCOM) Limited is the only electrical power supplier and it is a publicly owned company which was established by an Act of Parliament in 1957 which was revised in 1963 and then 1998. The total installed capacity of ESCOM is about 302 MW, of which 94% is generated by hydropower and the remaining 6% is thermal. Almost all the ESCOM's hydro generation stations are located in the Southern region of Malawi along Shire River, which is the main outlet of Lake Malawi; except for a capacity of 4.5 MW which is located in the

Northern region on Wovwe River. Electrical power is transmitted to all other parts of the country through 132 kV network with 66 kV being used as well in other areas. Distribution network is at 33 kV, 11 kV and 400/230 V. Overall, the electricity network is not in very good condition, resulting in substantial losses on the transmission and distribution networks of about 18-22% of the generated electrical energy. One of the important forms of energy is that plays a key role in a country's development is good supply of electrical energy. From the current installed electricity capacity of 302 MW from various hydro power stations in Malawi being operated by ESCOM, available capacity at most of the times is generally about 80% or less of the installed capacity.[11] Malawi has got more potential for generating electricity using hydro potential as evidenced by the outcome of some feasibility studies on various rivers in the country. The following are potential sites and the expected range of power and energy outputs: Manolo with a potential output of 60 to 130 MW, Henga valley with a potential output of 20 to 40 MW, Rumphi with a potential capacity of 3 to 13 MW, Chizuma with a potential capacity of 25 to 50 MW, Chasombo with a potential capacity of 25 to 50 MW, Malenga with a potential capacity of 30 to 60 MW, Mbongozi with a potential capacity of 25 to 50 MW, Kholombizo with a potential capacity of 140 to 280 MW, Mpatamanga with a potential capacity of 135 to 300 MW, Low Fufu with a potential capacity of 75 to 140 MW, Low Fufu and Tran with a potential capacity of 90 to 180 MW, High Fufu with a potential capacity of 90 to 175 MW, Chimgonda with a potential capacity of 20 to 50 MW and Zoa Falls with a potential capacity of 20 to 45 MW.[12] The current electricity power supply in Malawi is quite unreliable and according to recent estimates, Malawi loses about USD 16 million annually due to power outages. Investing by the private sector in electricity generation remains a challenge due to the government subsidy provided to ESCOM in electricity generation which gives unfair advantage to ESCOM over any would be investors hence ESCOM has remained the sole electricity generation company to date. Capacity of privately owned generators is difficult to ascertain but according to a survey that was done by National Electricity Council in 2001, it was estimated that the capacity of private generators was 51.3 MW, but there are no later figures. Malawi has got a small electricity supply system as compared to her neighbors which are 2483 MW for Mozambique, 1186 MW for Tanzania and 1737 MW for Zambia (all are installed capacities as of 2008).[13] In addition to local resources, there are plans to connect Malawi to the Southern African Power Pool in the next few years. The Malawi Rural Electrification Project (MAREP) was also established to increase the number of rural trading centers that have access to the national electricity grid and is now in its fifth phase. Electricity from photovoltaic modules is still insignificant when looking at the overall picture, but it is increasing in utilization, finding applications in telecommunications, lighting, refrigeration and water pumping. In the past, ESCOM has not been participating in any renewable energy technology projects but recently, ESCOM built a PV and wind hybrid system in Thyolo for electrical energy supply to a local community.

A study was done to determine the correlation between electricity consumption and GDP for Malawi from data between 1970 and 1999 extracted from the statistical bulletins and economic reports published by the National Economic Council and the National Statistical Office. Ganger-causality (GC) and error correction model (ECM) were used to examine causality between kWh and GDP. The results showed that there was a bi-directional causality between kWh and GDP using GC and one-way causality running from GDP to kWh using ECM.[14] In conclusion the author wrote that ECM results reflect better the Malawi economy that of being less dependent on electricity since the economy is heavily dominated by the agricultural sector. However, this might not be an ultimate conclusion since the agricultural sector also depends on electricity although to process crops. For the case of Malawi the agriculture sector does not use electricity mainly because of its absence in most of the rural areas where agricultural activities are concentrated. It can be argued that the agricultural industries can be having more electrical energy input if the electricity can be available. This would promote agricultural processing activities which in turn can have an impact in the causality between kWh and GDP, hence overall economy of the country. Inadequate electrical power supply has been identified as one of the constraints affecting private sector development in Malawi.

Other Renewable Energy Sources

Malawi is endowed with a number of renewable energy resources yet utilization of these resources is still in infancy stages. In the field of solar, quite high levels of solar energy in the range of 1200 W/m^2 in the warm months and 900 W/m^2 in the cool months are received in most parts of the country which would enable photovoltaic systems and solar thermal systems to perform well. For wind energy systems, there are quite a good number of areas in the

country with mean wind speeds above 5 meters per second almost throughout the year. There have been other programs and projects which promoted the use of renewable energy technologies in Malawi. In terms of bio-fuels, there are some crops that are known to have substantial amounts of oil in their seeds which are still being investigated for use in blending with conventional fuels that are in use today. Malawi lies along the Great Rift Valley and therefore traces of geo-thermal reservoirs have been said to exist. Technologies that use solar energy have a high potential of being implemented successfully since solar energy is a resource that is available in abundance throughout the country. This would be very important for most of the rural areas that are unable to access energy from the national electricity grid which is a common form of energy for various humans needs including water treatment which is a very essential element in healthy livelihood. There have been a number of initiatives in the renewable energy sources sector with the notable ones being the National Sustainable and Renewable Energy Program (NSREP, 1999), Barrier Removal to Renewable Energy in Malawi (BARREM, 2001), Program for Biomass Energy Conservation (ProBEC, 2002) and the Promotion of Alternative Energy Sources Project (PAESP).Department of Energy Affairs conducted a study to understand problems that inhibit the uptake of renewable energy technologies (RETs) in Malawi. A number of barriers to extensive utilization of RETs were identified at that time and included: there is a limited number of companies servicing this sector; there is lack of skilled personnel working in this sector; there are poor quality RETs systems; there is lack of information on RETs; absence of regulatory frameworks, particularly standards and code of practice for the design, installation and maintenance of RETs; and absence of dedicated financing mechanisms and incentives for the purchase of RETs. This led to the formulation of NSREP in 1999. The aim of the program was to enhance the efficient and sustainable utilization and marketing of renewable energy resources in rural, semi-urban and urban Malawi. The objectives of NSREP were:

- to increase the access to energy sources by the majority of the population in order to raise the level of productivity;
- to raise the living standards of the poor segment of the population;
- to empower women as key players in the society by recognizing their special relationship to energy, particularly at the household level;
- to promote and develop sustainable and renewable energy technologies, which will enhance socio-economic development;
- to enhance institutional and household capacity to access and manage renewable energy in sustainable ways.

BARREM which was funded by the UNDP-GEF project, started in 2002and was intended to run until 2006. BARREM evolved out of NSREP to focus on the promotion of solar PV. Utilizing GEF resources of 3.353 million USD, and planned co-funding from public and private sector resources (to a total of 7.304 million USD) the project was aimed to contribute toward greenhouse gas emissions by catalysing the development of the Malawi solar market for households, public institutions, commercial and agro-processing sectors. The project tackles five main areas: capacity building and institutional strengthening, creating of an enabling environment, development of financing mechanisms for renewable energy systems, promotion and demonstration of renewable energy technologies, and the support/creation of public awareness. From a global perspective, the objective of BARREM Project was to reduce atmospheric carbon dioxide emissions. Looking at the national level, the project aimed at removing market barriers to increase solar PV energy service delivery. The project focuses on: assisting local stakeholders in building capacity to promote, install and service solar PV systems; help to develop favourable regulatory frameworks for solar PV technologies; facilitate development of viable financing mechanisms for solar PV technologies; help to demonstrate the viability of investments in solar PV technologies and promote replication of PV systems countrywide.[15] Most

of BARREM objectives were fulfilled except developing viable financing mechanisms for renewable energy technologies and replication of PV systems countrywide.

Numbers of renewable energy technology installations have been increasing with the increased awareness of these technologies but there are still some challenges that need to be overcome. Some of these are: there is no coordination and sharing of information among various stakeholders participating in the development of this sector and this leads to repetitions of setbacks that have already been encountered by others; there are still difficulties in financing projects; weak industrial back-up for the various components which have to be imported.

Conclusion

The renewable energy component of the targeted energy mixes as set out in the national energy policy are far from being met and therefore there is a need for change of approach by formulating new renewable energy development strategies. Energy supply remains a great challenge for Malawi to date especially for people living in rural areas. Renewable energy technologies can contribute effectively in meeting the energy needs for these people. There are a number of renewable resources in the country but extracting energy from these remains a challenge. The performance of RETs in Malawi has been quite satisfactory but information dissemination on their capabilities and restrictions has not been fully realized and there are challenges in financing mechanisms. The government has put in place some incentives such as removal of import duty on all renewable energy technology components, establishment of necessary framework and built institutional capacity for the sector. There is a need for better coordination and dissemination of information about progress being made through establishment of a database on renewable energy delivery in Malawi and constructing a website with document storage/retrieval functionality for sharing of information.

Acknowledgement

We would like to express our gratitude to officials from Department of Energy Affairs, Malawi Energy Regulatory Authority, Electricity Supply Corporation of Malawi and University of Malawi for giving us information that we could not get from books, papers and websites.

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