Community based decentralised rEnewAble eNerGy systems and supporting structures for improving electricity Access in Low income countries

State of the Art (SOTA) Report

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Authors	**Peter Sandula, Gaye Edobor**
Reviewers	**Dr. Ehiaze Ehimen**

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The partners involved in the project are

Lead Partner

Ollscoil Teicneolaíochta an Atlantaigh Atlantic Technological University

Atlantic Technological University (Formerly Institute of Technology, Sligo-ITS)

Co-Partner

MALAWI UNIVERSITY OF BUSINESS AND APPLIED SCIENCES MUBAS

Malawi University of Applied Sciences (MUBAS)

Contents

1.0 Project Description

Energy supply and specifically electricity accessibility has been recognised as an important driver of economic growth and human development and deemed essential to helping achieve global poverty reduction goals in low-income countries globally. Goal 7 of the UN Sustainable Development Goals identifies the ‘universal access to affordable, reliable, sustainable, and modern energy for all as a target for the next 10 years. However, approximately 0.7 billion people globally have no access to electricity, the majority of whom are in Sub-Saharan Africa. Mechanisms that can be used to expand electricity access in such regions are therefore needed.

The CEANGAL project puts forward an ambitious adaptable and replicable model to support activities and know-how relevant to the selection, procurement, installation, and ownership of renewable energy systems (RES), as well as providing support structures to ensure their continuous local operation and maintenance.

The CEANGAL framework achieves this by addressing the major issues currently hindering RES adoption in developing communities, through the contribution of significant Irish expertise and knowledge in the community RES sector and working collaboratively with local knowledge partners and stakeholders to develop vital longstanding local funding, ownership and operational support hubs for community-driven RES projects. Through research partnerships with Malawian researchers, the project concept and outcomes will be developed, demonstrated and validated in pilot case sites in currently underserved rural areas of Malawi (a country having one of the lowest access to electricity globally with 82% of the population having no electricity access).

1.1 Main Objectives of the Project

The CEANGAL project has a practical innovation agenda that aims at providing replicable mechanisms to increase the uptake of community-based RES and sustained growth in electricity accessibility in low-income countries (LIC), especially focused on rural communities. The project will deliver several measurable, high impact, strategic, societal, economic and organisational objectives as below:

1. Develop an **adaptable framework focused on the concept of sustainable community-driven RES implementation** applicable in LIC communities. The CEANGAL framework will initially be refined and collaboratively developed with the Malawian University of Business and Applied Sciences (MUBAS). The framework

will provide proven data-driven best practices, operational guidelines and considerations that should be covered to afford improved success in achieving RES acquisition and operation for prospective community-driven electrification projects.

2. Develop an **integrated CEANGAL suite of tools,** with tools that will support the CEANGAL framework concept and provide tangible information, estimation and decision support tools with functionalities to afford a detailed knowledge of RES choices, their suitability to meet the local energy requirements, conditions and resources, and specific guides on the installation, operation and maintenance of several suitable RES. These tools will meet the project aim of reducing the currently observed lack of know-how and expertise in the operations and maintenance of RES.

3. Provide improved **local competencies and know-how on RES systems, community-driven RES projects implementation, and establishment of regional RES expertise hubs with capabilities for supporting communities** in achieving electricity accessibility goals through decentralised RES implementation.

4. Improve the overall **process economics** of RES acquisition, improvement of knowledge and overall **successful funding and purchase rates**, and facilitate significant uptake of community-based RES.
    a. Collate and analyse relevant funding schemes and models utilizable to meet RES acquisition.
    b. Afford cost-effective decision making on potential RES, and different ownership models.
    c. Achieving energy self-sufficiency, and identification of other potential energy carriers/uses.

5. Contribute to the goals of the Irish Government's "A Better World" and "Global Ireland: Ireland's Global Footprint to 2025" targets of creating a more equal and sustainable world by reaching those furthest behind, by **driving growth and development opportunities through improved electricity access in LIC communities.** This is expected to strengthen the operation of critical infrastructures and lead to the proliferation and growth of local industries.
6. Improve the **adoption and implementation** of the CEANGAL project solutions by the relevant community stakeholders

2.0 Scope of the SOTA Report

The document would be a living document and would incorporate changes happening in the ever-changing field with socio-economic and technical disruptions.

2.1 Why is the Document Relevant?

The document provides the backing of evidence-based research and stakeholder interactions for every task undertaken as part of the CEANGAL project. The ethos behind the project is the existence of a gap between the expectation and implementation of RES projects in Sub-Saharan African (SSA) countries, and in this context a structured review of the SOTA would be the only way to identify the relevant factors from a large list of potential candidates which limits the uptake of electricity in these regions. Further, the report also provides comparisons from different parts of the world and distils the relevant ones relevant to the region through an analysis of economic, political, social and technological similarities and differences. The report is comprehensive as it doesn't limit itself to technical feasibility only, by carefully deciphering the extra-technical components which are a result of community -interaction and political organisational structure.

2.2 Who is the Document targeted at?

The document is targeted at a variety of stakeholders and is publicly available on the CEANGAL website. The document holds a mirror to the current trends in RES uptake. With focus on LIC, the report provides a knowledge base on which CEANGAL project partners would propose, test, implement and improve possible solutions to accelerate and sustain the uptake of community scale renewable energy generation and use. Apart from the implementation team, the insights would be beneficial for policymakers to make research-informed decisions, researchers working in the area of RES technology and policy and organisations working on developing solutions in this field. The document is also useful for i.e., NGOs and stakeholders working in the area of energy poverty and RES technologies implementation to accelerate the attainment of SDG goals.

2.3 What is the Scope of the report in the future?

The report is positioned as a living document, with review and updates provided, where necessary, every 8 months during the project lifetime, as there might be relevant disruptions in the field as the CEANGAL project progresses. More specialised knowledge in the area might therefore be created which could then be updated in the document to make it a reference document that could be used by stakeholders not only in the present. but also, for the future while designing RES systems targeted at LIC communities, taking extra-technological factors into account.

2.4 What is the usefulness of this document?

The purpose of this document is not limited to the identified stakeholders and researchers only. It is intended to also form the blueprint and as an information source which government institutions can fall back on when citing is required. This document could also provide a starting information basis which organisations who want to invest in community scale renewable energy sector across the SSA region could consult to have first-hand and reliable information on where to invest, how to invest, what to watch out for and what to consider during preliminary assessment phases.

3.0 Why is Electrification Required?

3.1 United Nations Sustainable Development Goals (UN SDGs)

Over the last decade, access to electricity has expanded, with the use of renewable energy in the electricity sector increasing and improvements in energy efficiencies observed. However, millions of people globally are still without electricity, and one third of the global population lacking clean cooking fuels and technologies. The global electricity access rate improved from 83 per cent in 2010 to 90 per cent in 2019, with 1.1 billion people receiving electricity for the first time. However, 759 million people were still without access in 2019, with three quarters of them in sub-Saharan Africa (97 million in urban areas and 471 million in rural areas). Progress in ensuring energy access has been uneven across regions, leaving the most vulnerable even further behind. At the current pace, about 660 million people will still be without electricity in 2030, the vast majority of whom (≈ 555 million people) will be in Sub-Saharan Africa (SSA).

The COVID pandemic in 2019 has been observed to have resulted in reversing progress that had been previously made with regards energy access improvements, causing millions of people to lose access to electricity. In Africa, the number of people without electricity increased in 2020 after declining over the previous six years. In developing countries in Africa, basic electricity services are now unaffordable for more than 25 million people who had previously gained access, due to population growth and increasing levels of poverty. An additional 85 million people, mainly in developing countries in Asia, may be forced to scale back to basic electricity access because of an inability to pay for an extended bundle of services.

Although the use of renewable energy and energy efficiency have improved, progress is not fast enough to achieve Sustainable Development Goal 7. Under the UN SDG goals (2017), SDG 7 stipulates that by 2030, “Ensure access to affordable, reliable, sustainable, and modern energy for all.” Electrification using renewable sources would be one of the primary ways of providing sustainable energy. SDG 7 calls for ensuring universal access to modern energy services, improving energy efficiency and increasing the share of renewable energy. To accelerate the transition to an affordable, reliable and sustainable energy system that fulfils these demands, countries need to facilitate access to clean energy research and technology and to promote investment in resource- and energy-efficient solutions and related infrastructure.

The World Bank also recommends that 25% of investments in the energy sector (about $10 billion per year) be allocated to produce and distribute electricity in rural areas [1]. The World Bank, the United Nations Development Program, the African Development Bank, and the European Union, along with many bilateral aid agencies from countries like Australia and Japan amongst others have enhanced their focus on Rural Electrification (RE) [2]. However, the achievement of such targets as set out by the UN SDGs has not been attained yet.

3.2 Rural Electricity Access and impacts on Other SDG Goals

One out of 10 people still lacks electricity, and most live in rural areas of the developing world. More than half are in sub-Saharan Africa. Evidence-based research conducted across such communities i.e., from Zimbabwe [3], Brazil [4], and Indonesia [5] has shown the close relationship between electricity access and alleviation of poverty.

The studies have linked an increase in economic growth because of reliable power supply due to an increase in productivity and the generation or value addition of local livelihoods which had a direct impact on SDG 1 - the alleviation of poverty. So, though electrification is not an explicit SDG it has an undisputed role in assisting in achieving SDG 1, SDG 4 (education for all), SDG 10 (reducing inequalities) and SDG 11 (sustainable cities and communities). Electricity also potentially contributes to trickling effects of increasing human capital development and productivity because of better health (SDG 3) and educational (SDG 4) infrastructure facilitated by it. Also, renewable generated electricity and energy sources can reduce the impact on the local environment owing to its role in replacing fossil fuels (SDG 13 - Climate Action).

3.3 Energy Poverty Alleviation

Sub-Saharan Africa’s share of the global population without access to electricity rose to 77% from 74% before the COVID pandemic. The renewable energy sector employed a record 11.5 million people in 2019 globally. Furthermore, the changes needed in energy production and uses to achieve the Paris Agreement target of limiting the rise in temperature to below 2◦C have the potential to create 18 million jobs [6]. The implementation of renewable energy systems in communities currently without access therefore has the potential of not only reducing energy poverty but could potentially provide a valuable source of employment and income generation for such communities. Energy poverty is one of the main causes of the retarded economic growth in the SSA regions, with access to reliable energy being quite expensive even for industries as they tend to gravitate towards self-generation (i.e., the use of diesel generators) which in turn increases the cost of production, can be environmentally polluting, and could lead to increased shelf price of good and commodities. The need for electrification could hence cut down the reliance of self-generation thereby reducing the operating expenses (OPEX) of industries sited in such regions.

3.4 Electricity for Modernisation

Governments have a moral obligation to provide electricity as a key to the modern era which connects people across the world, it provides opportunities and widens horizons. Modern mass communication and information connectivity afforded by improved energy access could further provide inhabitants of SSA countries with solutions, products and knowledge that could enhance their overall standard of living.

Research shows that connectivity brought people closer, improved understanding of each other and other cultures, helped in the exchange of ideas within and across national borders, and is manifested in enhanced socio-economic cohesion [7]. Electricity is one of the major drivers for advancing any society as globalisation anchors on industrialisation.

Access to affordable energy in rural area could therefore support rapid economy growth and better improve life expectancy in such region. One of the trusted and reliable tools to shift a country's status from an underdeveloped country to a developing country lies largely on her access to energy, this positions the country in a strategic economy situation where raw materials can be easily processed, preserved and stored, and sent out for export and in turn create employment opportunity for her citizens, thereby creating wealth distribution. Energy access in SSA hence has the potential to increase the participation amongst nations to showcase their wealth of culture, expertise and ability to learn with modern day facilities.

3.5 Funding for Electrification in SSA

Despite the high impact of electricity on SDG goals, the implementation of RES is plagued by low private sector engagement in the domain notwithstanding the tremendous future growth potentials, with investors deterred by lack of profit in the short-medium term.

Many SSA rural communities are characterised by their sparseness and dispersed nature and as a result, providing grid extension could usually be unviable. Owing to the sparsely populated nature of the rural areas even off-grid schemes can be difficult to implement financially. This is mainly due to the low-income rates of inhabitants of such regions and the inability of such communities to economically back such projects. There would usually be a need to subsidise the electricity generation facilities or the electricity rates of such systems.

The role of developmental agencies in Africa, NGOs, and and those sponsored by the UN and other bilateral agencies like Japan International Cooperation Agency (JICA) are important for the realisation of electricity projects. International financial flows to developing countries in support of clean and renewable energy reached $10.9 billion in 2019, 23.6 per cent lower than that in 2018 and representing a contraction even before the onset of the COVID-19 pandemic. A longer five-year moving average trend shows that average annual commitments decreased for the first time since 2008 by 5.5 per cent from $17.5 billion in 2014-18 to $16.6 billion in 2015-19 [6]. Improvements in such investments would be necessary to enable continued expansion of RES systems use and improved electricity access in SSA countries.

3.6 Possibilities of Unconventional Off-grid Electricity in SSA

In the African context, If the electricity could be sourced from abundantly available renewable sources like solar or wind or micro-hydropower, fossil fuels related emissions, as well as the impact of transmission grids and transmission losses, can be minimised [8].

At the same time, the problem of lack of investment for huge transnational grids can be overcome and the delays due to the large scale of the projects and funding can be negated. The development of emerging trends in electrification in terms of solar photovoltaic and wind energy holds great potential if modulated and integrated by realities in the African scenario.

The IEA Net Zero Emissions by 2050 scenario (NZE) illustrates a trajectory to achieve full access to electricity by 2030. Slightly more than half of the people gaining access in the NZE by 2030 do so through decentralised solutions, including mini-grid and stand-alone systems, which are 90% based on renewable solutions. After 2030, it is expected that grid solutions will reach most of the population that initially gained access through off-grid solutions, emphasising the importance of grid-compatibility for the off-grid systems being built today. Decentralised solutions will play an important role on the uptake of bridging the gap of electricity access in SSA (especially rural area). Multiple standalone system increases deployment time and project success while reducing installation complexity.

4.0 Electrification in Malawi

This section presents an overview of the energy sector in Malawi. The section intends to reflect on the electricity landscape of the country assessing the situation regarding the history of electrification in Malawi, electricity market structure and policies related to electrification, a review of previous renewable energy projects in Malawi, barriers to electricity access, and potential factors important for the success of renewable energy systems implementation among others.

4.1 History and Status of Electrification in Malawi -Grid Based, Conventional and Renewable Energy Generation

This subsection gives an overview of the country's history of electricity generation through the national grid, the conventional energy resources that the country has, a background of renewable energy, and its potential use in Malawi.

4.1.1 National Electricity Grid

National electricity supply dates back to the 1950s when electricity was generated from a coal-powered plant at what is now called ESCOM Power House in Blantyre and a mini-hydro at Mulunguzi River in Zomba, the then capital of Malawi [9]. The generation capacity was increased when Nkula A Power Station, was built between 1966 and 1967 on the Shire River in Neno District. Between 1966 and 2021, additional power plants were constructed with around 485.7 MW capacity added to the national electricity grid as indicated in Table 4.1

Table 4-1 Malawi's total installed capacity. Source: [10]

Power Station	Installed Capacity (MW)	Year Commissioned
Nkula A and B Hydropower Station	135.10	1966-1992
Kapichira Hydropower Station	129.6	2000-2014
Tedzani Hydropower Station	102.0	1973-1996
Thermal Power Plants	53.2	2019
Wovwe Hydropower Station	4.5	1996
Likoma & Chizumula Solar Power Plant	1.3	2020

Salima Solar PV power plant	60	2021
Total Installed Capacity (2021)	**485.7**	

75% of this total installed capacity is from hydropower resources, with the remainder from the state-owned Electricity generation company, EGENCO, thermal power plants (diesel power generators) used for peak load. All major hydropower stations are in the southern region of the country along the Shire River. There is a small hydro station, the 4.5 MW Wovwe plant which operates in the Karonga district, in the northern part of Malawi [11].

As of 2021, the country’s total installed capacity is 485.7 MW with an available capacity of 263.30 MW which is against the current demand of 700 MW [10]. This generation capacity does not meet the national electricity demand as only 18% of the population has access to electricity, out of which 11.4% is from the national electricity grid and the rest is mainly from solar power systems and battery torches [12].

The situation is particularly worrisome in the rural areas which have an access rate of 3.9% [13]. Efforts to increase electricity generation to meet the demand have been met with challenges such as high wear and tear of electro-mechanical parts on the generation plant due to the sandblasting effect following environmental degradation along the waterways. Other challenges include; inadequate plant maintenance, sedimentation, an infestation of aquatic weeds in the reservoirs, and siltation of the river system causing low storage capacity[9].

As a way of addressing the challenge of inadequate generation capacity, in 2016, the Government of Malawi, GoM unbundled the Electricity Supply Corporation of Malawi, ESCOM, to form a new state-owned Electricity Generation Company, EGENCO which took over the generation assets from ESCOM [14]. The new market structure also allows Independent Power Producers, IPPs to generate electricity and feed into the national grid.

4.1.2 Conventional Energy Sources

4.1.2.1 Coal

Malawi has coal reserves estimated at 1 billion metric tonnes, 22 million of which are proven reserves of a bituminous type, with high ash and low Sulphur content. Most of the coal fields are located in the northern part of Malawi with two coal fields located in the southern region. Coal mining in Malawi dates back to 1985 with two fields currently being mined in the northern part of Malawi, the Rumphi district [14]. Coal is mainly used in industry for tobacco processing, beer brewing, textile and sugar production, as well as cement production. Some of the companies that use coal for the aforementioned activities include Castel Malawi, Illovo Sugar Company, and Shayona cement Company in, Lilongwe/Blantyre/Mzuzu, Chikwawa/Nkhotakota, and Kasungu respectively. Malawi Coal is sold at $190 per tonne compared to Mozambique coal which is sold at a cheaper price of $165 per tonne [15]. As such 35% of the consumed coal in Malawi is imported from Mozambique (easily transported through the railway system) and 65% sourced locally. The country plans to install two coalfired power stations at Zalewa and Salima with capacities of 300 MW and 100 MW respectively [16]. For the coal industry to improve in Malawi, investments must be made in new production equipment, quality, environmental stewardship, and transport infrastructure.

4.1.2.2 Hydrocarbon resources

Explorations made in the northern part of Lake Malawi show the existence of some hydrocarbon resources, although the quantities are not certain [16]. Malawi through petroleum importers limited, PIL, a consortium of oil marketing companies, imports 97% of its refined petroleum products with about 3% biofuels (especially ethanol being locally produced). The same study further shows that, as of 2015, Malawi was importing about 8000 barrels of petroleum products daily and had a monthly demand of 33.6 million litres. The total annual import bill for the year 2005 accounted for 8.8% of the total imports. A major consumer of liquid fuel is the transportation sector (89.99%), followed by domestic (5.25%), industry (2.87%), and agriculture (1.9%). Due to the rapid growth of the number of vehicles, the demand for petroleum products is expected to witness a growth in demand and is forecasted to be around 560 million litres by 2030 [14]. It is therefore important for the government to put in place strategies that ensure that such demands are met by among others intensifying the biofuel production.

4.1.2.3 Uranium

According to [14], before 2009 mining activities started, Malawi had proven reserves of about 63,000 tonnes of uranium in the northern district of Karonga, at Kayelekera. All the uranium mined was exported out of the country. Due to the sustained low uranium price on the world market, the Kayelekera site was placed on care and maintenance in May 2014. There is also another deposit at Ilomba in Chitipa District. GoM decided to harness the available Uranium for electricity generation, and the first nuclear power plant is expected to be commissioned by 2035.

4.1.3 Renewable Energy Resources and Background in Malawi

Malawi's first Solar Photovoltaics (PV) technology transfer to the rural areas occurred in 1997 when the United Nations Education Scientific and Cultural Organisation (UNESCO) financed the Makanjira Solar Demonstration Village Project in Mangochi District. Under the project, electricity was generated using several separate solar PV systems. The project mainly targeted government institutions and community facilities [17].

In 1999, the Department of Energy Affairs, DoEA, launched a UNDP-funded renewable energy project called the National Sustainable and Renewable Energy Programme (NSREP). The project was aimed at enhancing the utilisation of renewable energy sources in Malawi. NSREP activities included a baseline study to determine the level of renewable energy use in the country. The study concluded that there was very little utilization of renewable energy, including solar energy in Malawi. One of the findings of this study was that prices of renewable energy technologies were very high for most Malawians. The study further indicated that there was a lack of human capacity for renewable energy systems design, installation, operation, repair, and maintenance. There was also a lack of awareness about renewable energy among the general public. Another key finding was that the country had no policy on energy and this absence meant that there was no specific direction or strategy for the sector. Consequently, in 2001, the government came up with a project called Barrier Removal to Renewable Energy in Malawi (BARREM) to address these and other barriers that had been identified during the study. Notable successes of BARREM include; the formulation and launch of the National Energy Policy (NEP) in 2003 which among its objectives was to remove barriers to the adoption of renewable energy systems [9]. One of the key strategies was the introduction of solar villages, a concept of a centralized energy system discussed in section 5.0 of this paper.

Considering that the world over is concerned with negative impacts of that arise from use of greenhouse gas emitting resources, the research department of MoE embarked on a campaign to promote use of clean technologies. In the context, renewable energy (RE) is being promoted as one way of achieving clean and sustainable energy provision. The Department conducts research that aims at contributing knowledge and solutions to the technological, social and economic challenges of utilization of Renewable Energy. Some of the local challenges to the development of the RE sector are:

1. Technical know-how.
2. Policy and regulatory instruments.
3. Financing.

Having looked at the history of renewable energy in Malawi, the next sub-sections provide selected renewable energy resources which Malawi has.

4.1.3.1 Solar Energy

Malawi has an abundance of solar energy resources with average solar irradiation of 5.8kWh/m^2 and solar energy on horizontal surface ranges from 1642.5 to 2555 kWh/m^2 per annum [10]. Figure 4.1 presents the typical monthly solar irradiation for Malawi. Considering a 15% module efficiency, the stated solar irradiation can yield around 6000GWh per year from a land surface area of 18km^2. Solar thermal applications such as water heating and cooking have the potential of reducing electricity consumption from the national grid which currently does not meet the demand, a situation which has led to frequent power cuts across the country [14].

The key notable functional Solar PV projects include a 60 MW grid-connected Salima solar power plant, 850 kW grid-connected system at Kamuzu International Airport, and 80 kWp Sitolo Solar Mini-grid in Mchinji.

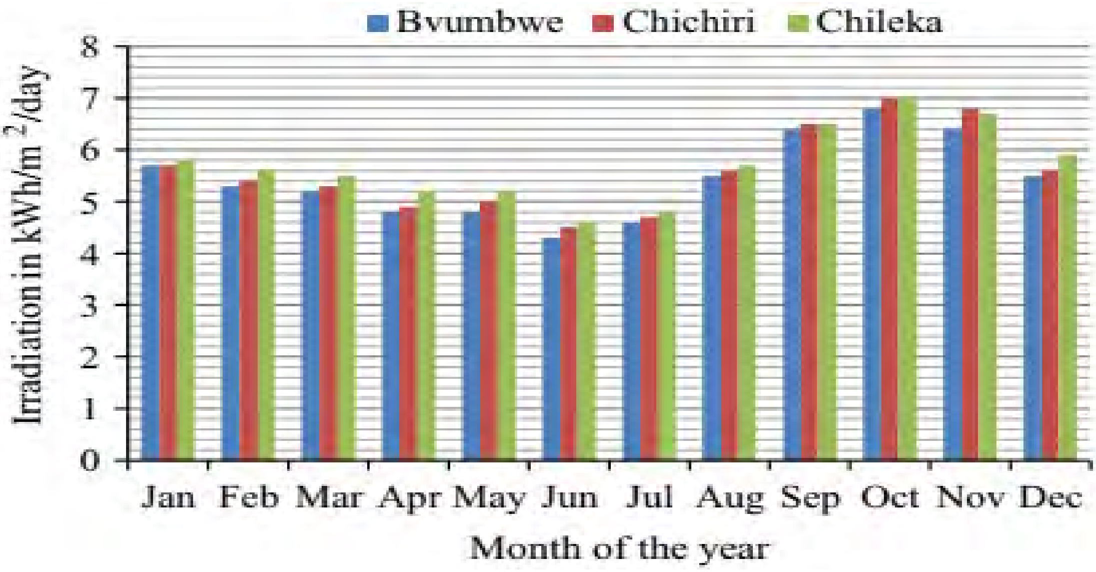

Figure 4.1: *Monthly mean solar irradiation from three weather stations for Malawi based on 2010 measured data from the Department of Climate Change and Meteorological Service* [18]

4.1.3.2 Wind resource

Wind energy has been used on a small scale to supply water for both livestock and irrigation in Malawi. Wind speeds in Malawi are typically moderate to low, ranging from 2.0 to 7.0 metres/second [16]. Results of the studies conducted from five stations in the following areas/districts; Chitipa (northern region), Nkhotakota, Salima (Central region), Chileka, and Ngabu (southern region) indicate that the monthly mean wind speeds are above 2m/s for a significant period at 2m hub-height. The peak wind speeds of 3m/s at 2m hub height are registered in July and October. During the same period, atmospheric temperatures are high necessitating space cooling; thus, there is a high probability of wind energy generation coinciding with demand. However, it would be essential to conduct further analysis by for example using a Weibull distribution to determine achievable capacity factors for the potential wind energy systems.

Two sites were identified for potential wind farms in the Northern part and the installation of wind masts for detailed wind speed measurements at the identified sites was planned for April 2013 [19]. With the aid of the international donor community, the Malawi government installed five hybrid small wind turbines of 10 kW capacity with solar PV systems in rural areas. Currently, there is a project in which detailed feasibility studies show that 100 MW plus grid-connected wind farms can be produced [14]. According to the reconnaissance study, the site has an average wind speed of 7.7 m/s. The project is in Chitipa, the northern part of Malawi. Another project has a potential of 86 MW of wind power and an average wind speed of 6m/s at 80m hub height. This is according to a feasibility study which was conducted by the Ministry of Energy Affairs. The project site is located in Kindwe Dedza District, the central part of Malawi[18].

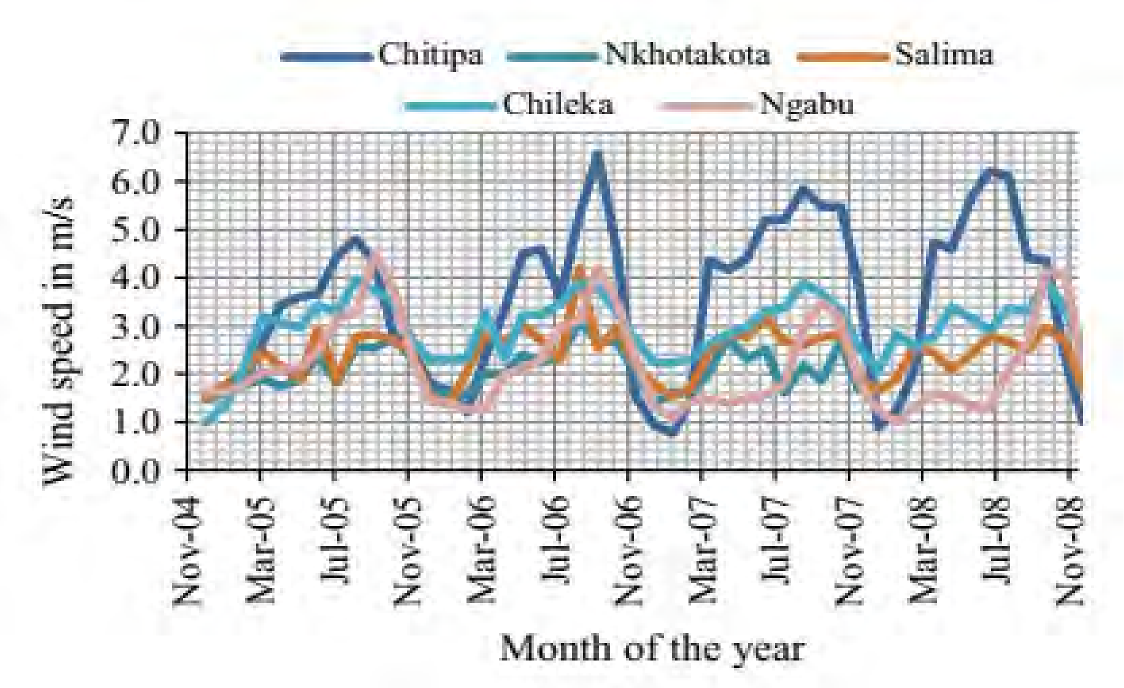

Figure 4.2: *Four years monthly average wind speeds at 2 m height for five selected stations for Malawi—based on measured data adopted* [18]

4.1.3.2 Hydropower

Malawi has over 1670MW of unexploited hydropower from rivers spread across the country with an estimated 6000GWh/day and 7000 respectively. The country mainly depends on the Shire River with 98% of hydropower generated from this river and has an untapped potential of 600MW [16]. Feasibility studies for various sites were conducted across all the major rivers in the country for possible investment by the private sector. Currently, the following projects have been identified as having the potential for further investment; Fufu hydropower project with a potential of 261MW, Kholombidzo power plant with a potential of 210MW, and Chizuma and Chasomba as shown in table [118].

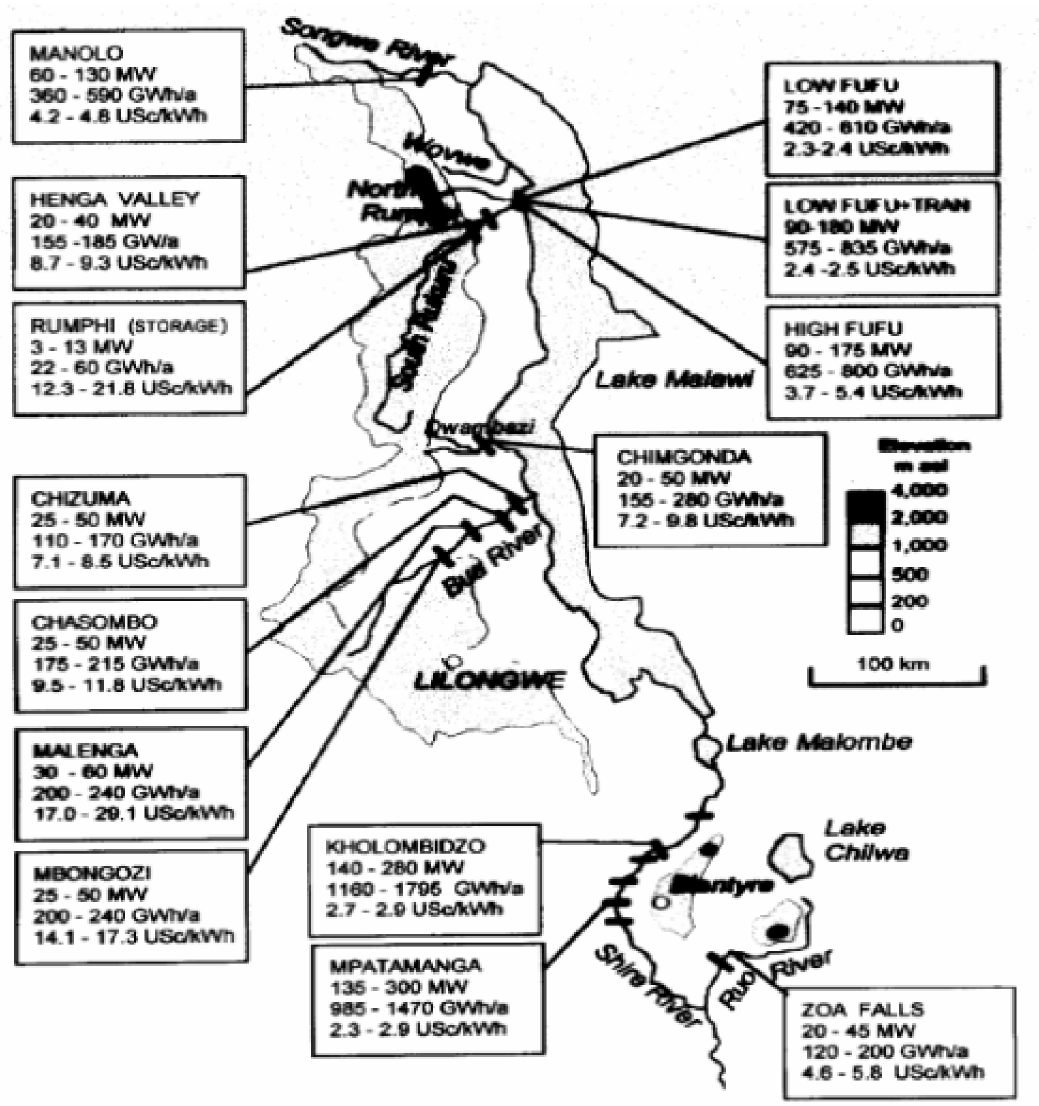

Figure 4.3: Sites Earmarked for Hydropower Development in Malawi- Adapted from [20]

4.1.3.4 Geothermal

Malawi has also geothermal resources which can generate an estimated 200MW. There are over 50 hot springs of which 18 of them have an average temperature of over 50 degrees Celsius as shown figure 4.4 [21]. The ministry of energy affairs identified additional 20 sites for possible detailed explorations [8]. The Government of Malawi is now looking for an independent power producer to develop the Chiweta geothermal power project, which is currently at the exploratory drilling stage.

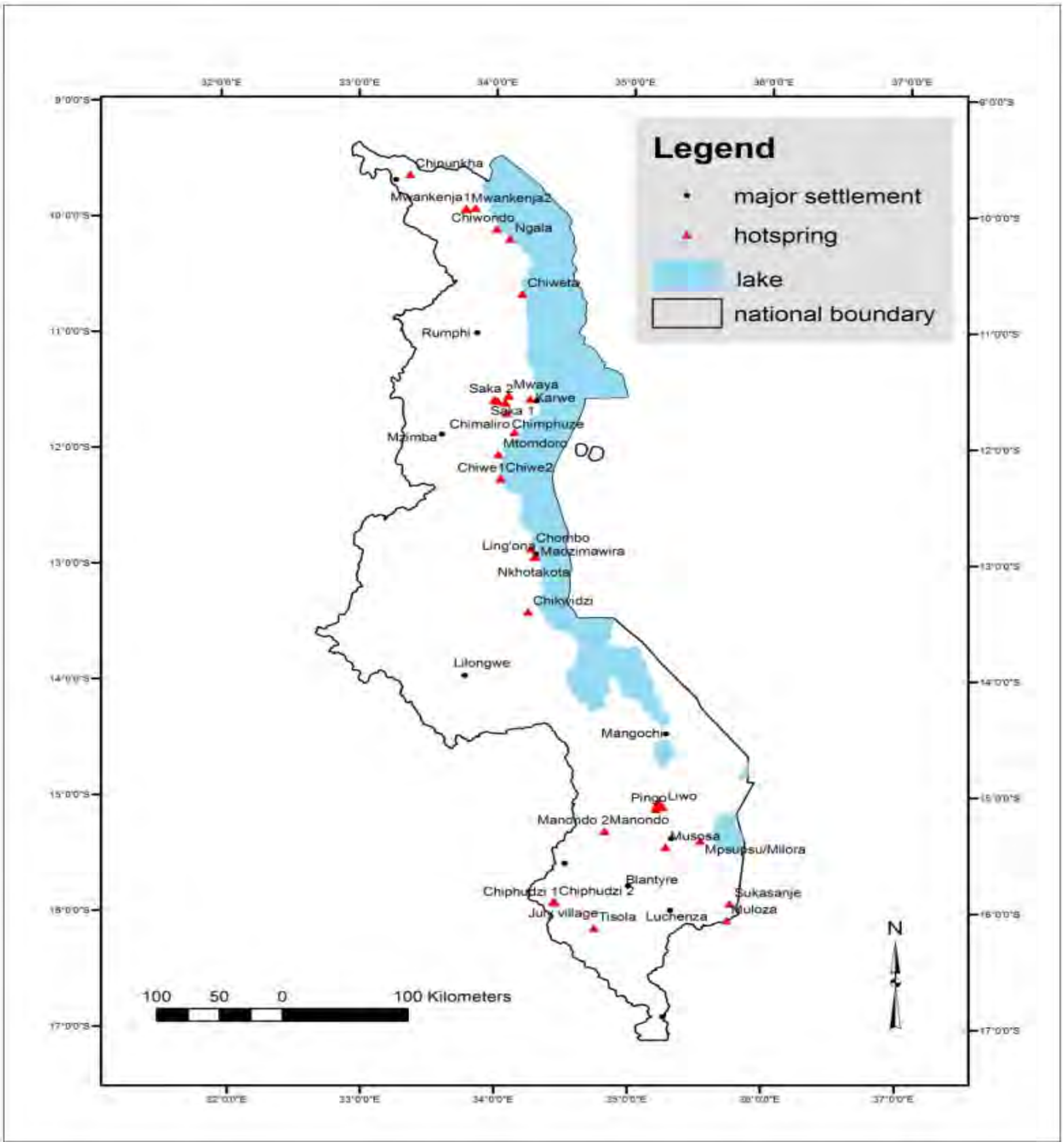

Figure 4.4 : Map showing Major hot springs in Malawi-adapted from [21]

4.2 Malawi Electricity Market Structure and Policy Guidelines relating to DER systems

This section presents the findings of a literature review carried out on the current electricity structure and policies related to energy access in Malawi. Four key policy documents pertinent to electricity access include National Energy Policy, Malawi Renewable Energy Strategy, Regulatory Framework for Mini-grid, and National Electrification Strategy. Other documents include Agenda 63, Independent power producers, IPP framework, and Malawi Growth Development Strategy, MGDS 3.

4.2.1 Malawi Electricity Market Structure

The overall mandate of Ministry of Energy is to ensure sustainable development and utilisation of energy resources for the socio-economic growth and development of Malawi. The Government of Malawi, GoM through the Ministry of Energy, MoE launched the National Energy Policy, NEP (2018) which governs the energy sector in Malawi.

NEP 2018 replaces the National Energy Policy of 2003 to provide a new policy direction and guidance to all stakeholders in the implementation of energy interventions The Malawi energy regulatory authority, MERA, was established by the energy regulatory act (2004) with the mandate to regulate activities in the energy sector fairly and transparently for the benefit of consumers and operators. Key roles performed by MERA include (a) reviewing tariff applications from the Electricity Supply Corporation of Malawi (ESCOM) and recommending tariff changes to the GoM; (b) granting licenses for generation and distribution operators under the 2004 energy legislation. A result of the Electricity Act (2016) which replaced the Electricity Act (2004) led to the bundling of ESCOM which led to the creation of two companies namely Electricity Generation Company Limited (EGENCO) and Power Market Limited, PML. ESCOM supplies power to large and small customers through the national grid. Power Market Limited has been recently established to play the role of a single buyer. However, currently, the single buyer functions are still performed by ESCOM. EGENCO is responsible for power generation together with independent power producers, IPPs which are privately-owned companies that generate power and feed into the national grid. MoE in collaboration with ESCOM electrifies rural trading centers across the country under Malawi Rural Electrification Program, MAREP. The program is funded through a 4.5% level of sales of petroleum products such as petrol, diesel, and paraffin [11]. Figure 4.3 indicates the electricity market structure in Malawi.

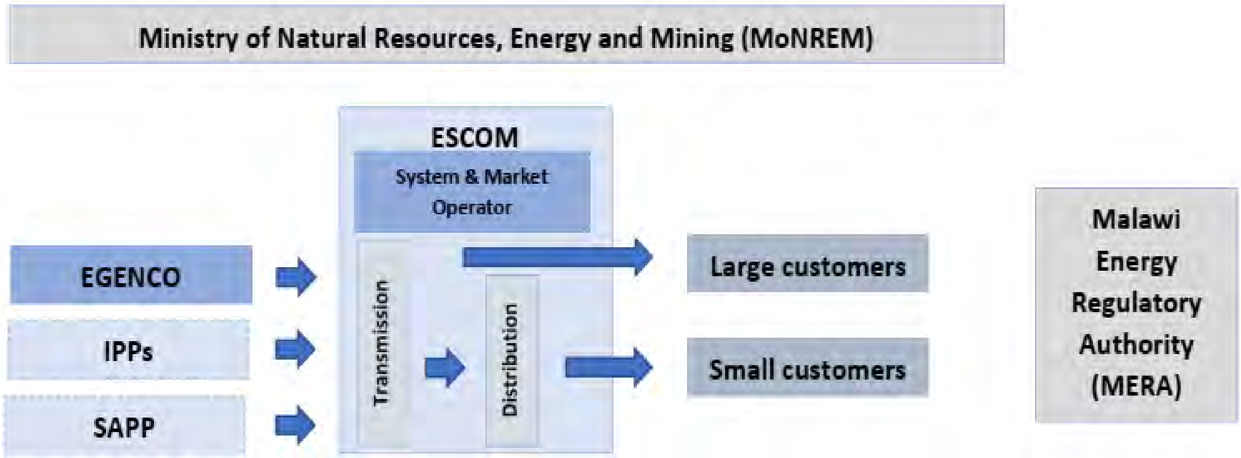

Figure 4.5: *Electricity Market Structure in Malawi-adapted from [11]*

4.2.2 Policy Guidelines relating to DER systems

4.2.2.1 National Energy Policy 2018

The National Energy Policy, NEP, was launched in 2018 as a successor to the 2003 national energy policy with the goal of **"increasing access to affordable, reliable, sustainable, efficient and modern energy for every person in the country."**. This Policy has categorised energy sources as follows: 1) Electricity from Non-Renewable Sources; 2) Electricity from Renewable Sources; 3) Biomass; 4) Petroleum Fuels; 4) Biofuels; 5) Liquefied Petroleum Gas (LPG); 6) Biogas and Natural Gas (NG); 7) Coal; and Electricity from Nuclear Energy[6]. Priority areas related to renewable energy systems are discussed in priority areas 1 and 8. **Priority area 1 (electricity)** plans to intensify the electrification of rural trading centres as well as villages by providing funding from the Rural Electrification Fund to off-grid rural electrification schemes. Finally, the NEP states that under priority area 1 the government will promote the use of renewable energy technologies and the manufacture of renewable energy products such as solar panels. **Priority area 8 (demand-side management)** outlines the intention to institute appliance testing, labelling, and standards, which will include minimum energy performance standards; reducing or eliminating import duty and taxes on energy-efficient products; conducting public information campaigns to raise awareness amongst consumers; the provision of financing for energy efficiency measures, allowing consumers to repay loans as part of their utility bills; and, promoting energy-saving electrical and biomass-fuelled devices.

4.2.2.2 Malawi Renewable Energy Strategy

The main objective of this strategy is *to ensure universal access to renewable electricity and a sustainable bioenergy sector*. The MRES specifies actions required to deliver the above objective, focusing on grid-scale power, clean mini-grids, off-grid power, clean cookstoves, solid biofuels, biogas, and biofuels in transport. Actions impacting the opportunities and barriers to electric cooking include: the continued delivery of Malawi's Rural Electrification Programme (MAREP) phased grid extensions into rural trading centres; the development of an Independent Power Producer (IPP) framework and the Power Purchase Agreement (PPA) process to increase generation capacity[22].

4.2.2.3 Mini-Grids Regulatory Framework

The regulatory framework for mini-grids is intended to achieve sustainable development and operation of mini-grids in Malawi while striving towards the provision of modern energy services to remote communities where grid extension is not economically feasible [23]. Building from the commitments of the National Energy Policy and the Renewable Energy Strategy the regulatory framework sets out the guidelines for the development and operation of mini grids in Malawi covering the following key areas: solicitation process; requirements for approval; terms and conditions for licensing and registration; governance structures; quality of supply and service standards; tariff methodologies and structures; linkages with the national grid. Critically, concessions and waivers have been included for sites with generation capacity under 150kW, and provision is made for a variety of subsidies that either reduce consumer tariffs, lower capital expenditure or incentivize new connections, which will increase rural electrification rates. The establishment of a regulatory framework sets a solid foundation for scaling up mini grids in Malawi and providing developers with the clarity and reassurance to invest in new projects.

4.2.2.4 Malawi National Electrification Strategy

The NES proposes a framework through which the Government of Malawi (GoM) will guide accelerated access to households and businesses at acceptable quality and levels of service that are anchored in the priority policies presented in the NEP 2018 [24]. The strategic elements are summarised in Table 4.1 and are organised in four thematic pillars that taken together define the means and processes by which electrification expansion will be implemented.

Table 4.3: A table showing a summary of National Electrification Strategy Pillars

Pillar I – Institutional	• Roles and responsibilities of the grid and off-grid electrification implementation agencies • Develop and implement capacity-building programs to strengthen electrification stakeholders at all levels of the value chain
Pillar II – Policy and Regulatory	• Define the minimum level of service with which access expansion will be measured • Adopt sound licensing, quality of service standards, fiscal exemptions, and material/equipment standards required to support sustainable off-grid electrification; define connection fee policy for low-income grid consumers • Scale-up mini-grid and standalone off-grid system development
Pillar III – Technical and Planning	• Identify power supply shortfalls that may impact grid densification and expansion planning on a temporal basis with which ESCOM and EGENCO can identify power supply options • Establish a least-cost geospatial planning framework for on- and off-grid electrification • Evaluate & establish low-cost electrification design standards
Pillar IV - Financial	• Promote affordable access to electricity service for both grid and off-grid electricity service • Develop a financing plan to support the electrification expansion goals

Source: *Adapted from* [24]

4.3 National Electricity Generation, Demand, and Utilisation in Malawi

4.3.1 Electricity Generation and Demand

Grid electricity increased from 1031.8 to 1887.7 GWh between 1999 and 2011, representing an average annual increase of 6%. Between 1996 and 2011, the average maximum demand for electricity had increased from 190.2 MW to 277 MW An average demand increased by 5 MW per year in the residential sector alone due to increased electrification [9]. Currently Malawi has installed capacity of 485MW and available capacity of 263.3MW which is attributed to power loss at Kapichira hydro power plant which was damaged by Cyclone [10]. According to [17], Malawi's annual population growth rate is 2.8%, and its urbanisation rate of 4.2% which consequently indicates that future demand for electricity is projected to outstrip supply. The supply and demand in Malawi's power sector show a trend of significant shortage in the foreseeable future, due to an increase in demand averaging 7% per year [18]. The electricity sector has been choked by the aging transmission infrastructure which has also resulted in power losses such that there is a significant difference between installed capacity and available capacity. To address this challenge, transmission networks have been upgraded such that Significant ESCOM's transmission system presently comprises some 1,340 km of 132 kV lines and 1,100 km of 66 kV lines and associated substations. Total system losses have seen a major improvement from 21 percent in 2012–to 13 to 18 percent between 2016 and 2017 [11].

On decentralised energy systems, studies by [26] show that Malawi's off-grid solar PV installed capacity increased from 0.2 MW in 2007 to 10.4 MW in 2016. Solar home systems, SHS, are offered by commercial companies registered with Malawi Energy Regulatory Authority MERA. An estimated 7000 off-grid PV systems were installed in 2012 but little is known about the systems which are in operation several off-grid solar delivery models have been deployed across the country with a notable one being the energy kiosks implemented by RENAMA[10]. Despite registering these successes, several projects were not sustainable, findings which resonate with studies by [27] who present failures of off-grid renewable energy projects in Sub-Saharan Africa, SSA. It is therefore important to consider sustainability issues from past deployments and ideally use a systematic framework to evaluate current and future renewable energy projects.

4.3.2 Energy Mix and Utilisation

Malawi's energy mix is dominated by biomass accounting for 81% of the energy supply, a factor attributed to the fact that Malawi's population heavily relies on biomass for cooking. mainly from. Liquid fuels and biofuels which are an essential community in the transport sector accounts account for 10% of the energy mix. Electricity from renewable energy sources mainly hydropower and solar energy constitute 7% of the energy supply profile. Coal, electricity from non-renewables constitutes, and LPG or natural gas and biogas constitute 2.3%, 0.3%, and 0.1% of the energy mix respectively. Even though Malawi has relatively small uranium reserves, the country is yet to start generating electricity from this nuclear energy source.

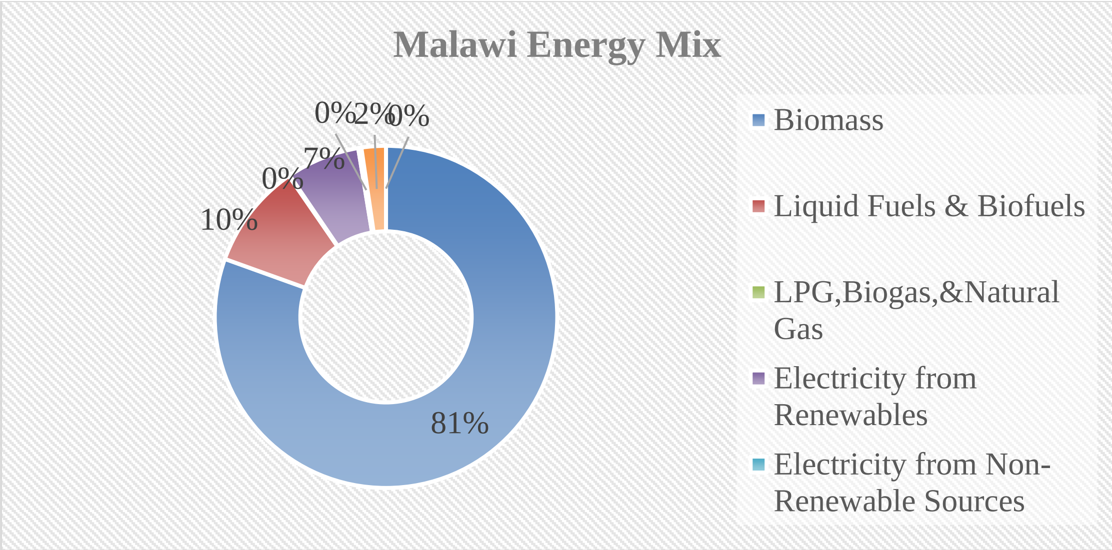

Figure 4.6: *Malawi Energy Mix 2015 (adapted from [14])*

The previous study related to energy consumption by sector was last conducted in 2008 where it indicated that households, transport, and industry constituted 84%, 5%, and 4% respectively [16]. However, it would be misleading to use this data as it reflects the 2008 situation, and a lot has changed since then.

A 2021 Malawi Energy Profile Report by [28] which only shows the electricity consumption from renewables indicates that households consume 48% of the electricity. This is attributed to among others the rapid population growth which has consequently resulted in increased electricity demand. The industry consumes 15% and other sectors consume 37% of the electricity from the renewables. The transport sector is reported to have a 0% share a fact attributed to the fact that this sector still heavily relies on fossil fuels, mainly petrol and diesel.

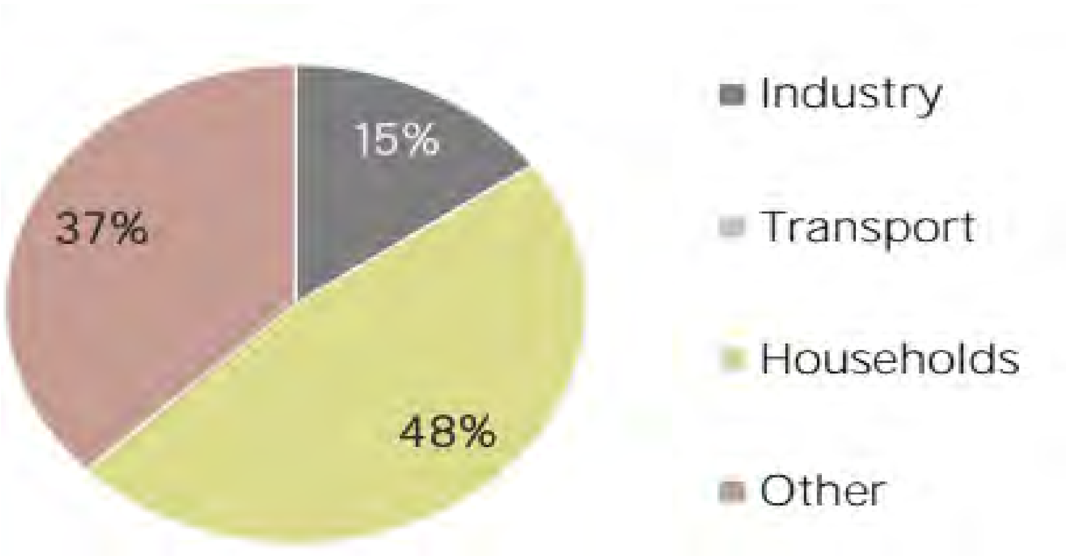

Figure 4.7: *Renewable energy consumption by sector adapted from* [28].

4.4 Ongoing Electrification Initiatives in Malawi

This section gives an overview of the efforts made by both government and the private sector to accelerate access to electricity across the country. These initiatives include national electricity grid extension and off-grid renewable energy systems.

4.4.1 Malawi Rural Electrification Programme, MAREP

As one way of accelerating rural electrification, in 1980 the government established the Malawi Rural Electrification Program to increase electrification access for people in peri-urban and rural areas from current 18% to 80% in 2035 by using the global tracking framework, GTF [14]. The program is managed by the Ministry of Energy, MoE, and Electricity Supply Corporation of Malawi, ESCOM. Since its inception, eight phases of the program have been implemented. This involved extending power distribution lines to district administration centres, major trading centres, tobacco growing areas, and the development of the 4.5 Mega Watt Wovwe Hydroelectric Power Plant. Under MAREP, 836 district administration and trading centres in rural areas were electrified. However, despite launching this initiative, access to the electricity grid is quite low with only 3.9% of rural households connected to the national grid. This implies that the main objective of the program is far from being fully met. As a way of addressing this challenge, the Malawi government through the department of energy affairs in collaboration with ESCOM is implementing the NDAWALA (local language which translates to ***fast walk***) project that aims at increasing the connectivity of rural households. It was noted that after bringing electricity close to households in peri-urban and rural areas through MAREP, households were taking a long to connect due to the inability to meet connection fees hence the introduction of NDAWALA. Therefore, the project was introduced to assist low-income households with wiring services and connections through a soft loan of $67.57 The loan is deducted over a period when customers are buying energy units, and 40% is deducted from every purchase made [29]. Potential customers are identified by the contractors and certification of the customers is done by ESCOM. Customers are required to pay a $6.14 commitment fee. The list of certified customers is submitted to contractors for the execution of works. Contractors are involved in the wiring of houses while meter connections are done by ESCOM. Since its commencement in 2019, NDAWALA Project has connected 9,156 households across the country out of the planned 12,982 households in the first phase of the project [14]. With over 2 years since the inception of the project, the verification exercise carried out by the Ministry of Energy has observed that the Energy Meters have not yet been activated to enable customers to buy electricity units. Additionally, ESCOM did not extend

Low Voltage, LV powerlines to customers who are far from Medium Voltage, MV networks despite having their houses wired. These factors indicate that NDALAWA Project has done little in accelerating electricity adoption from the national grid. It has also to be noted that this project was initiated on premise that the only challenge which is preventing people in rural areas to adopt electricity from the national grid is lack of finances. Therefore, the Ministry of Energy, MoE needs to conduct research aimed at understanding all aspects that are causing low electricity adoption in Malawi's remote areas.

4.4.2 Electrification initiatives by Private Owned Companies

The Government of Malawi, through the Ministry of Energy, MoE, formulated enabling policies aimed at bolstering private sector involvement in electrification programs across the country [14]. For instance, through the Increasing Access to Clean and Affordable Decentralised Energy Services, IACADES program, with funding from UNDP and GEF and the Scottish Government has been providing support to the scheme. The support has been going to grid extension, implementation of the 100kW power plant, and capacity building. With the support from DOE and the Scottish Government MEGA has managed to power 402 households, 3 schools, and 24 teacher houses [30]. Through the same program, MoE also collaborated with Community Energy Malawi to install a solar-powered mini-grid in the central region part of Malawi, Mchinji, Sitolo village. The solar village has an installed capacity of 80kW and is currently supplying electricity to 149 households and businesses. The mini grid is operated by Community Energy Malawi.

Through the same IACADES project, MoE is implementing a 50kW Micro-hydro power scheme in the Kavuzi area of Nkhatabay District and a 50Kw Chipopoma hydro mini scheme with each expected to supply electricity to over 100 households in the respective areas. Additionally, Solar home systems, SHS, Pico lighting systems, energy kiosks, and other off-grid energy solutions are offered by commercial companies registered with Malawi Energy Regulatory Authority MERA [18]. Finally, as already alluded to, in 2016, MoE undertook electricity sector reforms which created independent power producers, and privately-owned companies which generate electricity and feed it to the national grid. This initiative has resulted in the installation of a 60MW grid connected Salima solar power plant. Other grid-connected solar power plants are under construction in the central region districts of Nkhotakota. Once completed, these solar PV power plants will add 86MW to the national grid [10].

5.0 Critical Review of Electrification Projects in Malawi

This section analyses the cause of failure or underperformance as well as the successes of previous renewable energy projects in Malawi. It is essential to learn from past renewable energy projects in to develop a successful systematic framework for evaluating current and future renewable energy projects

5.1 The Centralised Systems Strategy: The Solar Village Concept Revisited

A solar-wind hybrid is set up to generate electricity in large enough quantities to supply between 100 and 150 households, a school, and a trading centre. The solar-wind hybrid systems had an installed capacity of 25kW and available capacity of 20Kw [9].

In 2007, a total of 6 solar villages were commissioned on the following sites; Kadzuwa in Thyolo District, Chigunda in Nkhotakota, Elunyeni in Mzimba, and Mdyaka in Nkhatabay, Kadambwe in Ntcheu, and Chitawo Solar in Chiradzulu District [17]. The installed capacity for the solar-wind hybrid system was 25kW and in 2008 each cost $60,000.00. A total of $360,000.00 was used to construct the six solar villages. In terms of financing and payment, some villages had been supplied free of charge while others paid $0.20 - $0.50 per month to a local fund, used for paying an operator of the plant, the security guard, and some minor repairs. The cost was $2 per connection including wiring materials or $1which did not include wiring accessories.

The concept of the solar village involved the government hiring a contractor to construct the electricity generation facility. Upon completion, the facility is handed over to the government. The government entered a one-year contract with the contractor for the repair and maintenance of the facility. The government then hands over the facility to the concerned community. The community assumes ownership and is expected to manage the facility. The community is then expected to establish a committee to be responsible for the day-to-day management of the facility, revenue collection, and repair and maintenance beyond the one-year contract. The labour and employment opportunities related to the plant operation, safety and maintenance is also expected to be drawn from the local community. For example, a member of the community is employed as the operator of the facility while another one is employed as the security guard.

Figure 5.1: *Chigunda solar-wind hybrid system adapted from* [31]

5.1.1 Successes

Findings made by [17] indicate that solar villages registered the following successes; There is a high sense of ownership of the facilities such that people displayed their acceptance of the facilities that had been established by forming committees to manage them including their daily operation, and revenue collection as well a repair and maintenance. Additionally, the community members were willing to pay for the electricity despite some cases of defaulters.

5.1.2 Challenges

Studies by [31] indicate that it was costly to install the solar villages and the operating costs were too high such that the locals would not afford to repair and maintain the system, especially batteries. Furthermore, there was a lack of dedicated funding for sustaining the programme such that currently, no solar village is operating. The other challenge was the unsustainable Electricity Pricing Mechanism such that electricity tariffs were equivalent to monthly expenditures on torches, candles, and other lighting sources used by the community members.

5.2 Decentralised Systems Strategy: The Barefoot Engineers Concept

In 2007, Barefoot Engineers concept was introduced in Malawi through a project that was financed by the Indian Government in collaboration with the Malawi Government through the Ministry of Foreign Affairs and International Cooperation [17]. The objective of the project was to disseminate solar home systems to vulnerable people in rural areas. Under this project, a total of 316 solar home systems were installed in 316 households in four villages in all three regions of Malawi. The Indian Government provided full scholarships for the training of selected rural women in solar PV engineering. These women were trained for a period of 6 months at Barefoot college, India. The last cohort of women to be trained under this project was in 2013. On its part, Barefoot College has partners in countries where the project is being implemented. In Malawi, the partner is the Centre for Community Organisation and Development (CCODE).

5.2.1 Successes

Since the Barefoot engineers' project focused on the installation of solar home systems which are simple and less complex, it was easy to transfer skills to the local community and less costly thereby making it easier to repair and maintain the systems. Additionally, there was a strong sense of ownership and community participation since each household had its solar home system. Thus, the decentralised systems strategy provides for a self-regulating environment as far as ownership, operation, care, repair, and maintenance are concerned. However, little is known on whether the solar home systems are still in operation

5.2.2 Challenges

The strategy is seriously weakened by the fact that the first lot of the systems were given out to the people free of charge. There is no provision for people purchasing the systems on their own. This means that the rest of the villagers are looking forward to "receiving" rather than "buying" the systems. Furthermore, due to its dependence on donations, the project had very limited coverage. For example, Chitala Centre comprises 19 villages but only 4 were covered by the project [9].

5.3 The Sunny Money Concept

At the first level is Solar Aid which saw the need and potential market for affordable lighting systems in the rural areas. At the second level is Sunny Money where a firm - Solar AID Imported solar PICO lights and sold them to customers [17]. It has used its ingenuity to design an innovative marketing system to deliver new products to hitherto unknown markets. Thus, Sunny Money is the secondary entrepreneur. At the third level are the individual dealers across the country. They have invested their resources in the marketing of solar PV technologies to end-users.

5.3.1 Lessons from the Concept

The significance of the Sunny Money concept is that it contributes to the development of the market infrastructure for the transfer of solar PV technologies. To be specific, the model highlights “dealerships” as a marketing strategy that enables the transfer of solar PV technologies deep into rural areas [17]. The dealership is therefore an important feature that should become one of the pillars of a sustainable strategy for the transfer of solar PV technologies to the rural areas

5.4 The Empower Concept

Empower Inc. is an Australian NGO that initiated a project to promote a savings culture as well as disseminate solar lanterns for lighting in the remote community of Kapita in Mzimba District in 2010.

The project was first piloted in Zatuba Village, Traditional Authority Khosolo in the South-East Mzimba District in the Northern Region of Malawi [31]. The project was designed in such a way as to empower the people economically, first and foremost. With this philosophy, Empower provided seed money to the tune of $10,000.00 for the project. One of the first activities was to establish a village bank, to engender self-reliance in the area through the promotion of a saving culture in the community. According to [17], in addition to promoting saving, the bank aimed at providing business and development loans in a region that has no financial services within a 50 km radius. At the community level, savers earn 7 percent interest on their savings while borrowers pay 20 percent interest on the loans. Empower engaged a local training and consultancy provider namely Business Expansion and Entrepreneurship Development (BEED), to train members of the community in business and entrepreneurship as well as establish a Village Revolving Fund. The fund would be the capital base for the provision of loans. One outstanding feature of the project design is the absence of donations.

5.4.1 Successes

The Empower concept is very close to being a sustainable strategy for solar PV technology transfer. The potential for sustainability lies in the fact that there are no donations involved. This means that any capital injections by Empower Inc referred to as seed money, will be repaid. The other favourable aspect of the model is that it has a built-in economic empowerment component, which enables participating communities to develop the financial capacity to purchase solar lanterns, among their other needs. The model has highlighted “economic empowerment” as an important pillar of a sustainable strategy for the transfer of solar PV technologies in remote areas of Malawi.

5.4.2 Challenges

There is no effective supply chain for the technologies built into the project design. People cannot access the solar lanterns on their own and must rely on the sponsors to keep bringing them in. This is where the sustainability of the project is compromised.

5.5 Mulanje Electricity Generation Agency

Mulanje Electricity Generation Agency, MEGA, is located in Mulanje district, Malawi, and is considered the first mini grid in Malawi. The concept of a community-based mini-hydropower project was introduced in 2008 and led to the establishment of the Mulanje Energy Generation Agency (MEGA) in 2011 by three founding partners [31].

The installed system capacity is 80kW and provides electricity to about 3,500 households. The findings of this study also show that MEGA has been receiving financial support from the European Union and the OPEC Fund for International Development (OFID), the Scottish Government, Mulanje Renewable Energy Agency, MUREA, Practical Action, UNDP/GEF, and other funders. Being a socially oriented company MEGA does not seek to maximise profits. The MEGA business model aims to achieve economies of scale for central operations by developing multiple sites.

Figure 5.2: *Distribution of powerlines at MEGA adapted from* [31]

6.0 Barriers to Electricity Access Through Renewable Energy Systems in Malawi

6.1 Political Will

Currently, little has been done to address the issue of non-compliance to installation standards, and the use of deployment models which are not business oriented. Furthermore, GoM through the Ministry of Energy has mainly focused on accelerating the electricity connection through grid extension under MAREP even though the program has the facility for a mini-grid subsidy to reduce electricity tariffs [32]. However, the program is yet to implement in a real-life project on decentralised energy systems such as mini grids. Additionally, the process of awarding contracts for RE projects links with the influence of politics in public RE projects. Despite the existence of a compressive procurement process, corruption still occurs. This may explain the low market penetration of renewable energy technologies and may have a knock-on effect on mini grids.

6.2 Business Models and Financing

So far, it remains a challenge to develop a sustainable business model for disseminating decentralised energy systems in Malawi. Research carried out in [33] suggests that productive use can be promoted as a driver towards sustainability, especially effective if coupled with training on skills, and access to microfinancing for enterprises. The study further proposed the promotion of business entrepreneurship, increasing the time and resource requirements to get a project off the ground. With regards to the issues of financing, [31] reports that capital for investment is a major challenge in Malawi as energy business models are not commonly understood by Malawian banks, and financial players tend to be risk-averse. Additional to these challenges, exchange rate fluctuations have impacted renewable energy projects' finances since most products are imported. Addressing the barrier of micro-finance availability for consumer products will increase the demand and profitability of renewable energy systems in Malawi.

6.3 Ability and Willingness to Pay

High poverty prevalence in Malawi has been a driver for the unsustainability of energy interventions as most Malawians cannot afford to pay for electricity. The process of determining households' willingness to pay for electricity from decentralised energy systems is inherently complex [31]. The study further argues that there is high uncertainty exists in determining the expected electricity demand of previously unconnected communities and considerable variation can exist between relative wealth levels in the village. Furthermore, tariff setting based on ability and willingness to pay was also identified as a key barrier.

6.4 Stakeholder Coordination

The challenge is that there is a lack of coordination among various players in Malawi's energy sector. As such, there is a duplication of efforts aimed at promoting electricity through off-grid renewable systems. Time and resources are therefore wasted by replication and resource overlap.

6.5 Lack of Knowledge and Availability of innovative technology

A combination of unavailability of modern renewable energy technology options, particularly recent innovations using hybrid systems, demand management, and payment solutions, and lack of knowledge is currently a significant barrier to the development of decentralised renewable energy systems in Malawi. Findings in [31] suggests that technologies and their development methodologies including financing mechanisms should be adapted to the contexts in which they would operate. This requires in-depth knowledge of several aspects such as energy needs and requirements; prioritisation of energy services; purchasing power; satisfaction with energy services and experiences with the prevailing energy technologies; social practices and technical skills. The other challenge is that many off-grid systems in Malawi are implemented without proper assessment of the renewable resource or effective demand assessment. This has consequently led to incorrect resource assessment whereby there is inadequate generation and inaccurate load forecasting. The study further reports that the few products found in Malawi are typically expensive compared to other countries in the region, and importation can prove a difficult task and remove the possibility of warrantees. The same study proposed that Renewable Energy Equipment Project Waiver provided by the Malawi Revenue Authority can help to reduce cost, the small quantities of goods currently being imported on a project-by-project basis offer no economy of scale.

6.6 Non-competitive Electricity from National Grid

As noted by [31], a risk to decentralised renewable energy systems is the arrival of the national electricity grid because mostly, electricity from the national grid has cheaper tariffs. However, this challenge can also be seen as an opportunity, as ESCOM is currently suffering from power shortages and frequent blackouts. Decentralised energy systems placed at the edge of the grid can provide additional stability and a welcome source of additional power for a wavering grid.

6.7 Legal Issues

Malawian energy legal system is currently unfavourable for decentralised energy systems especially mini-grids, although recent developments discussed previously are underway to ease legal requirements for mini-grid developers. The government has recognised this and is proposing to reduce regulation for smaller systems, with a proposal currently in review for all mini-grids under 100kW to be exempt from regulations[31].

The discussions in [31] went further and proposed that a clear legal framework is required to regulate transparent coordination among the Malawi Revenue Authority which takes control of the importation, the Malawi Bureau of Standards, Test and Training Centre for Renewable Energy Technologies, renewable energy consultants, and contractors.

The importation and selling of counterfeit products are also a challenge mainly with PV devices, with imitation and faulty systems such as Pico Solar Systems, solar modules, inverters, and charge controllers which are widely available in the market eroding consumer confidence in such systems.

7.0 Factors Important for the Success of Renewable Energy Systems Implementation

7.1. Transparency

Transparency is a critical aspect of projects in general and renewable projects in particular. It is therefore important to clarify how public projects are designed and implemented. [34] suggests the defragmenting of administrative and bureaucratic procedures, implementing checks and balances in stakeholder relationships, and prioritizing public interests over other interests

7.2. Ownership

Ownership is one of the key factors in ensuring the success and sustainability of decentralised renewable energy projects. Findings made by [35] pointed out that there is a lack of clarity on which stakeholders have authorised ownership of most RE projects. For instance, in some cases, there are differing views on its ownership structures and mechanisms from shared ownership, government ownership, or public ownership. It is even more common for stakeholders to deny ownership in the event of a malfunctioning project to evade responsibility for maintenance. To address this challenge, there is a need of assigning ownership and responsibility to renewable energy projects:

7.3. Shared Responsibility Among Stakeholders

It is a known fact that all public projects involve multiple stakeholders united by common interests. Research carried out in [35] proposes the need to provide and improve public services as a common reason for the implementation of renewable energy projects. The different stakeholders should therefore share the responsibility of promoting sustainable management of renewable energy projects. The study further presents three key factors to consider in ensuring that this shared responsibility is realised, and these include establishing and maintaining communication amongst stakeholders, ensuring that project infrastructure is safe and protected as well as ensuring management of RES projects.

7.4. Community Participation

Lack of community involvement is also one of the major factors leading to failures and unsustainable management of renewable energy projects in Sub-Saharan Africa and Malawi in particular. This may include involving local entrepreneurs, end-users, and local investors. Furthermore, setting up local management and maintenance services is important for the sustainability of RE projects. Studies by [36] have recommended the need of involving the local community when implementing renewable energy projects as several case studies indicated the success of community involvement. Nevertheless, studies by [37] show some cases where sharing of responsibilities resulted in operational inefficiencies and sometimes the community members were uncooperative. However, there is a need for planning, training, and community-building from the commencement of the project

7.5 Knowledge and skills

There is a lack of awareness of renewable energy in public, industry, utility, and financial institutions. Availability and access to existing renewable energy resource information are limited. There is also limited empirical knowledge on the costs and benefits of the range of technologies available for providing renewable energy-based energy services. Therefore, there is a need of intensifying awareness programs such as using village fairs, exhibitions, RES posters, and the distribution of calendars. There is also a need of training people on use, maintenance, and repair services, managing the RES as well as building up enterprises for selling RES, and work in organisations that perform research and development of RES.

7.6 Financing Mechanisms

The initial costs of renewable energy systems are high, and this is one of the major barriers to the adoption of RES. One of the major challenges to RES diffusion is the high costs. Especially initial investment costs are high. Furthermore, there are no dedicated financing mechanisms for renewable energy activities within most financial institutions. There is also a need of putting financial procedures in place to make the RES more affordable, based on microcredit mechanisms as well as the fee-for-service option and such financial mechanisms should be extended further.

7.7 Removal of policy barriers

Some projects are delayed or even fail due to delays resulting from bureaucratic procedures in the public sector. As such, the process for project approval is lengthy and complex. The other challenge is that most of the programs in Malawi are primarily government and donor-funded and focus on research and development, rather than product commercialisation and private sector involvement. Additionally, RES implementation activities especially in rural communities where large-scale funding is unlikely, usually depend on national budgets, which creates uncertainties in the allocation of financing and time delays associated with decision making.

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