Renewable Energy Mini-grids in Malawi: Status, Barriers and Opportunities

A Working Paper produced by the University of Strathclyde and Community Energy Malawi for the Scottish Government

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University of Strathclyde Engineering

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Riaghaltas na h-Alba

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Executive Summary

This report outlines recent research conducted by the University of Strathclyde and Community Energy Malawi on the mini-grid sector in Malawi. It is intended to inform key stakeholders with an interest or involvement in the Malawian mini-grid sector on the status, barriers and opportunities for progressing the nascent sector, as well as signposting to further sources of information.

Data has been collected through literature review, stakeholder surveys and case study evaluations of existing mini-grids in Malawi through household surveys, focus group discussions and expert interviews. Analysis and findings are presented with recommendations for policy makers and developers from the Malawian mini-grid sector.

Mini-grids offer a sustainable solution to rural electrification, combat poverty, and grow local economies. Despite a huge market of un-electrified rural communities in Malawi, the mini-grid sector is in a nascent state, with less than a dozen existing initiatives currently operational in Malawi. Case study evaluations revealed significant social and economic impacts offered to rural communities living in poverty from mini-grid electrification, with business models becoming viable as demonstrated by MEGA. Challenges with previous projects include lack of community engagement and inadequate hand-over and maintenance provision.

Barriers to the Malawian mini-grid ecosystem have been framed under themes of: Political (uncertainty surrounding mini-grid policies), Economic (lack of capital and proven business models), Social (lack of perception and awareness in rural communities), Technical (supply chain challenges and market blockages for innovative technologies), Legal (unfavourable regulatory system and high license costs) and Environmental (low opportunities for addressing deforestation).

Several opportunities have been identified for mini-grids in Malawi, including a high rural off-grid population, abundant renewable resources, significant global and national policy drivers, recent proposed changes to the regulatory environment and identified funding opportunities.

Recommendations are given at all levels for decision makers and practitioners to stimulate the sector to provide sustainable electricity to populations currently unserved.

This report is intended as a working document and is circulated for consultation, feedback and input from key stakeholders with an intention to stimulate discussion and frame dialogue for planned mini-grid stakeholder workshops in 2018.

Disclaimer: This report is funded by the Scottish Government. The views, opinions and assumptions expressed in this report are those of the authors (University of Strathclyde and Community Energy Malawi) and do not necessarily reflect the official policy or position of any agency of the Scottish Government.

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1. Introduction

1.1. Background and Report Objectives

The University of Strathclyde (UoS) Energy for Development research group has been working in the off grid energy sector in Malawi for over 10 years, conducting research and project management to reduce poverty through sustainable implementation of renewable energy technologies. Community Energy Malawi (CEM) is a Malawian organisation with over 5 years experience working with Malawian communities in renewable energy solutions that help to meet their energy needs. UoS and CEM have been working closely on a variety of projects funded by the Scottish Government including institutional solar PV, solar micro-grids, policy advocacy, capacity building and market assessments.

From July 2017 to April 2018, UoS and CEM, with funding from the Scottish government, has conducted research to analyse the current status, opportunities and barriers for mini-grids in Malawi, with an objective to inform debate and provide recommendations for progressing the sector as a whole. It is recognised that several other initiatives are addressing the mini-grid sector in Malawi, and it is intended for this work to complement additional programmes and research.

This is a working report intended to stimulate discussion and inform dialogue at future stakeholder workshops planned for 2018. If any readers would like to comment or provide input to the report their ideas and opinions would be welcome. Please contact Aran Eales <aran.eales@strath.ac.uk> and Berias Unyolo <unyoloberias@gmail.com>.

1.2. Energy Access in Malawi

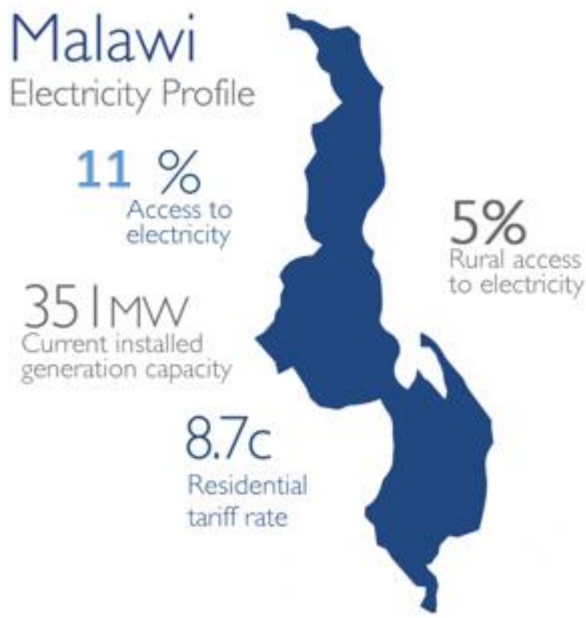
Malawi is one of the poorest countries in the world, with an economy highly dependent on agriculture. In 2016, Malawi had a population of 18.09 million and a GDP per Capita of $300 [2]. The country's headline inflation rate continues to decelerate, falling to 7.1% in January 2018, compared to 19.9% in October 2016. This downward trend has largely been due to a sustained decline in food prices resulting from the increased availability of maize, and a stable exchange rate. Sustainable growth is predicated on sound macroeconomic management and structural reforms to lay the foundations for a more resilient and diversified agriculture sector.

Malawi has one of the lowest electricity access rates in the Southern African Development Community (SADC), with an electricity use per capita of 85 kWh compared with 169 kWh in eastern Africa, and an electricity access rate of 11.9% in 2014 [3], mostly urban households in the cities of Blantyre, Lilongwe, Mzuzu, and Zomba. Only 1% of the rural population have access to electricity. Grid electricity suffers from inadequate generation capacity and outdated transmission and distribution lines resulting in frequent black-outs and load shedding.

Access to energy is an enabler for development and a lack of energy is a barrier to economic empowerment and poverty eradication. This has been globally recognised with the UN Secretary General's "Sustainable Energy for All" initiative [4] and the subsequent Sustainable Development Goal 7, with a target of universal access to energy [5].

Malawi's installed capacity of electricity generation is lower than demand by approximately 10%. In October- November 2017, the country's Electricity Generation Company (ENGECO) was only able to generate 145 to 150 MW despite an average demand of 300 MW. There are plans to increase the generation capacity by adding 6MW, 10MW and 20MW for Mzuzu, Lilongwe and Blantyre respectively by March 2018 through diesel powered generators. ESCOM as of November 2017 is selling electricity to consumers at $0.08 per kilowatt-hour.

Figure 1 Malawi Electricity Profile



1.2.1. Energy Policy in Malawi

Existing energy policy in Malawi is out of date and rural electrification has primarily focussed on grid extension, with little impact. However, the energy sector in Malawi is currently mobilising to address these challenges. A new National Energy Policy and Renewable Energy Strategy are due to be launched in 2018 in parallel with Malawi's Sustainable Energy for all Action Agenda. These initiatives include significant targets for off-grid renewable energy technologies.

The draft Energy Policy [6] states that current installed national generating capacity is 350 MW, which is predominantly hydro (>95%), the majority on the Shire river (ENGECO also operates a 4.5MW Hydro on Wovwe River in North Malawi). There are plans to significantly expand this in coming years, with a target of 1500 MW by 2020. There is a current supressed demand of 450 MW, which has a significant detrimental effect on national industry, as many companies are failing sustain operations (or even begin in the first place) due to lack of adequate energy. Government of Malawi's Malawi Rural Electrification Programme (MAREP) is devoted mainly to grid extension, with some ad-hoc support for mini-grid initiatives discussed in this report. However, extending a network that already has a generation shortage instead of focusing on diversification of generation options to include off grid private and community renewable energy systems suggests misplaced policy priority. In fact, a recent DFID report has indicated that mini-grids would be the most appropriate way of gaining access to electricity for over 4.5 million Malawians [7]. Fortunately, the new draft policy [6] proposes to reform MAREP and open up the market for off grid solutions and private actors.

The regulatory framework on energy enterprises was so strict that it favored state owned Electricity Supply Commission of Malawi (ESCOM) and stifled IPPs (Independent Power Producers). However, the government focus is to increase private sector investment towards grid connected systems. Currently there are 17 MOU's signed with Independent Power Producers (IPPs) to generate and feed into the grid. Future plans include diversifying the generation mix to coal, solar (there is a government plan to include 400 MW from solar, but a key challenge is the potential for grid imbalance), wind and geothermal, as well as broadening hydro capacity into the north. There are also discussions for Malawi–Mozambique interconnections; currently there are distribution connections across the borders but no transmission.

However, grid extension is yet to produce significant results in rural areas, consequently, there have been a number of off-grid systems using micro hydro, solar and wind, however the scale of these initiatives is still very limited. A key hope and recent development is the development of new energy policy which will potentially also lead to legislative reforms for energy sector in the country (the first draft was produced in February 2016).

In essence, Malawi is struggling to end poverty as a long term goal and as a means of doing so, is addressing energy poverty as well. This gives Malawi a very unique position as far as energy advocacy is concerned. On one hand policy makers have to optimize very limited resources to meet the enormous social needs (education, health care, housing etc.) of a rapidly growing population and on the other hand to attempt to grow the economy. Locating where energy sits in the overall equation is not easy, as it is both viewed as a sector requiring investment from an already stretched national budget yet it also has the potential to support economic growth.

1.2.2. Renewable Energy Subsectors

The major energy subsectors in Malawi are biomass, electricity, liquid fuels, renewable energy and coal. By usage, biomass constitutes 88.5% of energy sources in Malawi, followed by liquid fuels at 6.4%, electricity at 2.8% and coal at 2.4%. At a micro level there are other sources of energy such as solar power, wind power and thermal power [8]

Households are the major energy consumers accounting for 83% of total energy consumption with 97%, particularly, rural households relying on wood-based fuel for cooking. The 2012 Integrated Household Survey by National Statistical Office shows that over 51.8% use paraffin for lighting although generally there is a decrease in use of paraffin for lighting with solar lighting and battery-powered torches increasing.

Urban households rely on multiple sources of energy for cooking and lighting. For cooking, urban households rely on charcoal (43%), firewood (41.8 %) and electricity (13.6 %). For lighting, in the urban areas 46.5 % use paraffin, 37.5 percent use electricity and 15.3 percent use candles [9] (Malawi Roadmap for Action towards Sustainable Bioenergy Development and Food Security, Working Draft, December 2013).

Biomass Energy

Biomass is Malawi's main source of energy, mainly in the form of wood. It accounts for an estimated 88.5% of total demand, ranging from 98% in the household sector through 54% in the industrial sector and 27% in the service sector to 5% in the transport sector [10].

There have been a number of programmes aimed at promoting improved biomass stoves that are cleaner and more energy-efficient than traditional cook stoves, lead by practitioners including GIZ, United Purpose, Total Land Care, Pride Africa and USAID among others. It is estimated that there are more than 500,000 clean and efficient cook stoves being used in Malawi which include electrified households which totalled were 308, 278 in June, 2015 [10].

Hydro Power

The total installed capacity of electricity in Malawi is 351 MW (which represents 95% of the total electricity capacity) against an estimated demand of 700 MW. About 345.5 MW of the installed hydroelectricity is located along the Shire River in the south of the country. Only 4.5 MW is produced at a hydroelectric plant on the Wovwe River in the north of the country [11]. The reliance on hydropower and especially on one river (Shire River) makes Malawi highly vulnerable to changing rain patterns, siltation and flooding of the power plants. Changing rain patterns has been exacerbated by deforestation along the catchment areas of the Shire River.

Solar Energy

Malawi's off grid PV installed capacity has increased from 0.2 MW in 2007 to 10.4 MW in 2016 [12]. In 2012 there was an estimated 7,000 PV systems present in the country, though many are known by practitioners not to be fully functional [13]. Recent market assessment for off grid technologies found that PV systems have a significant role to play in the electrification of off-grid communities in Malawi, that PV is scalable across the entire country and its modularity and simplicity are ideally matched to the needs of off-grid communities, where technical capacity and individual household demand is low [14] .

The largest existing single photovoltaic plant in Malawi is located at Lilongwe International Airport with an installed capacity of 830 kW feeding power to the grid. On a smaller scale, solar lighting systems have been installed in households, private institutions such as offices and public institutions such as hospitals. However, these systems usually fail after a short period apparently due to poor technical capability (poor designs, poor installation, limited knowledge on operation and maintenance, supply of poor quality products etc.). The main PV market in Malawi is Pico Solar Products, with a growing Solar Home System market. There are also five known solar energy kiosk centres to cater for the rural communities far away from the grid. An energy kiosk is a centre that provides services such as charging of batteries that are used for household energy services

Owing to Malawi's abundant solar resource (see Section 4.3), several Independent Power Producers (IPPs) have indicated interest to invest in solar energy generation. Approximately 30 prospective investors have signed memorandum of understandings with the government, although no concrete steps to implement projects have yet been taken. A perceived constraint to the take-off of IPPs is land requirement particularly for solar power generation, however the real constraint is a lack of a government endorsed master plan on renewable energy development. With such a plan, land with predefined capacity of solar power generation can be advertised to IPPs for development.

Wind Power

No utility grade wind turbines have been constructed in Malawi except for the six solar/wind hybrid projects implemented by the government in six districts (see section 2.1). There is a small number of small wind turbines installed in various parts of the country at household and institutional levels. There are a few windmills installed for water pumping although the technology was introduced in Malawi as early in the 1940s. The Government is currently supporting a wind resource mapping exercise, in which two wind monitoring stations for resource assessment have been installed in Mzimba and Rumphi. A recent market assessment for small wind turbines in Malawi concluded that small wind technology is less appropriate than solar PV for off grid electrification [14].

Biogas Energy

A number of biogas plants have been installed mainly at household level, by institutions of higher learning, individuals and NGOs in various parts of the country. Mzuzu University has so far installed over 40 biogas plants in Mzuzu, Mzimba and Mchinji and Chipata in Zambia with a biogas production capacity ranging between 2 and 3 m^3.

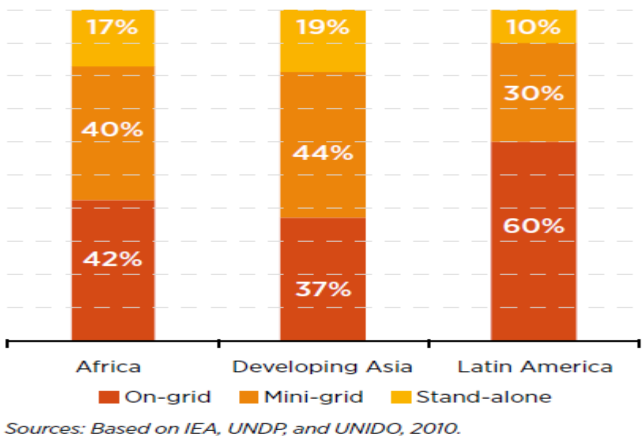
Ethanol Fuel

Malawi has the longest history of consistent use of liquid biofuels for transport in Africa, with blends ranging from 10-24% since 1982 [15]. Ethanol is currently produced from sugarcane molasses by two companies– EthCo Ltd and Presscane Ltd with a combined total production of approximately 18 million litres against a total capacity of 32 million litres. The primary constraint to meeting the current installed ethanol production capacity is inadequate molasses. In addition ethanol is only available during the period when sugar harvesting is in season due to storage constraints.

1.3. Mini-grids as an emerging solution

Meeting the challenge of the United Nations Sustainable Energy for All (SE4All) initiative in providing energy access to the 589 million people in Africa currently living without it by 2030 [4] demands new and innovative solutions for rural electrification. SE4All has significantly progressed the development of mini-grids as a solution for rural (and peri-urban) areas unlikely to receive grid connection in the near future. Mini-grids are thus emerging as a third alternative to rural electrification, coming between the option of large-scale national grid extension and stand-alone solutions such as pico-solar products and solar home systems [16]. Mini-grids can also effectively serve communities close to the grid. In such cases, 'grid-tied' or 'interconnected' mini-grids can deliver high-quality service while reducing load on the grid [17]. With such promise and potential, there has been substantial interest in implementing mini-grids in developing countries, including Malawi. The International Energy Agency estimates that mini-grids will be the best solution for over a third of the global population currently living without electricity access [18].

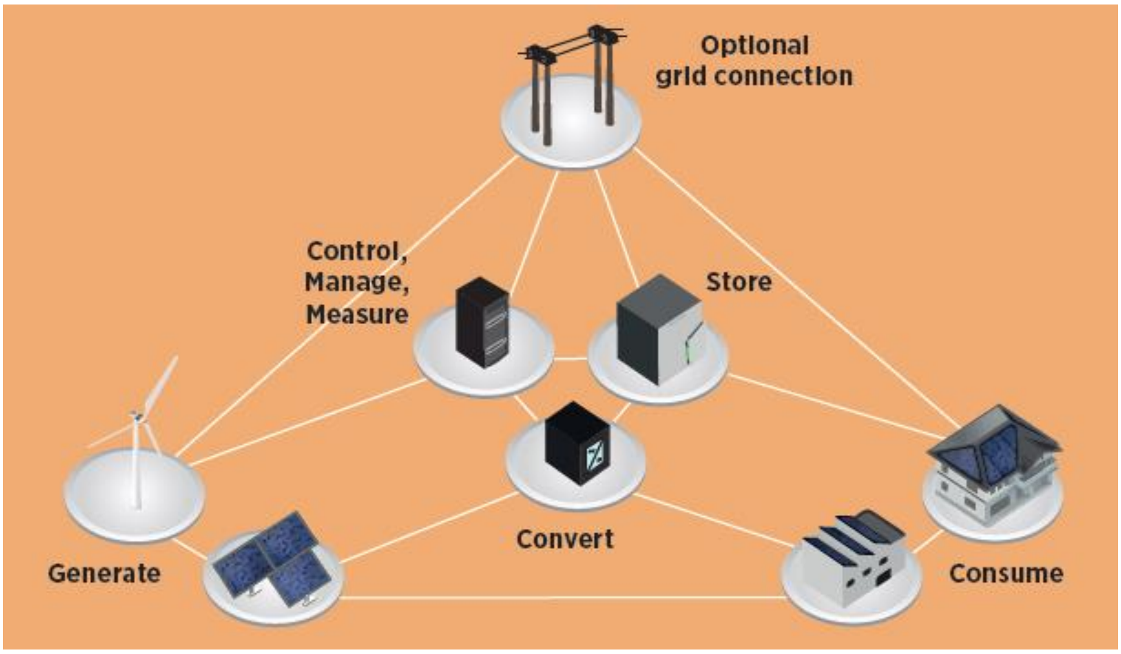
Figure 2 Additional generation needed for universal electricity access by 2030 (by region and source)



Globally, about 5 million households are connected to renewable-based mini-grids [18]. One of the reasons for using grids in the western world include economic benefits from sharing generation sources and distribution. This is more pronounced with off grid systems because storage is required which can be shared between customers. Connections become cheaper with economies of scale, and people don't use energy at the same time so demand per customer is reduced and in general sharing electricity has economic and efficiency benefits.

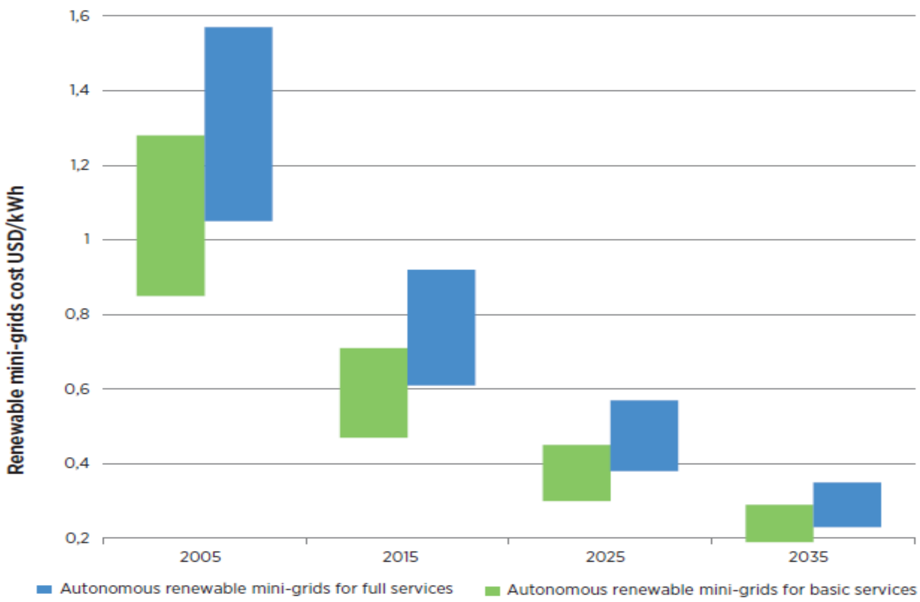
In very simple terms, a mini-grid can be defined as linking together demand points within a limited area without connection to the main grid, for the user an experience that is something in between a main grid experience and a standalone experience in terms of quality and quantity of power. The deployment of renewable mini-grids accelerated in 2016, with the global market now exceeding $200 billion annually and renewable mini/micro-grids are either emerging or mature in markets on almost every continent [18]. Mini-grid projects are being implemented with an increasing interest in interconnection, both to centralised grids and/or to other mini-grids. The UN, World Bank, DFID USAID, and GIZ are all investing in mini-grids across Africa, with more than 23 MW of mini/micro-grid projects based on solar PV and wind power were announced in 2016, most of them in Africa [18]. There is clear growing interest globally but proven success required for Venture Capital funders is not yet being proven, as proven models which can be scaled are yet to emerge ubiquitously.

Figure 3 Key components of a mini-grid



As shown in Figure 4, the cost of mini-grids has been declining in recent years and is predicted by IRENA to continue to fall [18]. This is due in part to global decrease in component costs such as solar PV, batteries and inverters, along with the development of supply chains and business models for manufacturers and suppliers of mini-grid equipment.

Figure 4 Cost trends for renewable based mini-grids, past and predicted



As previously stated, Malawi is one of the least electrified countries in the world. Provision of sufficient, reliable and clean energy in Malawi is a critical challenge, as recognized by the Government. To increase access, effort is needed to develop power plants and mini-grids close to the end-users in rural areas. Given the remote locations of many of the communities that need to be served, and the cost reductions in renewable energy technologies, an important vehicle for meeting these targets is to be clean energy mini-grids.

1.4. Methodology

A concise literature review has been carried out to discover lessons learned from the existing mini-grid sector in Malawi and Sub-Saharan Africa. Case study evaluations of existing mini-grids in Malawi were conducted through household surveys, expert interviews and focus group discussions at three existing mini-grids in Malawi. The researchers visited MEGA hydropower scheme in Mulanje, and two Government of Malawi mini-grid systems installed under the Solar Villages Initiative (Mdyaka solar PV hybrid system in Nkhotakota and Chigunda solar PV system in Nkhata Bay). Focus group discussions were held at each of the site, as were surveys conducted at the household level to determine the effects and impacts of the mini-grid on the quality of life of the mini-grid customer. Extensive and structured questionnaires were designed and conducted with mini-grid customers to elicit quantitative and qualitative data in order to obtain a community perspective on the installations. Mobile data collection platform KoBoToolbox [19] was utilised, a suite of open source tools for field data collection that utilise smart phones to collect survey data which is then uploaded to a digital server. Household surveys can be accessed in Appendix 1.

Figure 5: Location of Case Studies

Table 1 Data collection details

Mini-grid Site	Data Collection	Number of Surveys
MEGA	Surveys, focus group discussions	n = 24
Chigunda		n = 10
Mdyaka		n =11
	TOTAL	*45*

Stakeholder surveys were sent to a variety of key players representing academia, government, private sector and NGOs. A general survey was included for all respondents, followed by more specific questions for industry experts depending on what sector they represented. A link to the questionnaires can be found in Appendix 2. Table 2 outlines the stakeholder organisations that responded. The data collected has been analysed through thematic coding and excel analysis, and is presented in the following sections.

Table 2: Stakeholder Organisation Respondees

Organisation	Sector
UNIMA – The polytechnic	Academia
Malawi Energy Regulatory Authority	Government
Department of Energy Affairs	Government
Mawerera enterprises	Private Sector
SONLITE SOLAR	Private Sector
Mulanje Renewable Energy Agency (MuREA)	NGO
Mzuzu University	Academia

2. Status

2.1. Mini-grid Projects in Malawi: Past, Existing and Planned

There is a growing consensus on the role of community mini grids in Malawi to complement the currently overwhelmed national utility power supply via ESCOM. Today, about a dozen isolated mini-grids are operating in Malawi, owned by Government and run by ESCOM utility (diesel-based MGs on islands) or owned and run by charities or private sector. Several other projects are at various stages of development, ranging from pre-feasibility to procurement. The Department of Energy's Malawi Rural Electrification Programme (MAREP) has led on a number of existing projects, with plans to implement further systems. MAREP is a long standing initiative that primarily focuses on extending the grid to more isolated administrative and trading centres.

Mini-grids present a significant opportunity to both enhance energy access and promote private sector participation in energy delivery. However, there is a lack of valid evidence in terms of impact regarding mini-grids in Malawi, which is being address project with a focus of scaling up mini grids in Malawi under the GEF-UNDP GoM Increasing Access to Clean and Affordable Decentralised Energy Services in Selected Vulnerable Areas of Malawi. Additional initiatives are being implemented in Malawi related to mini-grids are listed in Table 3.

Table 3: Initiatives addressing mini-grids in Malawi

Initiative	**Lead Organisation(s)**
Malawi SE4All Village Power Programme	SE4All
Sustainable Energy Management Support Project	UNDP and DoE
Increasing access to clean and affordable decentralised energy services in selected vulnerable areas of Malawi	Global Environment Facility (GEF)
Low Carbon Sustainable Rural Electrification in Malawi	World Bank Group
Cooperation Network for Renewable Energy in Malawi	(CONREMA)
Sustainable Energy for All National (SE4All) Roadmap and National Action Plan	National Sustainable and Renewable Energy Program (NSREP)

A variety of mini-grid initiatives exist in Malawi: Mulanje Electricity Generating Agency (MEGA), supported by Mulanje Renewable Energy Agency (MuREA) and Practical Action is a social enterprise established with the mission to provide affordable electricity to villages using micro-hydro power technology. MEGA has constructed one micro-hydro scheme and has two more schemes in the pipeline in nearby communities. The privately-owned Lujeri Tea Estate operates a 1MW hydro mini-grid for commercial purposes. It is reported that other tea and commodity estates are exploring such renewable energy systems with the possibility of connecting local communities, although implementation is considered some way off. Community Energy Malawi are in the process of developing an 80kW Solar mini-grid in Sitolo, and Practical Action have completed a feasibility study for a 100kW hydro mini-grid in Usingini serving coffee producers as anchor loads. Similarly, Practical Action and CARD have implemented the Sustainable Energy for Rural Communities (SE4RC) in Chikwawa, a solar mini-grid providing domestic energy and irrigation services. A Summary of Past and Current projects is provided in Table 4.

Table 4 Summary of past and present mini-grid initiatives in Malawi

Name and Location of Mini-grid	Key Stakeholders And Funders	System description	End Users and Business Model	Status	Notes on Successful or challenging aspects
MEGA, Mulanje	MMCT, Practical Action SG, Sgurr	Hydro 80kW	Domestic	Active since 2014	Only breaks even after 5 sites are installed, heavily reliant on funding
SE4RC: Nyamvuwu, Chimombo in Nsanje district (30KW and 15 KW respectively) and Mwalija and Oleole in Chikwawa (55kw and 30KW)	PAC, CARD, FISD	55KW, 30KW,3OKW and 10KW	Domestic, Irrigation	Active since 2018	Improved access to modern energy services that has contributed to better well-being Enhanced community participation and skill transfer. Increased business operation hours and study time in the evening Crop production has increased through irrigation schemes
Sitolo , Mchinji	CEM, CES	Solar 80KW	Domestic	On-going implementation	Financed by UNDP, community participation, skills transfer commercialization and entrepreneurship development strategy.
Solar Villages Mini-grids, Nkhata Bay, Nkhotakota; Chiladzulu; Mzimba; Thyolo, Ntcheu	GoM	Hybrid (solar and wind) 35KW in all sites	Domestic	None is working currently since 2012	No community participation during implementation Lack of financial and business model No skills transferred to communities Lack of PUE activities
Likoma Island	GoM	Three diesel generators each rated 250kVA	Domestic and institutional	Still active with periodic power cut. 14 hour supply daily	The intermittent electricity supply affects medical care, education services, and the business sector leading to increased vulnerability of livelihoods. It is difficult to supply electricity to whole mainland for 24 hours daily because fuel consumption is higher. There is a need to integrate PV and wind electricity to reduce fuel cost
Usingini	PAC	Hydro (300KW)	Domestic and commercial	On going project (still at implementation stage)	Financed by UNDP, community participation, skills transfer commercialization, and entrepreneurship development strategy
Mthengowathenga	Roman catholic Church	Solar Mini Grid (50KW)	Domestic and commercial	Active since 2017	Appreciable reduction of energy costs Reliable and sustainable energy In the hospital, which is connected to the public grid, longer power cuts appear almost every day. Supply but now the power cut has been minimised
ST Gabriel	Roman catholic	Solar-diesel Mini-grid (35KW)	Domestic and commercial	Active since 2017	The costs for public electricity and fuel for the two diesel generators a significant financial burden. Reliable 24 hours energy supply. Programmable, fully automatically working system, switching on and off, according to energy demand.
Nkhata Bay Hospital	GoM	Solar Mini Grid and solar Geyser	Institutional	Active since 2015	Programmable system automatically guarantees a 100% safe and uninterrupted energy supply with high ecological sustainability and economical use of the available energy sources.
Dedza Microgrid	United Purpose, University of Strathclyde	Solar Micro-grid (5kW)	Domestic and Productive Users	Feasibility study complete	Successful business model relies on CAPEX funding, however smaller capacity means lower upfront costs

Government of Malawi implemented six solar PV hybrid mini grid in 2004 to supply households, schools and trading centres. The names of the mini-grids are Kadzuwa in Thyolo District, Chigunda in Nkhotakota, Elunyeni in Mzimba, Mdyaka in Nkhatabay, and Kadambwe in Nctheu and , Chitawo Solar Village in Chiradzulo District. The sizes of the systems range from 20 kW to 25 kW, each intended to supply up to 150 households within a radius of 1 km from the energy system. Of the six systems installed only one that is in Ntcheu was operational as of April 2016. The Government were responsible for all maintenances and in all the mini-grids, however financial and technical models were unsustainable, community participation during implementations was limited, an inadequate tariff system was implemented, substandard materials were used and community skills transfer were not considered.

Other mini-grid projects implemented in rural areas by Non-Governmental Organisation paid attention to business models, tariff structures, community participation, skills transfer, access to credit and marketing systems. Some models utilised a commercialisation and entrepreneurship development strategies which have had positive effects on the sustainability of the system. Such methods reduce reliance on donor funding, avoiding dependency syndrome from the outset. Entrepreneurship brings into the strategy economic empowerment, financial independence and ability to pay for the systems. Entrepreneurship also enables solar/wind/hydro electrification to enhance productivity in already existing enterprises, and promotes community ownership. Additionally, there are some institutional mini grids in Mtengowathenga hospital, Likoma hospital, ST Gabriel hospital and Nkhata Bay hospital that are operated based on the decentralised systems strategy managements, and has potential to be sustainable.

2.2. Case Study Evaluations

Community Energy Malawi (CEM) and the University of Strathclyde (UoS) initiated a research and knowledge exchange activity to gather and disseminate information regarding planning, design, and implementation of mini grids for rural electrification in Malawi. In Malawi some off grid communities have benefited from mini grid initiatives in the past, but in this report CEM and UoS generated evidence that few are still operating, and the sector as a whole is still in its infancy.

As part of the research three mini-grid systems were evaluated that have been transferred to rural community areas in Malawi. Research methods and sites are described in Section 1.4. The selection criteria of three mini grids visited was based on system management and operation, stakeholders involvement in the implementation of the project, governance, financial and business models adopted and different strategies used to transfer the technology to communities.

The two Solar Villages sites were not functioning at the time of the visit and were managed by a committee of 8 people: 4 men and 4 women known as the Energy Committee. The committee was responsible for the overall care of the facility and ensures that electricity is supplied at the right time. It was also responsible for the collection of revenue from the users as well as punishing defaulters through power disconnections. The committee also vets and approves new connections. It charged K2,500 per connection including materials or K1,000 excluding materials. Electricity users pay K200 per month for lighting only and K300 per month if electrical appliances are included. On average, MWK 18,000 was collected per month when the mini-grid was functioning. In short, in Mdyaka and Chigunda and the other four solar PV hybrid had no financial and business model and well defined governing structures. As the two GoM solar village project were no longer functioning, survey questions were asked relating to when they were active.

Figure 6 Mdyaka Mini-grid Power house

MEGA hydropower generation is in Mulanje and is not run-of by the-river, but diverts some of the water from the river, which is channelled along the side of a valley before being 'dropped' into the turbine via a penstock pipe. The concept of a community-based mini-hydropower project was first discussed in 2008 and led to the establishment of the Mulanje Energy Generation Agency (MEGA) in 2011 by three founding partners. Two of these have a place on the Board of Directors; these are MMCT (majority owner) and the Mulanje Renewable Energy Agency (MUREA, itself an implementing arm of MMCT), while the third founding partner, the international NGO Practical Action, has been providing project management and technical assistance. MEGA also works with Fairtrade Foundation on community development and the Scottish consultancy SgurrEnergy in project engineering and management. MuREA in partnership with Practical Action and financial support from EU Commission established the first licenced micro hydro scheme on Lichenya River in Malawi. Currently, MuREA is responsible for the Productive Use of Electricity component in the Scottish Government / GEF funded Powering Development in Mulanje (PDM) Project.

The installed system capacity is 80 kW and provides electricity to about 3,500 households in the service area, 2 to 3 maize mills, around 5 shops, 2 primary schools and 1 clinic. MEGA has been receiving the financial support from the European Union and the OPEC Fund for International Development (OFID), Scottish Government, MUREA, Practical Action, UNDP/GEF and other funders. Being a socially-oriented company MEGA does not seek to maximise profits but will balance the pricing of its electricity tariffs between its social objective of offering low-cost electricity and being financially viable. The business plan forecasts that revenue from sales will cover all running costs, including staffing, operations, maintenance, VAT, site insurance and a 1% annual contribution to a community fund. The MEGA business model aims to achieve economies of scale for central operations by developing multiple sites.

The analysis is collated to include both MEGA and Solar Villages sites, to represented the whole sample of respondents. This allows for broad insight into successes and challenges of mini-grids in Malawi in general. The purpose of the case study analysis is to draw out key lessons from experience of three previous initiatives to inform future initiatives.

Figure 7 distribution at MEGA

2.2.1. Focus Group Discussions Results

A summary of the responses from the focus group discussion from all the mini-grids evaluated is presented under the heading of effect on community life and home activities, effect on children, and female members of the community. Negative aspects are listed, as are questions relating to the involvement of the community in the planning and implementation of the grid. In general, communities hold the initiatives in high regard with positive impacts quoted. Technical challenges are noted, and general desire for more consultation.

Effect on community, life, home activities

- We are now able to charge our phones and make communication easier
- We are now able to do productive uses: welding activities, electric maize mills, barbershop, bicycle repair, shop lighting, phone charging, video shows, running bars, bars, TV shows, and chicken rearing business,
- We were also able to do businesses, operating even during odd hours of the day
- We are able to drink cold drinks
- No longer using diesel powered maize mills
- People are able to work even at night because they have lights all over
- People are able to watch TV, and listen to radios, charge phones
- We have also been able to save money in terms of cutting cost for buying batteries, paraffin and we do not spend money to go and charge phones
- We lived a modern life as we are able to watch TV
- Usually we are busy during the day doing entrepreneurial things and at night we were able to watch TV's which was more important as we were able to grasp information on what is happening in the world.
- Communication was made simple, as we were able to charge our phones.

Effects on children's life

- Children are able to study even at night and this has helped them to improve in their passing rates
- Children have a privilege of having teachers since teachers no longer turn out to postings in their area due to electricity
- Children are now able to use some electric materials in their schools such as computers
- Children were not going anywhere far to look for video shows
- We had enough security since we had street lights
- We were able to change nappies for our kids even at night since we had lights as compared to the time we were using candles

Effects on female members of the community

- People are able to cook using electric cookers and this has eased women in most work and women have enough time to do other things i.e. household chores
- Women no longer walk long distances to fetch firewood
- We had a water pumping system which assisted women not to fetch water from far places
- Family divorce issues which used to leave female headed household were minimized as we had everything at our home especially TVs which men used to take it as an excuse to leave home while they go to do other things
- We were also able to save money instead of buying candles we used that money for buying relish
- We were able to cook in lights during the night as we stopped using the candles

Negative effects of the mini-grid

- We experience some challenges when it comes to purchasing credit
- Once the canal opens there is always flooding of land in the surrounding area (MEGA)
- Limited time to use (Chigunda)
- Some appliances are not allowed on the system
- Some of us used to do chicken rearing business and the system used to provide power for only 4hrs which made us to spend a lot to supplement the lighting
- Maintenance issues we were waiting for a contractor to come from Lilongwe
- Even the office of the District Council knew nothing about this project
- We were not told about the cost of the systems and we came up with a monthly fee based on the costs
- We were not able to use the system 24 hours due to weather issues
- Technical expert was not available in the community so we had to wait for an expert to come from Lilongwe to fix the system, preventing use of electricity
- Our invertor was not an original one since it needed maintenance every month
- Earthing was poor which resulted to lighting destroying the system. 20 people were injured with the lighting and were sent to hospital.

Extent community was consulted/involved in the mini-grid development

- They first of all consulted the GVHs from our area then they called for community meeting where a committee was selected and coordinated the whole development process
- We were not really consulted as a community. They gave us this project out of their mind.
- The chief was not consulted either, we were asked to locate a place where a solar power house would be located. We were told to have a solar committee. The power house was built by themselves. The contractor came with all the materials and nothing came from us.

- We all need to be involved in all projects that need to come to our community and we should be there when selecting the contractors to ensure power to the people and that we should feel ownership of the systems.
- The total amount spent on this mini-grid was not known which did not create transparency on the project
- The committee should be in front to direct the Govt/ NGO on the number of households to be connected.
- No training was given on using the electricity - they should have trained us or some community members on the technical issues of the system
- At a later stage they called for a community meeting after everything was set, it was more or less like a hand over meeting where we were told to be contributing MK100 per month to sustain the guard and the system operator

Figure 8 Focus Group Discussion at Mdyaka

2.2.2. Enumerator Observations

The following observations were made by the enumerators through informal interviews with mini-grid communities. In general the comments echo the positive responses listed above with negative comments mainly regarding community engagement.

Improved Quality of Services

During a visit to the communities by CEM team, the Chiefs, his aides and members of the local community expressed some positive sentiments about the electricity. In Mdyaka and Chigunda mini grids, the people were particularly grateful for the solar and wind electricity that Government of Malawi connected to their houses. Women reported that prior to the project, they were required to carry paraffin lamps to the kitchen when going for preparing food, and paraffin was expensive. This was no longer the case. Teachers were able to prepare their lessons in the evening hours. Parents also reported that their children were able to study at the in the evening before the mini grids stop functioning, a factor that was attributed to some improvement in performance in government examinations. Following the installation of the solar- wind mini grid at their communities, the people were able to enjoy various forms of entertainment which they could only hear of before the installation. They could have video shows. Thus the community started to enjoy a more vibrant social life, which is healthy for any society.

Members of the community spoke about the social transformation that they were experiencing with the coming of electricity. The people were able to prepare food any time in the evening. This was particularly crucial for women and girl child. They reported that before the solar electrification, they were required to cook their food. This was no longer the case.

Increased Public Awareness about Solar Energy

The mini-grids installed by government also contributed to public awareness about solar energy within the neighbourhood and the surrounding areas. From observation, several households and commercial enterprises, mainly bottle stores, had acquired their own solar PV systems, although the installations appeared rudimentary, underlining the fact that there was no local expertise for installing them.

Improved Livelihoods

While the community felt that they were not getting as much benefit from the electricity supplied to them, they were still happy that they had lighting in their homes, which made life much easier as they could perform many domestic chores after daytime. For example, they emphasized the fact that their children were now able to study for longer periods than before. They also stated that before the system broke down following a strike by lightning in December 2012, they never had to buy paraffin, implying that there were savings on their income. In addition, the connected households are able to use the electricity to power television sets, radios as well as charge cellular phones. They can communicate more easily and are able to follow national and global events through the radio and television. They also get education and entertainment from the same services.

Community Engagement and Ownership

The village headmen in all visited sites reported that the villagers received the news about the planned projects with great enthusiasm right away from the start. Even though they were not required to participate or contribute to the project, some of them helped with the clearing of the project site voluntarily. This happened at Mdyaka and Chigunda.

After the completion of the projects, the people displayed their acceptance of the facilities that had been established by forming committees to manage them including their daily operation, revenue collection as well a repair and maintenance. Although the contractor played a role in the establishment of the committee, it is quite impressive to see that the committees are still surviving and active, seven years after its establishment.

The people in all the villages take proper care for the installed systems. Each village has employed a security guard who is paid from the monthly contributions collected from the electricity users. At Chigunda Primary School, the school committee is planning to reinforce the classroom doors so as to prevent vandalism of the wiring system. A great sense of care for the facility is also evidenced by the prompt reporting of faults by the respective committees to the Department of Energy Affairs as well as the villagers' readiness to finance and carry out minor repairs on their own.

What Was Missing in the Implementations of six mini grids?

The above evaluation shows that different strategies were used in the implementation of the mini grid projects in question. No project was completely perfect and no project was completely bad. Yet the people responsible for formulating and implementing the projects all had similar goals and objectives. Ordinarily, they all desired to promote the transfer of electricity technologies to the rural areas in their respect to ensure that there is greater uptake of the systems in order to improve rural livelihood.

However, the project design apparently did not provide for mechanisms to fund maintenance of the installed systems, which would ensure their sustainability beyond the project life. At the time of the visit, most of the facilities that had been established were in a state of disrepair and there was no local technical capacity for their maintenance. The community expected the Department of Energy Affaires the Malawi Government department which had done the installations, to be responsible for the maintenance of the systems. Secondly, in terms of raising awareness, it was somehow difficult for members of the community to appreciate the systems as an energy supply option for households when there was only 150 households benefited from single mini grid installation. The community members were supposed to be given equal access to energy, but the Government mini grid handpicked 150 households without real basic selection criteria. This is where technology transfer faces the toughest test. Thus, the omission of the other households sector rendered the project weak in terms of community participation. Thus one may argue that the strategy employed in the project did not prove sustainable in terms of ownership and maintenance of the installed systems.

Figure 9 Chigunda Power House where all the solar panels were shared to community members

For the mini grids in six districts, the evaluation showed that there was limited participation of the local community. In addition, some households were not included in the project but there were no properly selection criteria. One can also argue that much as there seems to be great interest and goodwill to replicate the project, most of the interest is external to the community.

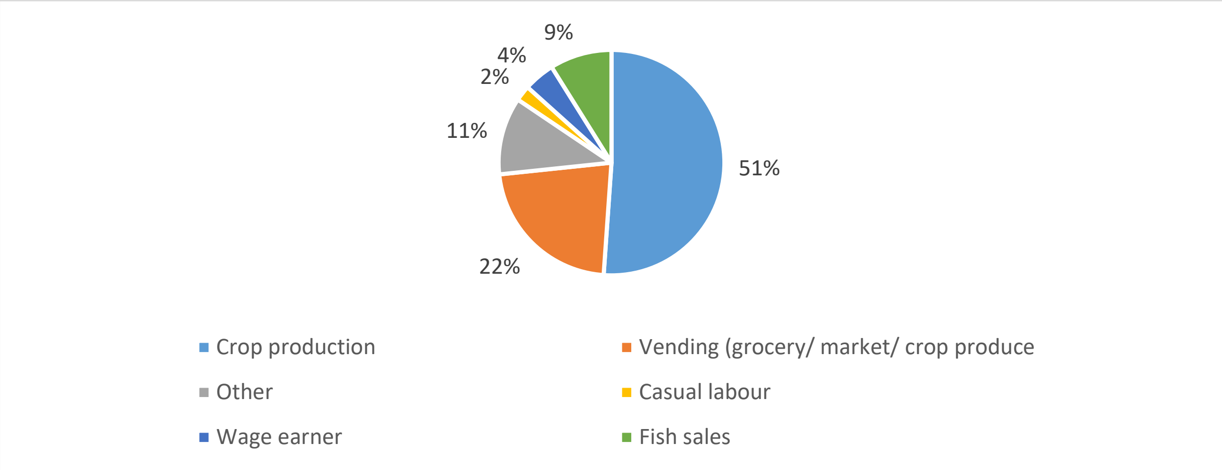
MEGA hydro in Mulanje stands out amongst the existing initiatives for its inclusion of all households based on the selection criteria. Everyone has been given equal chances to apply for electricity and this ensures community participation to the project. Unlike the mini-grids installed by government of Malawi that rely on handout, MEGA hydro project management decided not to give the electricity to households for free.

2.2.3. Survey Data

Analysis of the survey data drawing key observations is presented below. Qualitative and quantitative data was collected and analysed to draw insight into the effect of the mini-grid on income levels, hours of study for children and appliance use. Customers also gave suggestions for improving the grid as well as health and environmental impacts.

As shown in Figure 10, despite a mini-grid connection, the majority of customers still state crop production as their main source of income, other include teachers, business people, barbershop and bakers.

Figure 10 Primary source of income for mini-grid customers



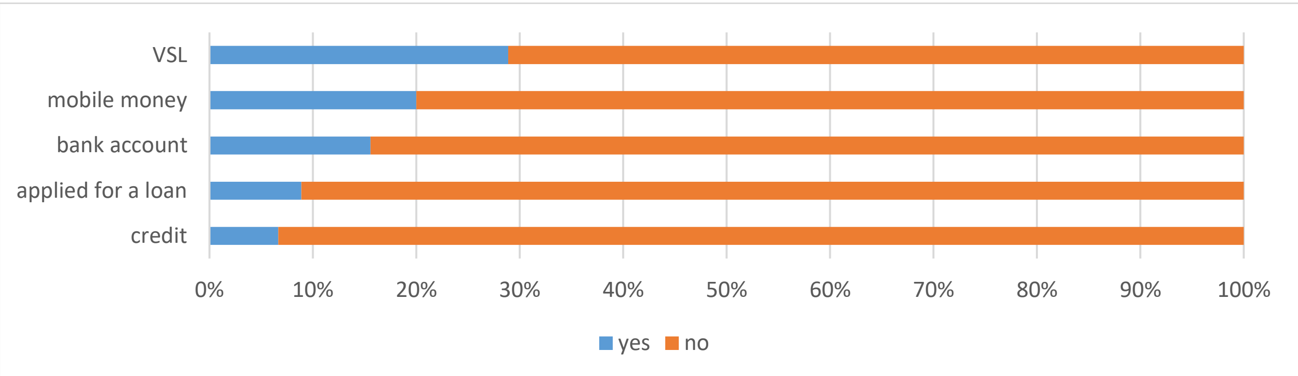
The mean, max and median incomes reported were compared with incomes of un-electrified customers from a previous study in Dedza [20]. It was found that mini-grid customers have significantly higher incomes than non-electrified village, as shown in Table 5.

Table 5 Comparison of mini-grid customer income with non-mini-grid customer income

	Case Study Mini-grid Customers			**No mini-grid access**
	agricultural income (MWK)	**non-agricultural income (MWK)**	**TOTAL income (MWK)**	**TOTAL Income (MWK)**
MEAN	33,788	10,579	41,388	14,413
MAX	16,500	50,000	175,000	150,000
MEDIAN	25,833	3,958	25,667	6,000

Figure 11 Availability of finance mechanism for mini-grid customersFigure 11 shows that mini-grid customers surveyed generally have a low availability of finance mechanism such as credit, bank loans, Village Savings and Loans and mobile money. This can be a barrier to appliance purchasing, and the lack of mobile money is a barrier to innovative payment mechanisms.

Figure 11 Availability of finance mechanism for mini-grid customers



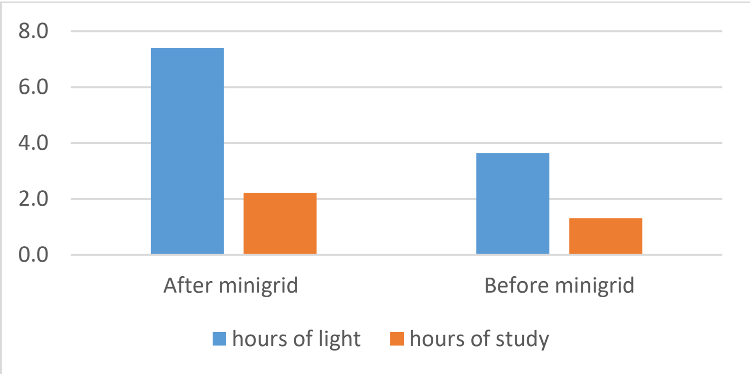
When asked if income had increased since the introduction of the mini-grid, 58% stated it had. Responses to what forms of income generation had started since the arrival of the grid included selling beer, grocery shop, barbershop, video show, keeping chicken, speaker and a radio, using light to secure animal houses, refrigerator (cold drinks, phone charging, computer and amplifier, electronic repair and battery charging. Respondents were asked to estimate how much additional income was earned per month since the grid came, results are shown in Table 6.

Table 6 additional monthly income earned since the arrival of the mini-grid (MWK)

MAX	89,000
MIN	1,500
AVERAGE	25,781
n	16

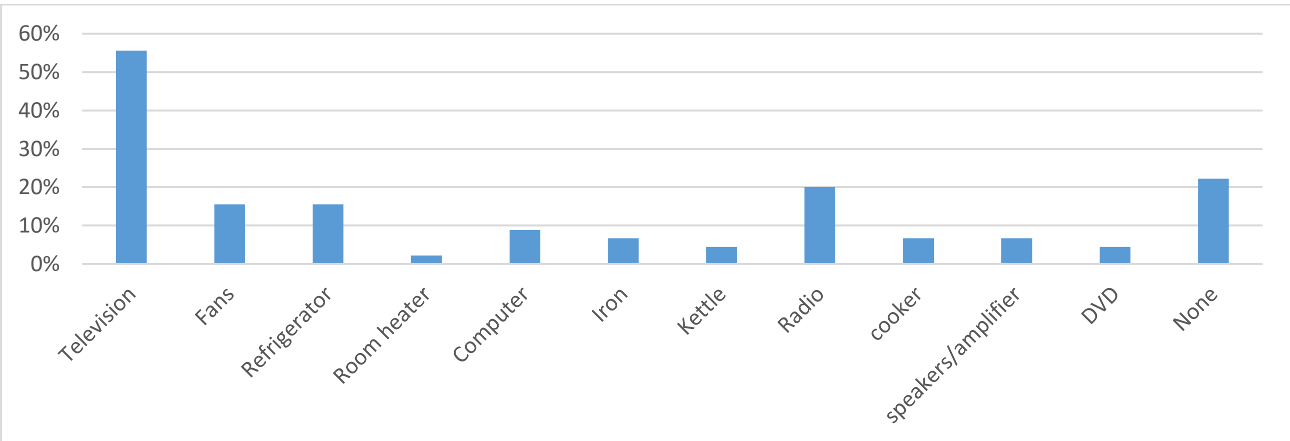
In terms of lighting, the average number of hours of light and hours of study enjoyed by communities both increased significantly with the arrival of mini-grid electricity. The average spend on lighting before the mini-grid was 2,700 MWK, while the average monthly electricity bill for MEGA is 2,300 MWK, which suggests a significant saving, given that the lighting is not the only electricity demand for MEGA customers. The solar villages customers were paying 100 MWK a month which is obviously a huge saving on lighting costs but unrealistic in terms of business models.

Figure 12 hours of light and study before and after the arrival of the mini-grid



Regarding appliance use and purchase patterns, Figure 13 shows what appliances have been purchased since the arrival of the grid, demonstrating the importance of TV's and radios. Nobody had purchased a water heater, air conditioner, washing machine, mixer/grinder or a microwave.

Figure 13 What appliances have you purchased since being connected to the grid?



100% of MEGA customers indicated they decreased their kerosene, candles and torch cells usage since having the electricity. The energy use before the mini-grid of all sites is shown in Figure 14, showing a prevalence of dry cell batteries, followed by paraffin and candles.

Figure 14 Energy Use before the grid

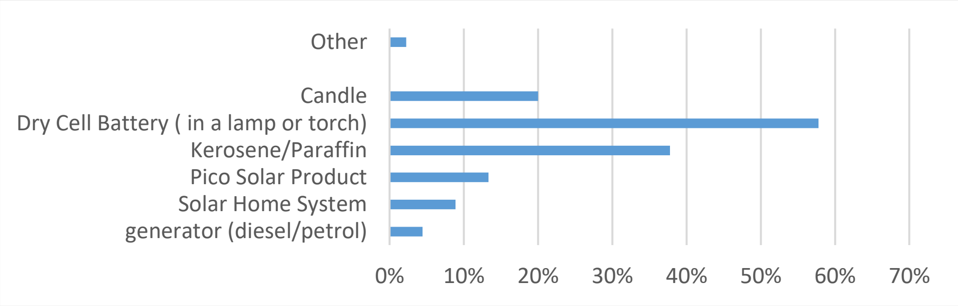


Table 7 lists suggestions for respondents for improving the quality of the grid, including greater levels of access for higher powered appliances, reliable power all day, and community involvement during implementation.

Table 8 states some of the responses related to changes in health and environment since the arrival of mini-grid electricity. Health improvements through less kerosene use is quoted, and tree planting/cutting quoted as environmental impacts.

Table 7 customer suggestions for improving the electricity supply

- Allow customers to use the electricity for business rather than just lighting .
- The project was not supposed to be given for free. If we were paying for electricity maintenances would not be an issue
- Community involvement during the implementation is needed
- We need to have enough power to power our equipment such as fridges, cooking and water pumping
- An assessment on the equipment that we have in our homes should be done/there is need for load assessment
- We need a bigger system that can cater for bigger loads
- Community should be technically trained rather than depending on people from away to maintain
- We need to have reliable power all day/Increase the generation capacity
- They need to tell us in advance when the system will be down
- It takes long time for them to replace the equipment
- Improve the canal, some months we don't get power due to water levels
- They need to improve the tariff system, it takes time to get the token number

Table 8 Changes in Health and Environment since the mini-grid

Health	**Environment**
• Children no longer suffer from flu or eye problems • no frequent illnesses in my family • we are not experiencing frequent coughing and flue than before • reduced cases of sickness • Yes, reduction in health problems since we were using candles and kerosene lamps • no coughing or sneezing	• Yes, reduction in the use of batteries hence the environment being saved • we are now planting more trees to preserve soil erosion because of the coming of hydro power • the time they were installing the poles they had to cut some trees where the wires were supposed to pass • reduction in firewood usage and no longer cutting down of trees

2.3. Stakeholder Mapping

This section outlines the responses of the stakeholders regarding the status of mini-grids in Malawi. The stakeholders surveyed have been involved in mini-grid implementation in Malawi in a variety of ways, including providing regulatory guidance, planning, implementation, and co-financing. Private sector stated they offered a quality range of mini grid solar power plant to their customers, and have been involved in designing some solar mini-grids in Chikwawa and Nsanje, some have provided training on mini-grid development, standards, regulation compliance, feasibility studies and engineering.

Stakeholders were all interested in being a part of mini-grid developments in Malawi, stating that they had skills to address gaps in the sector. They stated a desire to learn more, on subjects including design and project sustainability; accessing and commenting on the necessary information relating to mini-grids; and learning on how the mini-grids can be sustainably managed. Other responses included suggestions for building a robust learning and research institution focussed on mini-grids; contributing on mechanisms for advocating and enforcing regulatory and standards compliance in mini-grids development processes; drawing experiences from existing IPP, productive use aspect of mini-grids; and implementation of the Governments rural electrification master plan. A summary of relevant findings from the stakeholder surveys by sector is outlined below.

2.3.1. Policy, legislative, regulatory institutions and civil society

The current regulations that mini-grid developers should adhere to when implementing a project include the Partiary from Rural Electrification Act and electricity regulations, and these are likely to change in the future. Nothing notable has worked well with the current policies and legislative frameworks for mini grid implementation, as it was admitted that there are few mini–grid specific regulations are available, however more are being planned.

Policy stakeholders suggested poorly designed systems, inability to sustainably pay for services, and a need to plan for sustainability as the key lessons from the mini-grids currently not working. In terms of which renewable energy technologies seem to be liked by communities, Solar PV was quoted as predictable and with available resource, as was a need to promote technologies for cooking. Business opportunities, more financing initiatives and mass awareness on the benefits and availability of the technology were quoted as the key advocacy points for Malawian mini-grid policy to ensure that there is an improvement in mini-grid community transfer.

2.3.2. Installers

A variety of installers are present in Malawi offering Solar Home Systems and Pico Solar Products, however few have experience of installing mini-grids. PV systems are typically used for lighting, barbershop, shops, TV, with a small percentage used to power AC fridges. The key benefit of solar power was quoted to be its modularity, making it possible for everyone to use depending on their energy requirement and financial availability

Installers stated that although most systems are currently working, others are not because of system tampering, or system overload, caused by customers assuming solar power can provide the same as grid power. Renewable energy technology components for maintenance are generally sourced from China, South Africa, Dubai, Germany, USA and India, and transportation was quoted as the main challenge in supply. Price and tax are also challenges for the equipment to arrive in Malawi, making products more expensive in order to allow for a profit

Installation expertise is generally provided in-house, as a companies have their own trained technical team responsible for both installations and maintenance. Installers are keen to take on bigger projects, to electrify other off grid communities “If funds are available”.

Most installations offer a 1 year warranty and maintenance service, faults are responded to with replacement components installed when necessary. Installers ensure that customers are given quality products or services by purchasing products from reliable suppliers, specifically by dealing with suppliers who are able to provide warranties.

A challenge facing installers is the fact that renewable energy suppliers are able to import sub-standard materials, with most clients failing to differentiate between a fake and original product. Installers generally have designs checked by MERA to ensure they meet installation standards. Concerns were stated that there is a lack of information on standards, they are not readily available to local people. Although many installers conduct sensitisation for customers prior to installation, some stated challenges with customers being frustrated with buying energy systems without proper technical know-how leading to system failure; there is need for awareness on how these systems work to most masses.

2.3.1. Academia

Several Universities in Malawi have been involved in mini-grid design and planning including Mzuzu and UNIMA, working on projects including the design of a 400 kW for a university and designing of 10 kW household systems. Academic stakeholders were aware of published academic papers relating to mini-grids in Malawi, but stated there were few and not very detailed in nature. The main research questions relating to mini-grids in Malawi that can be addressed by academia were stated as exploring the impact of mini-grid on livelihoods in rural villages, and how to co-design mini-grids deployment business with communities. A recent research sandpit held in Zomba identified mini-grids as a high priority area for research.

2.4. Case Study: Developing a Mini-grid in Malawi

This section captures key lessons from a recent mini-grid development by Community Energy Malawi in Sitolo, including design, planning, implementation, operation and maintenance.

CEM in partnership with Community Energy Scotland is installing a solar mini-grid at Sitolo Village, which is situated 18 km from Mchinji Boma (12 km from the national grid), to generate and distribute power. This project is supported by UNDP and the Department of Energy with CEM offering implementation supervision of the deliverables. The project covers four Villages in Group Headmen Ndawambe (Sitolo, Mulosiyo, Chisenga and Ndawambe under Traditional Authority Mulonyeni). CEM conducted market assessments the selected communities, which reviewed customer willingness to pay for electricity. The project engaged Local Village Energy Committees, set up as liaison between the project and the community, and held meetings at District Council and VDC/ADC level.

The project integrates community capacity building in productive uses of energy to spur economic activities. A Build, Own and Operate model will be used through CEM Trading, the trading arm of the charity CEM. This method promotes sustainable management of the project to guarantee supply of quality and clean electricity to the community, with an inclusive approach to gender.

2.4.1. Technical details of the proposed solar PV mini-grid, Sitolo

The mini-grid will comprise an 80 kW solar array with a 3 km radius transmission (11 kV) and distribution (400/230 V) system targeting households and businesses. The Energy Department of Mzuzu University has completed engineering design: modelling was completed initially for a 45 kW system based on an estimated peak demand of 17 kW and energy production of 197 kWh per day. However, a 45 kW system would have only been able to meet 84% of the peak load, even if a maize mill was not included. The 45 kW system would have costed USD 300,000 including 164 batteries of

3300 Ah, accessories and installation, covered by a grant provided through the UNDP-GEF project (plus an additional USD 100,000 for technical assistance and staffing, local capacity building and village awareness creation). At this capital cost, the system could produce energy at USD 0.08 per kWh (break-even) and sell at USD 0.10/kWh (allowing for a small margin). A second review of the energy demand (by CES) suggested a higher household demand (by including refrigeration). The village maize mill would represent the largest single load on the system.

Expectations are high in the village and local mobilisation for the mill is well-established with the building for the business under construction. However, the inclusion of the mill will bring sustainable income to support system operation, economic development for the village, and wider socio-economic impacts with the time saved from not having to travel 18 km on foot to similar facilities. Currently, the load demand is being studied, in particular how the mill can be accurately included.

2.4.2. Gender Mainstreaming of the mini grid in Sitolo

Gender mainstreaming is being considered from all angles within the project. In line with MDGS [21], the project aims for empowerment of disenfranchised groups like women, girls and children. Strategies to achieve this include: mobilising women groups to enhance potential productive energy uses activities; ensure 30% of connected houses are female headed; design appropriate wiring for houses with disabled people (e.g. switched within reach of wheelchair users); and providing street lights in the villages as a corporate social responsibility element. The latter will enhance security at night especially for women and girls who can be targets for sexual assault. Another aim is to recruit and train out of school youths as technicians responsible for providing first line of support in maintaining domestic circuits.

2.4.3. Lessons Learnt

- During District Executive Committee (DEC) meeting, the project aroused interest from the members to the extent that several off-grid communities were mentioned for consideration, with the DEC suggesting that phase two of the project should target additional villages rather than scaling up at the initial site. CEM was also requested to provide guidance to the DEC on issues around Community Energy.
- Entrepreneurs from Mchinji started erecting a structure for a maize mill, to push for its inclusion in the technical design. One villager had already purchased metal work equipment in anticipation of running a welding shop, with an aim of offering battery charging and repairing of ox carts as a business service. The school inquired into the possibility of opening up an ICT centre, a request which CEM is considering.
- Dairy farmers have inquired about milk cooling and Heifer international [22] will be engaged to collaborate in this area. Following radio promotion of the grid on Zodiak Radio station, Maliwane Village (Traditional Authority Mlonyeni) requested for a connection. Following geographical assessments, CEM established that the national grid is within 5 km and advised the village to make a case with MAREP.
- With gender mainstreaming in place, the project envisages gender related improvements in the community. The presence of the electricity in the community is expected to improve social economic profile of the customers and also impact on education of children. The project intends to positively impact health services with the expected connection of a health clinic, allowing women to start accessing local antenatal and maternity services, saving pregnant women the trip to Mchinji (18kms away). More than 800 women in the four communities get basic medical services from Sitolo clinic. With mini-grid lighting, families will save money from reduced spending on lighting alternatives like kerosene, candles, and battery torches. An average electricity light user will recoup the cost of connection fees, saving $170 a year or around 8% of their income.

2.4.4. Capacity Building

Twenty technicians (30% female) attended a seven-day course including: electricity basics and solar PV systems, PV system design, components, maintenance, and troubleshooting, and health & safety. CEM also conducted learning journeys to similar projects implemented with objectives to increase capacity of technicians. Throughout the training period, technician participation, concentration and understanding was encouraging and technicians were able to apply their general knowledge and experience in this project.

CEM also conducted specific training in productive uses of energy for forty community members (43% female). The course was conducted in a group discussion manner whereby members were able to freely express and share their experience on the benefits of using electricity within a community for different uses including schools, health centres, households, community water pumping as well as productive use). Discussions were held about how electricity use can improve the prospects and lives of women and children in the community; and how electricity can be used to start a business. The participation of the members was encouraging as both female and male members showed a strong interest in learning and were able to contribute and debate throughout the training period. Electricity user training was also conducted at 250 households, receiving electricity for lighting and small electrical appliances in the home where they wish to purchase them through the project.

Local entrepreneurs who want to set up different businesses in the initial phrase of mini grid installation were trained in entrepreneurship, to ensure the coming of electricity will be fully used and provide a new source of employment and income. 12 local community representatives (three from each village) comprising the management structure for the mini grid, have been trained on the financial systems and management of the mini grid, covering both the billing system and the record keeping system. Project staff will support them over the full period of the helping with financial review, maintenance and repair costs and tariff review to ensure sustainability. The actual electricity billing process, collection of fees and financial database management will be done by CEM Trading and the costs to cover this have been be built into the tariff system at the start.

Figure 15: Energy committee visiting the powerhouse in Mdyaka

3. Barriers

A PESTEL analysis is a framework or tool used by marketers to analyse and monitor the macro-environmental (external marketing environment) factors that have an impact on an organisation [23]. This framework, which stands for Political, Economic, Social, Technological, Legal and Environmental has been utilised to frame the barriers to mini-grids in Malawi.

While mini-grid technology is mature, mini-grid development in Malawi is ad-hoc and fragmented. Major barriers to the scale-up of mini-grid is needed to lower transaction costs and attract the commercial financial investments that are required for rapid and widespread deployment.

3.1. Political

3.1.1. Political Uncertainty

In general, stakeholders felt there is inadequate regulatory framework, policy gaps and uncertainty regarding mini-grids in Malawi. Other challenges are non-compliance to installation standards, and the use of deployment models which are not business oriented. Political will for mini-grids is regarded to be absent, with a mis-guided focus on only grid extension with limited generation capacity. There is no real off-grid policy or masterplan, although one is in development.

Government support for mini-grid initiatives is limited, as the majority of its funding is dedicated to expanding rural electrification through the Malawi Rural Electrification Programme MAREP (administered through a Rural Electrification Management Committee) to be achieved through support of national grid extension enabling the electrification of trading centres, at a cost of c. 90,000,000 MWK per trading centre) [24]. MAREP has a facility for mini-grid subsidy to reduce electricity tariff to customers but it has not yet been implemented on a real life project.

3.1.2. Party Politics

Local party politics on development projects can present a barrier for mini-grid deployments. The locations of the six Solar Village energy projects were based on relative advantage to political leaders who were in power, rather than being led by technical aspects such as renewable resource assessment. Another key challenge to mini-grid implementation is the manner in which a project can be introduced to the people of the area. Instead of government officials announcing the coming of the project, it was the local Member of Parliament who made the announcement. Although the announcement was made at a development meeting and not a political rally, the connotation was that the ruling party had facilitated the project and, ordinarily, the people expected that the electricity to be generated would be free. As a result, they were surprised when they later learned that they were required to pay for the electricity, albeit a heavily subsided amount.

3.1.3. Philanthropic Politics

Apart from political interferences, observation that politicians can distribute renewable energy technologies for free to households for campaigning reasons have been observed. Whilst this practice can lead to improved adoption and diffusion of renewable energy technologies, it should be noted that philanthropic financing of renewable energy systems exacerbates sustainability challenges by creating donation dependency and reducing sense of system ownership. Such approaches can also fail to provide long-term solutions to high capital cost challenges; some beneficiaries would not be able to purchase the systems at the end of the life of the free systems and thus the benefits of the technology could be temporary. [13].

3.1.4. VAT and Import Tax

Although the Government has waived all import duties on renewable energy technologies, the customer still has to pay 16.5% VAT of the purchase price. This may explain the low market penetration of renewable energy technologies and may have a knock on effect on mini-grids. The entry into the energy market of largescale solar independent power producers may create a conductive environment for removal of purchase VAT on renewable energy technologies.

3.2. Economic

3.2.1. Business Models

Developing business models that will allow transformation to scale-up from pilot projects within the mini-grid sector remains challenging. To be successful, any business model for commercially viable mini-grids must address the needs of three key stakeholder groups. Customers need a guarantee of service that they can afford and are willing to pay for; Power suppliers need to be able to guarantee a rate of return to their investors while covering all operational costs; and investors need to be confident of the risks they are taking [25].

Business models for utilities in mature energy markets work because the roles and relationships between these three stakeholder groups are well-defined. In Malawi, this utility model breaks down as a result of three main challenges: the high cost of power provision to remote customers, a lack of consistent cash flows from customers to the power supplier, and poorly understood investment risk profile due to the small number and high variability of projects. In short, Malawi suffers from early stage market fragmentation and unmade linkages. The challenge of devising business models that can provide viable returns through provision of electricity to remote and dispersed poor rural communities is real and involves balancing the high cost of operation, maintenance and administration with the returns from poor consumers with seasonal incomes that can afford only minimal amounts of electricity.

Productive use can be promoted as a driver towards sustainability, especially effective if coupled with training on skills, and access to microfinancing for enterprises. However, the situation on the ground in Malawi doesn't offer many opportunities for existing productive uses of energy already being supplied by diesel generators for example. This means a promotion of business and entrepreneurship is required as well as energy supply, increasing the time and resource requirements to get a project off the ground.

3.2.2. Finance

Another challenge is support in terms of financing. The MAREP levy subsidises the ESCOM billing system; if made accessible to independent players, the outreach would be recognisable as many areas would have independent power generation schemes. Such projects could even feed into the national grid and supply many areas.

Capital for investment is a key challenge in Malawi as energy business models are not commonly understood by Malawian banks, and financial players tend to be risk averse. Interest rates in Malawi are extremely high, with banks regularly charging in excess of 40%. Additional to these challenges, exchange rate fluctuations have impacted renewable energy projects finances, especially when components are purchased from abroad. Some micro finance initiatives exist (e.g. CUMO), but will rarely allow enough capital to purchase a mini-grid up front. There is very little private sector investment for mini-grids in Malawi. In fact the only renewable energy sector with such investment is the pico-solar and solar home system market, which has private equity and debt from local development banks providing working capital for enterprises. The lack of reliable financing mechanisms can be a severe barrier to mini-grid implementation.

The majority of energy projects in Malawi are currently funded by overseas donor grants, frequently receiving criticism. Some state that the amounts offered are insufficient to achieve government and SE4All targets for energy access in Malawi, while others complain of donor funding distorting markets and hindering private sector initiatives. Either way, despite energy's increased prominence in Malawi, it is still considered a relatively niche sector for donors in Malawi.

Beyond electricity supply technologies, availability of quality electrical equipment and appliances is limited for consumers in homes, enterprises and public facilities. Access to high efficiency products – including light bulbs, TVs, fridges, etc. - is particularly important for rural consumers relying on systems with limited generating capacity. Addressing the barrier of micro-finance availability for consumer products will increase demand and profitability of mini-grid developments.

3.2.3. Ability and Willingness to Pay

Poverty prevalence is high in Malawi which is a key policy driver for pushing energy access on one hand and on the other hand it is a driver for unsustainability of energy interventions as most Malawians think or have due to political issues already explained been conditioned to believe that they are too poor to pay for energy services. Low interest loans could be a facilitating factor and donors have an opportunity to partner with the government to progress such initiatives.

Determining the Ability and Willingness to pay of customers is an inherently difficult process. High uncertainty exists with determining the expected electricity demand of previously unconnected communities and considerable variation can exist between relative wealth levels in the village. When conducting surveys on economic matters both "recall" (respondents not knowing or being able to remember income/expenditure) and gaming (respondents directing answers based on what they think is expected or what will benefit them such as understating incomes) are both prevailing challenges. Tariff setting based on Ability and Willingness to pay is therefore an identified barrier.

3.2.4. Energy Demand

Malawi has a very small industry base, the mere availability of additional power may not necessarily lead to an increased use of energy. The low commercial power demand and lack of anchor loads may dissuade potential investors from investing in mini-grid.

3.2.5. Case Study Insight: Unsustainable Tariff Setting in the Solar Villages

The guidelines for pricing of the electricity supplied to the consumers in mini-grids involved households paying an equivalent of their monthly expenditure on illuminating paraffin and on batteries for torches, radios and any other electrical appliances used for entertainment. From the case studies, it was found that while the villagers at all six mini grid were paying between K150 and K300 per month, the people at Mdyaka and Chigunda Solar Villages pay K100 per month each. According to ESCOM, a rural household supplied with electricity from the national grid were paying an average of K770 per month, assuming the uses are limited to lighting, supplying power to a radio and charging cellular phones. This means that the electricity tariffs in the mini grids were too low considering that actual power supply is for about four hours only in a day. When one looks at the mini grids as standalone investments, these prices cannot justify the capital expenditure. However, one can argue that this is typical of any social project, where the government is obliged to provide a service to its people. The only problem in this case is that the government does not seem to be ready to finance the repair and maintenance of the mini-grids. This calls for cost-reflective price for the electricity supplied to the people, otherwise the whole initiative can simply fall apart.

The systems are also very costly. For example, according to the Department of Energy Affairs a mini-grid system with a capacity of 20 kW and a water supply component cost around K50 million in 2008

(K44 million without a water supply component). It is difficult for a rural community to maintain such expensive facilities, communities at Mdyaka and Chigunda were unable to replace the 60 batteries that are burnt out and the Mdyaka Solar Village community were stranded and left with a non-functioning power house since December 2012, when it was struck by lightning. The story is the same for Chigunda Solar Village where there has been no electricity supply since October, 2012 due to worn out batteries. The rehabilitation of Chigunda Solar Village has been quoted as approximately K20 million, which compares to a the cost of extending the grid to the region. This raises serious questions about the sustainability of the mini-grids financial model, particularly in its current design.

Figure 16 Inside Chigunda power house, the batteries were shared to community members and now the battery cages is used to store maize

3.3. Social

3.3.1. Human Capacity

Given the nascent status of mini-grids in Malawi, human resources for mini-grid development and implementation are lacking at all levels. Challenges exist in developing the wide ranging skills set required to successfully develop businesses, including among others: negotiation, business, presentation, finance, contracting, regulations, technology, partnerships, planning, data and IT. Similarly entrepreneurs suffer from a lack of knowledge about modern technology options, particularly recent innovations using hybrid systems, demand management and payment solutions. Challenges exist in devising business models that can provide viable returns through provision of electricity to remote and dispersed poor rural communities, such as balancing the high cost of operation, maintenance and administration with the returns from poor consumers with seasonal incomes that can afford only minimal amounts of electricity.

Evidence suggests that most of the solar PV installations in Malawi are not working either due to poor installation, lack of proper maintenance or inability to acquire new batteries. Reasons for this include Malawi's general lack of appropriate technical skills to install, repair or maintain the systems and communities low financial capacity to buy replacement batteries once the initial batteries' life span runs out.

Capacity development is therefore required to make mini-grids development a success, at all levels ranging from project development, site selection, project management and finance as well as local capacity building for operation and maintenance. Past governmental assessments further confirmed by recent consultations held by a World Bank team have indicated a shortage in skilled technicians for the operation and maintenance of renewable and/or decentralized energy systems as a major barrier for the uptake of renewable energy in Malawi. With so few systems in place it is difficult to identify technical people experienced in the specifics of village power technologies.

It has also been noted that capacity within the Malawian institutional setup to drive the sector seems inadequate. Furthermore, the link between national planning and district implementation is constrained by lack of both human and financial resources. This is being addressed in part through technical courses being offered at Mzuzu University and District Energy Officer initiatives providing training on energy literacy to extension workers.

3.3.2. Perception and Awareness

The connections and wiring at some communities evaluated were vandalised one year after installation. This has been a major setback as the pupils had become used to studying at the school in the evening. Now they are confined to studying in their homes. This is quite a problem for those pupils whose homes are not connected as they have to make arrangements with those who have electricity to study with them.

Another social problem is high expectations against a background of limited resources. As already pointed out above, mini-grid projects tend to raise high expectations within the areas where they are being implemented. Nearly everybody hopes to be connected to the local grid to be established by the project, however limits to electricity demand are enforced by putting a ceiling on the number of households to be connected, as financial constraints limit the potential for generation capacity associated capital costs.

3.3.3. Stakeholder Coordination

Many players in the energy sector disparately doing more or less the same activities, but lacking coordination. As representatives of a sub energy sector, mini-grid players do not speak with one voice to influence public policy. Time and resources are therefore wasted by replication and resource overlap.

3.3.1. Case Study Insight: Social Challenges with Operation and Maintenance

Delays in Maintenance Services

The committee at Chigunda reported that it is difficult for them to purchase costly spare parts or pay for major repair works using the little money collected from the users. For instance, during CEM visit to the village in September 2017, the team found out that all the mini grids were not working and some needed replacement batteries. They did not even know where the batteries could be sourced. The matter had been duly reported to the Department of Energy Affairs but help was not forthcoming.

Lack of Comprehensive Training for Plant Operator

There is a general concern that the contractor did not adequately train any member of the community in the operation and maintenance of the facility. Individuals who used to hang around the construction site, watching and observing how the contractor was working just out of interest were entrusted with the operation of the plant. If this is indeed the case, then there is great possibility that the facilities would not be operated efficiently and effectively. In addition, it is highly risky for a person like them to be entrusted with the operation of such a sophisticated piece of engineering. For the operator, issues of safety at the workplace do come into play.

In one of the interviews, the people reported that an inverter burned out in 2010. This happened within 1 year after the commissioning of the plant. Fortunately, this was within the warranty period provided for in the contract and the contractor sorted out the problem. However, with an untrained person in charge of daily operation of the facilities, one wonders whether the burning out of the component was as a result of normal wear and tear or was caused by poor handling of the system.

Lack of Adequate Handover Process

There is often no formal handover of the systems to the local communities on completion of the project. It could be that the contractor was not required to do that in the contract or that the contractor thought this was the responsibility of the government, as the client. The government too is not very clear on this issue. Whatever the case, the fact that there was no handover has got its own effects on the day to day running of the facilities. As already stated above, the people do not know where to source batteries for the system. Even more, they do not know where to buy the right type of light bulbs, which are rated at 11 Watts. As a result, they end up purchasing ordinary incandescent bulbs, which are not suitable for the kind of electricity under discussion. A well planned handover process, during which the people could be advised on how to use the electricity, might have minimized such problems.

3.4. Technology

3.4.1. Availability of innovative technology

A lack of knowledge and market availability of modern technology options, particularly recent innovations using hybrid systems, demand management and payment solutions is a barrier to mini-grid development. Technologies and their development methodologies including financing mechanisms should be adapted to contexts in which they would operate. This requires in-depth knowledge of a number of aspects such as energy needs and requirements; prioritisation of energy services; purchasing power; satisfaction of energy services and experiences with prevailing energy technologies; social practices and social set-up of communities; and available technical skills. Similarly, the use of poor quality materials is also a challenge in Malawi.

Accessing modern village power technologies (including generation, distribution, batteries, monitoring and control, payment platforms, etc.) is a challenge for project developers, and tests sustainability of systems with poor access to replacement parts. 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. Whilst the Renewable Energy Equipment Project Waiver provided by the Malawi Revenue Authority helps reduce cost, the small quantities of goods currently being imported on a project by project basis offer no economy of scale.

3.4.2. Mobile Money Payments

The nascent state of mobile money platforms for energy payments in Malawi presents a barrier, increasing costs through the necessitation of an on-site vendor at the mini-grid site to take customer payments. Opportunities exist to collaborate with telecom companies and mobile money operators, exploring potential relationships and requirements for utilising mobile money for energy transactions, which could have cost saving implications.

The success of all existing initiatives relies on high mobile network penetration and the availability of mobile finance platforms. In Malawi, mobile money operators are Airtel and telecom, both of which have not yet reached a critical mass to allow cheap enough transaction fees for customers. A 10% commission charge is still taken from each transaction which can have negative effects on businesses relying on the service. As more customers sign up to use the service the transaction costs will reduce the service costs and make use of the service more affordable.

3.4.1. Grid Connection

A risk to mini-grid developers is the arrival of the mains grid, as electricity from ESCOM will always be cheaper than that powered by renewable energy die to the subsidies offered to ESCOM from GoM. However, this challenge can also be seen as an opportunity, as ESCOM is currently suffering from power shortages and frequent blackouts. Mini-grids placed at the edge of the grid can provide additional stability and a welcome source of additional power for a wavering grid. However, in order for the technical benefits of mini-grids interconnecting with the main grid, a robust framework for feed-in-tariffs and regulations for mini-grids to grid-connect needs to be in place. Although the Feed-In tariff framework was introduced in 2012, there is little precedent for sustainable and profitable grid connected mini-grids to work from. A pilot project looking specifically at a mini-grid feeding into the main grid with effective monitoring and evaluation would increase developer confidence and reduce risk to potential funders of such strategies.

3.4.1. Resource and Demand Assessment

Many mini-grids in Malawi are implemented without proper assessment of the renewable resource or effective demand assessment. Incorrect resource assessment can lead to inadequate generation and inaccurate load forecasting can lead to over or under sizing projects, both leading to poorly designed systems with cost and sustainability concerns.

3.4.2. Case Study Insight: Technical Challenges at the Solar Villages

Limited Periods of Power Supply and Limited Coverage

The communities complained about short periods of power supply. They reported that they could only have electricity from 6 to 10 o'clock in the evening. Their preference was to have power all day everyday just like electricity from the national grid, under normal circumstances. The people also lamented the fact that they are not allowed to use the power for fridges or haircutting appliances because the inverter is said to be too small for such functions.

Both the Group Village Headman's and the people lamented the fact that the network did not go as far as the 3 kilometers radius as originally announced. Instead the actual coverage is between 1 and 2 kilometers. This means that quite a few households which would have benefitted from the project missed out.

Complex and Costly Electricity Generation and Supply Systems

The solar, wind or hybrid systems that were being established in the six communities were not simple as to be operated by anybody. On the contrary, they are complex, just looking at the powerhouse engineering alone. Coupled with the network of distribution lines, stay wires and everything else, the mini grid are too complex to be entrusted to local people to operate or manage due to unavailability of qualified personnel resident in the village.

3.5. Legal

Similar to Policy, the Malawian energy legal system is currently unfavourable for mini-grids, although recent developments discussed previously are underway to ease legal requirements for mini-grid developers.

A number of institutions contribute to the policy and regulatory framework in Malawi: the Ministry of Energy, including the Malawi Rural Electrification Programme (MAREP); the energy Regulatory Authority (MERA), the Electricity Supply Company (ESCOM), as well as a number of other Ministries, including Finance, Planning and Local Government. The Malawi Renewable Energy Strategy is currently under review by Government of Malawi and includes comprehensive targets for mini-grids. The MERA's website has the following statement: "MERA is committed to development of not only mini-grids but the whole spectrum of renewable energy technologies, especially in the rural areas in order to complement Government's policy on increasing access to modern and clean energy at national level".

Well designed and specific policies and regulations can provide guidance and support for mini-grid implementers, whereas outdated and grid-centric frameworks will suppress activity. Unfortunately, Malawi falls within the latter category with a complicated regulatory environment unsuited to mini-grid development, as the following figures, taken from RISE 2017 [26] serves to demonstrate.

Figure 18 Figure 17 shows that on average it takes between 1 and 2 years to obtain common permits to set up a mini-grid facility in Malawi, and Figure 18 shows that it takes on average 120 days to obtain environmental clearance. Additionally, the cost of obtaining permits to set up a mini-grid facility is the highest of all countries surveyed in the RISE report, with a quoted figure of $15,082.

Figure 17 Days to obtain a mini-grid permit

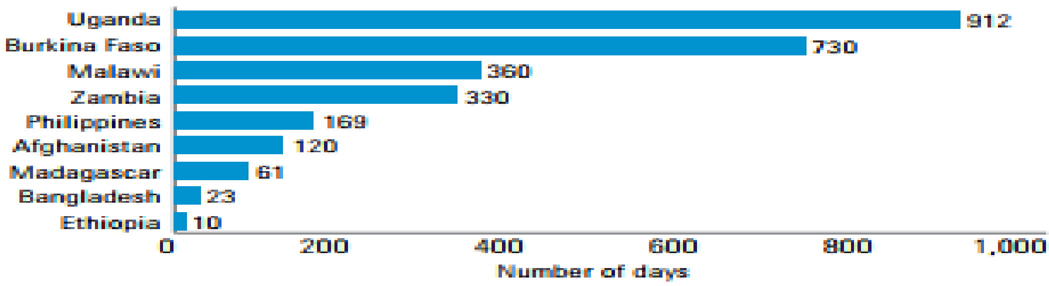
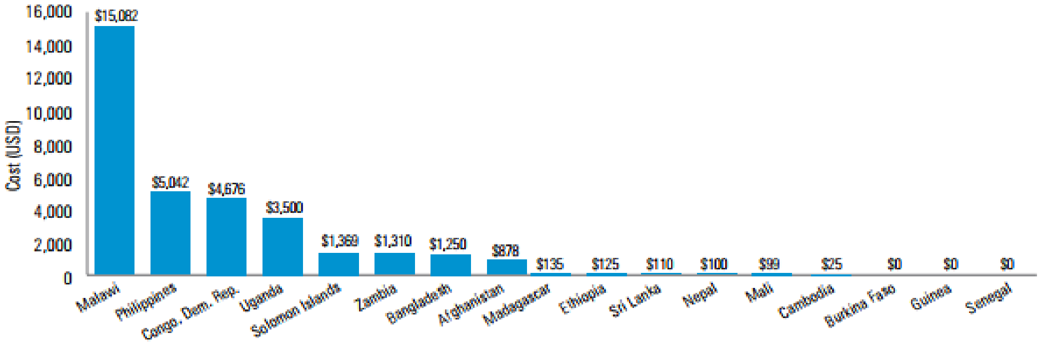


Figure 18 total cost of obtaining permits to set up a mini-grid facility in 17 countries surveys



The reason for the high costs and long delays to receive mini-grid permits is due to the fact that the same regulations and license procedures apply for any generating capacity below 2MW, meaning a mini-grid operator looking to install a 100kW solar system is required to pay the same license fee as a 2MW grid-connected diesel plant. Additionally, a separate license is required for both distribution and generation, meaning that if demand is far away from generation two licenses are required and the process to secure them can be very complicated. The government have recognised this and are proposing to reduce regulation for smaller systems, with a proposal currently in review for all mini-grids under 100kW to be exempt from regulations [27].

Lessons can be learned from neighbouring countries with less stringent regulations: in Tanzania and Kenya, licenses are required only for projects that exceed 1 MW, with smaller projects only required to register their businesses without approval requirements from the regulator, greatly reducing regulatory related deterrence of smaller practitioners. In Cameroon the lower limit is 5 MW, Rwanda 50kW and Zimbabwe 100 kW [26]. In some countries mini-grid developers can apply for provisional license (even if not required by law), to secure a site from competition or to communicate project legitimacy to financers or other key stakeholders.

The duty and surtax waiver on importation of renewable energy technology equipment helps to reduce capital costs, which enhances affordability of some mini-grid components which can lead to lower tariffs for customers. However, the tax waiver on importation of renewable energy technologies is not always reflected in the retail prices [13], and not all components (cabling and wires for example) are immediately classified as renewable energy; mini-grid technologies in the short term remain at prohibitive prices.

Importation of low quality products is also a challenge, with no warrantees or quality control, and many low quality counterfeit energy products being sold. This is more of a problem with smaller scale PV devises such as Pico Solar Systems and Solar Home Systems, but could be a challenge with PV modules or inverters for larger scale systems. Other problems are with staffing: companies interview staff members in order to obtain certification, but some companies simply hire an RE student just before the interview, then fire them straight afterwards.

Finally, a clear legal framework is required to regulate a transparent coordination among Malawi Revenue Authority which takes control of importation, Malawi Bureau of Standards, TCRET, renewable energy consultants, and contractors.

3.6. Environmental

Although mini-grid energy supply is for the most part considered in terms of electricity, it should be noted as stated earlier that 95 – 98% of energy use in Malawi is biomass with clear links to deforestation. There are drivers to increase efficiency and sustainability of biomass use through wood fuel and charcoal production. Generally mini-grids focus on electrical power for lighting, communications and productive uses, not addressing from the outset the need to reduce firewood and charcoal consumption.

Electric cookers powered by mini-grid presents an opportunity to address the environmental concerns, however the high electrical load of current electric cookers presents a barrier to mini-grid system designers, as the cost per kWh to cook a meal will likely be higher than the equivalent cost of firewood and above the customer's ability and willingness to pay. This is in part being addressed through current research to develop low power appliances including an electric nsima cooker at the University of Strathclyde.

In terms of Carbon emissions contributing to global climate change, renewable energy mini-grids have potential to reduce emissions if used instead of polluting diesel generators, but their implementation can have local environmental impacts, and the manufacture of batteries and PV requires energy which has potential for further emissions. Consideration should therefore be given to full environmental impact assessment, appropriate environmental management systems should be designed for the potential impacts, and project level life cycle assessments with carbon auditing should be conducted [13].

4. Opportunities

4.1. Stakeholder Opinions

All stakeholders agreed that despite the barriers outlined, mini-grids will play a major part in providing energy access to rural parts of Malawi in the next 5 years. When asked why, responses included that grid extension is currently limited to trading centres, and that grid level hydro power is unreliable and unable to meet the demand. Mini-grids offer a strong opportunity to increase electrification rates in communities that are far away from the grid: it is cost effective and offers opportunities to provide motive power. Some stated that there are many rural areas in Malawi where productivity is limited, and providing access to electricity offers an opportunity for economic development. The Department of Energy stated that mini-grids are considered as one of the options for rural electrification in their strategies and policy. Success of existing mini-grid projects being piloted in Malawi were also quoted as a learning opportunity, for example Likoma mini-grid is making an impact on lives of many.

"I am very much convinced that given the chance mini-grids could be a solution to the electricity challenges that Malawi as a nation is facing over years. The only power supplier (ESCOM) has failed Malawians as they cannot meet the overgrowing demand. Therefore, having mini-grids would reduce the pressure and make their supply relevant."

4.2. Drivers

- **Energy Security:** Reduce current dependency on one watershed, the Shire Basin, where almost all of the country's power stations are located.
- **High poverty levels and mini-grid electricity as an accelerator of wider human development:** Malawi is among the poorest countries in the world and as such there is a complex nexus of poverty, energy and sustainable development. The need for economic and sustainable development and the effective delivery of social services like health, education, community services are the main drivers for rural energy access in Malawi
- **Low existing levels of access:** There a huge need for households to meet the basic needs especially food and income for basic services like energy for lighting and cooking.
- **Increased appliance availability:** A rapid increase of rural growth centres and increased access to technologies such as mobile phones, radios and televisions that require energy to power them.
- **Increased agricultural productivity:** With increasing population there is also increasing agricultural expansion and irrigation development which is also a key potential user for mini-grid electricity.
- **Safer, cleaner, more affordable lighting:** Lighting with kerosene in rural areas is costly and dangerous, dry cell batteries also have environmental and cost implications.

4.3. Renewable Resources

Malawi has well endowed renewable resources which offer a good opportunity for renewable energy mini-grids. Solar Resources are well mapped in Malawi through online repositories such as IRENA and an ESMAP report commissioned by the World Bank [28]. The figures below shows Global Tilted irradiation and optimum tilt of PV modules across Malawi, and seasonal solar resource for Lilongwe based on satellite and meteorological modelling, validated by ground measurements.

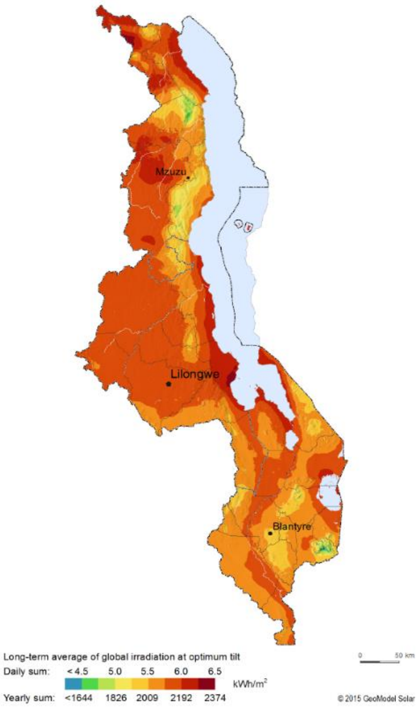


Figure 19: Global Tilted Irradiation at optimum angle – long-term averages at daily/yearly totals [Source: ESMAP]

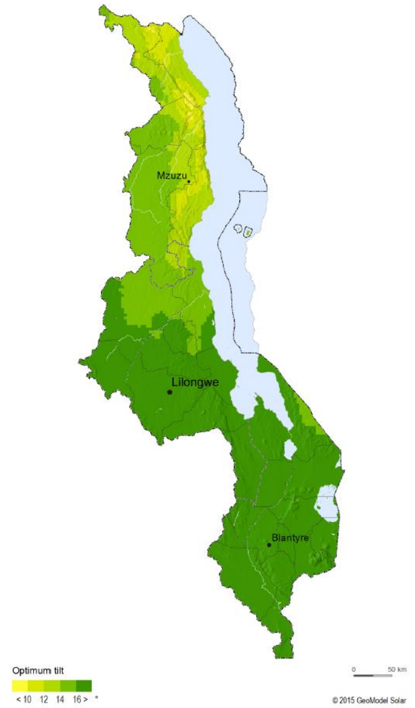
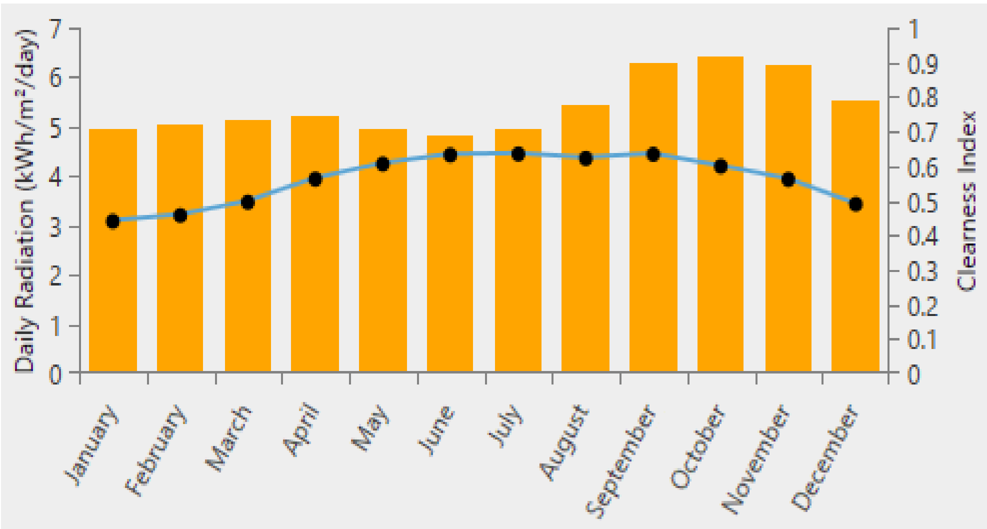


Figure 20: Optimum tilt of PV modules towards North to maximize yearly energy yield. [Source: ESMAP]

Figure 21: Solar Resource and Clearness Index for Lilongwe



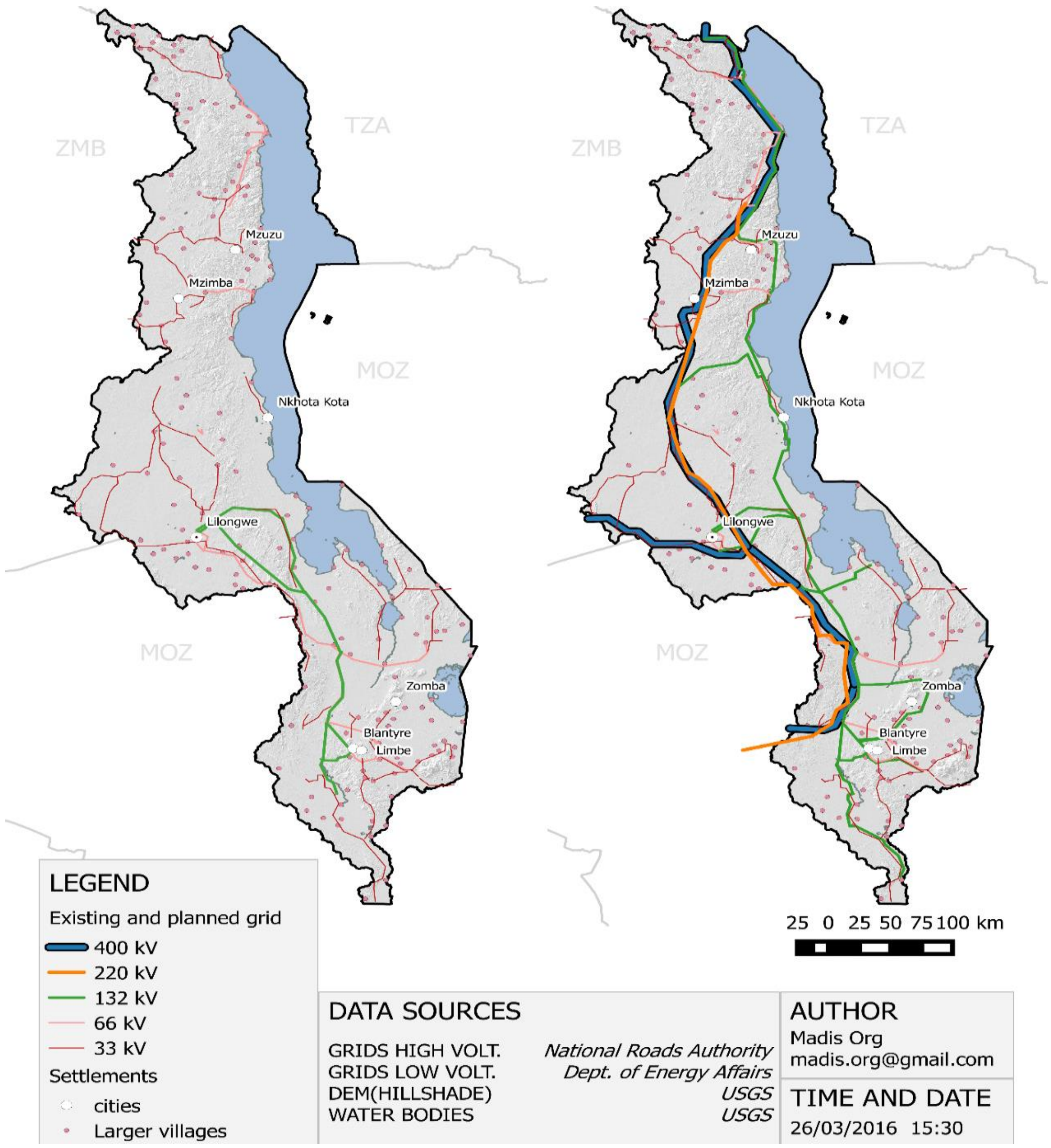
4.1. Market Potential

The potential market for mini-grids is large, with over 85% of the population not connected to the main grid. Table 9 outlines the population in Malawi living without access to electricity, disaggregated by population density and vicinity to a medium voltage grid line. The total population without access is almost 17 million. Figure 22 shows a map of the current and planned grid connect in Malawi giving an indication of where these un-electrified communities are living.

Table 9 Population in Malawi living without access to electricity

Population density	Population living <5km from MV line	Population living >5km from MV line	Total
<250hab/km²	2,285,822 (14%)	4,508,842 (27%)	6,794,664 (40%)
>= 250hab/km²	5,437,076 (32%)	4,545,807 (27%)	9,982,883 (60%)
Total	7,722,898 (46%)	9,054,649 (54%)	16,777,547

Figure 22 Grid Connection, Existing and planned in Malawi



4.2. Policy Drivers and Opportunities

A draft energy policy is emerging which includes guidance on off-grid policy and increased energy access targets for 13,500 mini grids by 2030. This key opportunity needs to be finalised and published forthwith to reduce uncertainty and accelerate progress in the sector. The unbundling of ESCOM has created a much awaited space for the private sector participation in the generation, transmission and distribution of electric power. Currently, ESCOM is already soliciting bids for the provision of 70MW from independent power producers. This will open up a market for renewable energy technologies in Malawi for on-grid power supply as well as off-grid power supply. A Feed-in Tariff Policy is set for review on the adoption of the New National Energy Policy.

4.2.1. SE4All an SDGS

Malawi is participating in the envisaged SE4ALL country action processes and recent discussion of the draft energy policy and Growth and Development Strategy provided an opportunity to address issues of energy access for rural communities in a more proactive and innovative manner. It commenced with a partnership declaration ("opt-in") within Rio+ 20 in 2012 which was followed by a an energy rapid assessments or gap analysis. The Department of Energy has been supported by the African Development Bank (AfDB) through the United Nations Development Programme (UNDP) to provide technical and financial assistance for the development of an Action Agenda and Investment Prospectus that will guide the country towards achieving targets set under the SE4All. So far Malawi has officially launched the SE4ALL initiative, and created a road map towards the SE4All Action Agenda and Investment Prospectus processes. Malawi's specific targets with regard to SE4All include improving access to electricity to 20% by 2020 and 30% by 2030, and to increase the contribution of renewable energy in the mix by 6% by 2030. Malawi is also participating in the Sustainable Development Goals, the link of Goal 7 (affordable and clean energy) to other goals is outlined in Figure 23.

Figure 23 SDG 7: Affordable and Clean Energy Impacts on several other SDGs

4.2.2. Malawi Rural Electrification Fund

A major opportunity for mini-grids in Malawi is the existence of the Malawi Rural Electrification Fund as stipulated in the Rural Electrification Act (No.21 of 2004) of the Laws of Malawi. The fund obtains revenue from rural electrification levies on energy sales, and is primarily meant for: *"the capital cost of rural electrification grid extension and off-grid electrification; the capital cost of solar home system equipment to be acquired for public institutions; and operational and maintenance costs of rural electrification projects, to the extent to which it makes the project viable."*

4.2.3. Rural Electrification Management Committee

The Rural Electrification Act also established the Rural Electrification Management Committee. According to the Act, the Committee's members include: the Principal Secretary responsible for energy affairs; the Director of Energy Affairs, MERA's Chief Executive, the Secretary for Economic Planning and Development, the Secretary to the Treasury, the Secretary for Local Government as well as representatives of the Board of Engineers and the Society of Accountants of Malawi.

The Committee's functions include developing a rural electrification master plan for the country and updating it at regular intervals; set criteria for the selection of sites; seek and access donor funding and soft credit for rural electrification; and administer the Rural Electrification Fund.

4.2.4. Malawi Energy Regulatory Authority

As of December 2017 MERA had developed a mini-grid regulatory framework, the impetus for which coming from the realisation that mini-grids like MEGA were being subjected to same conventional regulations as those applying to ESCOM. Consultations have since started on proposals including removal license requirements for mini-grids under 100kW, and producing a tariff setting guide, outlined below.

MERA is proposing to use the Revenue Requirement (RR) Methodology approach with a revenue cap in determining electricity tariffs, the guiding principle of which is that revenues of the regulated utilities should cover: efficient operating and maintenance expenses; taxes and depreciation, and ensure a fair rate of return on assets utilised for provision of electricity. To arrive at an average tariff, MERA reviews and verifies all information related to the various components that make up the revenue requirement in the utility's tariff application. MERA further examines the marginal costs by customer type and customer load characteristics that forms the basis of costs of service by customer [27].

MERA indicated they will allow mini-grids to charge retail tariffs above the uniform national tariff if required to enable them recover efficient OPEX and CAPEX. This approach will ensure sustainability of electricity service provision. Additionally, mini-grid operators will be allowed to cross-subsidize between customer classes specifically targeting domestic customers who are less able to afford electricity services but costly to serve. Finally, mini-grid operators will be allowed to charge tariffs that include depreciation on equipment financed through grants such as MAREP Funds, development partners, etc. Mini-grid Initiatives

4.3. Funding Opportunities

Limited small scale funding opportunities exist for mini-grids in Malawi, and high rural poverty limits off-grid operators' ability to recover up-front investment costs. Commercial banks are reluctant to finance small scale off-grid power generation ventures as there are no guarantees that such ventures would be able pay back the loans. This means that the majority of mini hydro and off-grid solar systems are either donor funded or Government funded. Funding opportunities for renewable energy mini-grids exist through ongoing programmes such as World Bank, REDD+, and USAID Limodzi funding opportunity. Other funding opportunities exist in Malawi, listed below:

4.3.1. UK Department for International Development

The aim of UK Aid Direct is to support civil society to deliver solutions to achieve sustained poverty reduction and to achieve the Global Goals. DFIDs Community Partnership grants are open to applications from small, non-governmental organisations that are registered as a not-for-profit organisation in the UK, working with communities in developing countries including Malawi. Applicants can apply for up funding for up to £250,000 per grant.

https://www.ukaiddirect.org/apply/community-partnership/

4.3.2. Ecokraft

Ecokraft offer a unique opportunity to invest in projects that will transform Malawian communities, supplying energy for education, health, and new enterprise. Projects can be compared using performance metrics, and choose the project that best suits you as the investor.

Ecokraft aim to provide de-risked Impact investments offerings, de-risked through targeted technical assistance provided during the early stages of the project. During project operation, projects are de-risked through use of a mobile Energy Services Payment tool powered by blockchain technology

Investors can track the impact of their projects at any stage, and stay updated on project performance and operational metrics. Performance metrics can be found out such as the total energy generation, energy reliability, and social and environmental impact of your investment.

http://www.eco-kraft.com/invest/

4.3.3. Scottish Government Investment Stream

The Scottish Governments International Development Fund aims to consider sustainable development and the impact on developing countries in particular, in everyday decisions and behaviour around social, economic and environmental choices. The three streams are Development Assistance, Capacity building and investment [29].

The Scottish Governments Investment stream is up to 5% of their total of £9 million per year, with aims to empower partner countries that want iinvestment, Malawi included. Priorities of trade & investment are deemed important, as are roles of private sector to support Malawi to move beyond aid & build sustainable economic growth domestically, in line with wider government policies.

Support too for social enterprise models is stated, and a recent investment initiative for Malawi saw SG obtain £1M in match funding from private individuals.

https://beta.gov.scot/policies/international-development/

5. Recommendations

Achieving a sustainable national mini-grid sector in Malawi in line with government and SE4All targets requires scale-up and replication of existing initiatives. Private sector led delivery offers the most promising approach to achieve the scale and speed required of the SE4All target of universal access to energy by 2030. The government has a critical role to play in enabling and accelerating deployment through clear and focused policy and regulatory frameworks. Furthermore, a step change in public sector funding from the Malawi government and energy sector, and donor partners is necessary.

Recommendations are therefore given below for developers and policy makers as steps to take on a variety of levels towards furthering energy access in Malawi through mini-grid implementation. Further sections are provided on recommendations around themes of capacity building, research and knowledge exchange.

5.1. For Developers and Practitioners

Engage with Communities: utilising participatory methods for project development such as setting up a Village Energy Committee ensures community voices are heard and collective development of the grid from the outset, contributing to sustainability. Pastors or head teachers have experience of community leadership and can make ideal committee members. Some Community Based Organisations have prior experience of energy projects; searching for existing social infrastructure by engaging in such organisations on the planning and delivery of mini-grid projects contributes to project sustainability. Within this context further recommendations are given to ensure women's voices are heard in the mini-grid development process.

Conduct pilot projects to quantify local costs of installed systems. Several components for the system will need to be imported and quantifying exact costs to get them to local sites will be essential for modelling CAPEX to scale projects nationally. Employing effective monitoring and evaluation methods gains valuable data on electricity demand and system performance, analysis of which is essential to inform future projects.

Embrace innovation: Technical innovations for smart metering, data logging, remote monitoring and control should be utilised. Many products already exist on the market to fulfil such requirements including Steamaco's Bitharvester, Powerhive, and SparkMeter. Efforts should be made to explore supply chain option for such technology, as well as developing opportunities for local manufacture to increase the local value chain elements, spurring economic development.

Develop and trial viable business models that engage communities: More research is required to develop and trial mini-grid ownership and business models, linked with innovative financing mechanisms. Innovation is also key regarding community engagement to ensure community dynamics are well handled. Low ability to pay, credit default culture and dependency syndrome from prevailing aid complicates the economics of community systems is complicated in Malawi. However, setting affordable tariffs for well utilised mini-grid electricity has high potential to promote economic growth that would raise disposable income.

Develop local capacity for operation and maintenance: Local capacity building for operation and maintenance of mini-grids is essential for projects to be sustainable. Currently the image of mini-grid are marred with poor installations and a lack of capacity building activities for local communities, which has ultimately resulted in vandalism and abuse of these systems. Private sector organisations should therefore invest in technical and business training for their staff through existing institutional technical capacity building bodies.

Develop financing schemes in sync with income generating activities: Communities have higher affordability when they are selling an agricultural products or have opportunities for labour such as in tea estates. With this in mind, innovative financing mechanisms that take account of seasonal fluctuations in customer income should be considered.

Consider the grid: Strong consideration should be put on the possibility of the grid extending to the areas when selecting the sites. To mitigate risk of mini-grids becoming obsolete, developers should work with MAREP to avoid sites likely to be connected to the grid, and consider using wiring configurations that can conform to current grid stipulations so that if the grid does arrive, the mini-grid can integrate, rather than be ousted by the national grid.

Target Productive Uses: A mini-grids profitability is dependent on effective utilisation of the energy generated, sometime know as the load factor. Increasing a load factor can have significant positive effects on the mini-grid and for this reason, stimulating productive uses of energy are key. This is a challenge in Malawi, where existing PUE run off diesel generators are few and far between. Investing some resources to community sensitisation on productive uses will increase energy demand and increase the profitability of the mini-grid over time. Project promoters should forge partnerships with other organisations that can help to harness the PUE potential.

Utilise effective planning tools: several tools are available for mini-grid development and should be utilised, ranging from system design to financial planning. Several templates for business models, cash flow forecasting and system design aids are available for free online. A list of such tools can be found in Appendix 3.

5.2. For Policy Makers

Put in place favourable regulatory system: removing regulations for mini-grids under 100kW will accelerate smaller mini-grid deployment**.** MAREP levy should be accessed by all would be investors in the energy industry especially those targeting off-grid communities.

Increase awareness of the benefits and limitations of mini-grids systems: Community awareness is limited, as illustrated by the case of various DoE owned projects. Perception challenges also prevent adoption of mini-grid technologies. Some Malawians have put their faith in ESCOM Power and they believe such power is far superior to off grid options due to their limited capacity and range of household appliances. Lack of familiarity with the basics of mini-grid technology among most Malawians is a significant constraint, as there are high levels of illiteracy and limited access to information sources such as the internet. Investing in community awareness is therefore vital to progress the sector.

Increase quality control and raise consumer awareness of product quality: The quality of RE products is not currently regulated and as such, there are varying qualities of products with some very poor quality. There is currently no quality certification, as the current focus is revenue generation through VAT since there is a duty exemption. Such challenges should be addressed through product testing at TCRET and increased consumer awareness. Whilst policies relating to quality standards are in place, various agencies need to do more to ensure enforcement and promote product quality standards and raise consumer awareness.

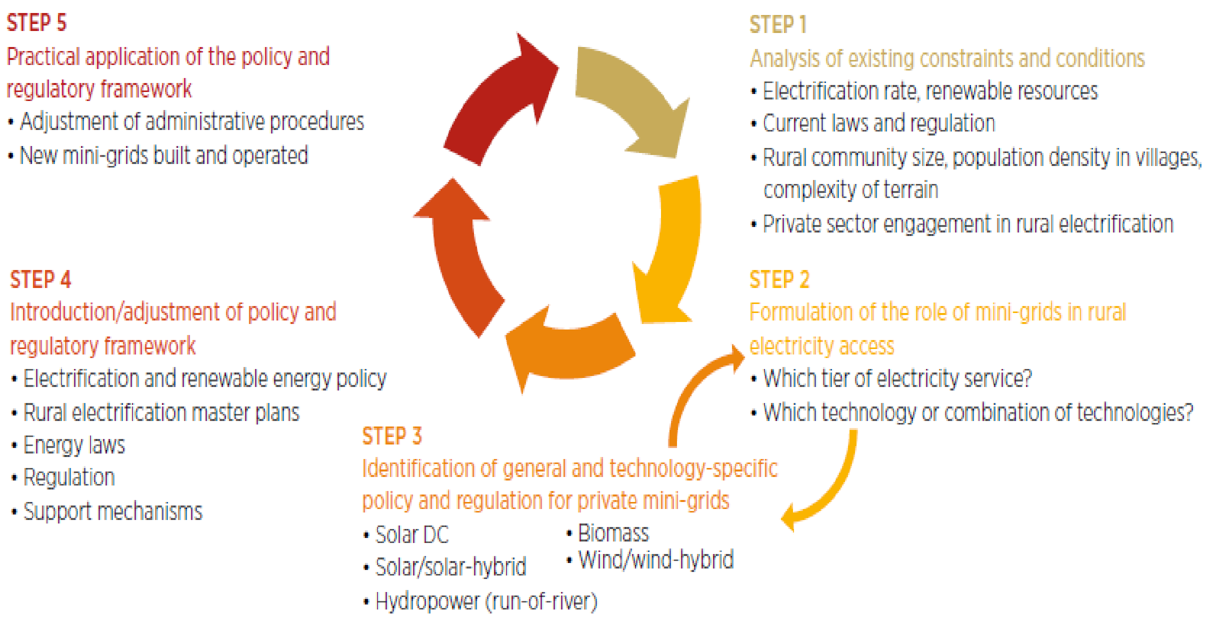
Increase access to capital and funding opportunities: Capital access in Malawi is generally a huge challenge, financial institutions in Malawi do not understand how the energy sector works, proposing very short and unrealistic loan periods for those interested to invest in energy. Interest rates are also generally higher in Malawi, and local banks give a very short payback period for loans which does not suit mini-grid projects. Checklists used by banks to approve loans often find energy projects too risky to be financed. Weak local currency means importation of spare parts becomes a huge challenge as local revenues get eroded so easily in value. Addressing such financing challenges is key for successful mini-grid development, particularly promoting sustainable financial and market facilitation.

Consider subsidisation There is need for an intervention so that with the current power challenges, mini-grid electricity should be at a subsidised price in order for it to be provided to customers at an affordable price.

Engage District Energy Officers: The Government of Malawi is dedicated to rural electrification through the Malawi Rural Electrification Programme fund, and is committed to implementation of District Energy Officers (DEOs) (to be working in all 28 Malawi districts by 2020) by providing the District Energy Officer salary. DEOs can play a pivotal role in identifying mini-grid sites through their Energyscaping activities, and connecting developers, communities and funding through the Malawi Rural Electrification fund. As DEOs are rolled out to all districts of Malawi, specific training and frameworks should be implemented to maximize DEO impact on the mini-grid sector.

Figure 24 outlines a five-step cycle required for policy development.

Figure 24 Policy Development cycle for the mini-grid sector[30]



5.1. Capacity Building, Research and Knowledge Exchange

Lack of knowledge, information and research to drive and promote mini-grid technology is preventing the progress of the sector as a whole. Capacity building is needed at all levels, from technical design of mini-grids, to financial planning, to installation and maintenance. The barrier also offers an opportunity, as new job can be created in a growing mini-grid sector.

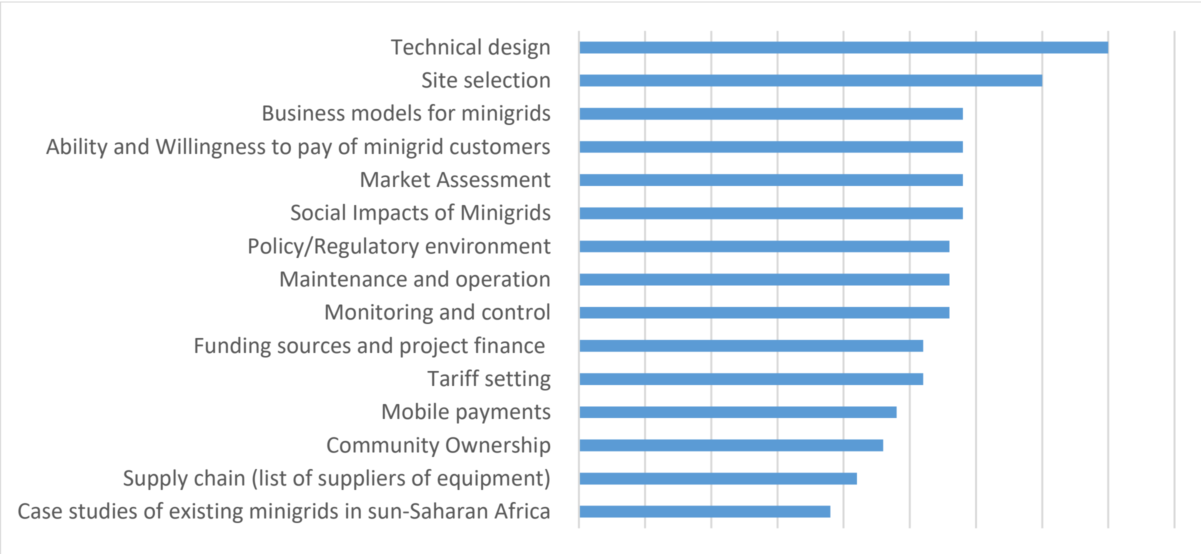
Any mini-grid initiative should therefore be accompanied with effective sensitisation and awareness campaigns. Mini-grid developers don't often have the time or resources for these activities, so could be supported by NGO's with experience in such community development practices. Community engagement should include workshops intended to stimulate productive uses of energy, and toolkits such as the Renewable Electricity for Productive Uses [31] can be useful in the achievement of such goals.

The opening of Renewable Energy Department at the University of Mzuzu and the provision of training on renewable energy technologies may minimise the problem in the medium to long term, as will short courses beginning to be offered by University of Malawi Polytech and other vocational training institutions. Courses in softer modules within existing mechanic/electrical engineering faculties might bridge the gap between system design and on the ground implementation, including subjects such as setting tariffs, marketing to customers, fielding complaints at the local level and collecting revenue.

Stakeholders interviewed suggested that sharing knowledge, skills and information regarding mini-grids is essential to provide synergy on capacity. A collaborative approach allows a platform to advocate for policy from government. However some said that such methods are a good idea but they will make less impact on improvement of installations if the legal and regulatory frameworks are not enforced.

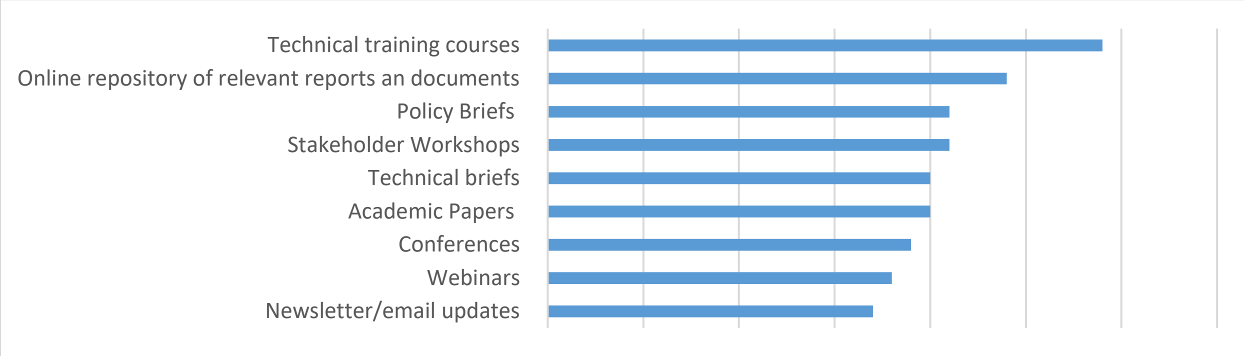
Figure 25 below shows the order of preference for required information about mini-grids as deemed by the stakeholders, with technical design, site selection and business models as the top three. Other suggestions for research and knowledge exchange include economics, standards, local culture/ politics, feasibility studies, legal and compliance, community stakeholder engagement, procurement, installation and commissioning, operation and maintenance, standards, models for change management in project community mobilisation processes, and resource assessment.

Figure 25 Stakeholder response: "Which of the following information would be useful for mini-grid developers?"



In terms of methods for sharing and disseminating knowledge, Figure 26 shows the order of preference indicated by the stakeholders. Technical Training courses, an online repository of relevant report and documents, policy briefs and stakeholder workshops are most popular.

Figure 26 Stakeholder response: "How useful do you think the following methods of information dissemination are (related to the mini-grid information)? "



Academia can play a key part in addressing the barriers presented above. Through conducting research the knowledgebase on mini-grids in increased in Malawi, and ensuring effective research dissemination paths ensures pathways to impact and wider applicability of the research outputs. A selection of areas for future research are outlined below.

Market Assessment of Mini-grids in Malawi: A need is identified to develop a methodology for assessing the market for mini-grid in Malawi, assessing the viability of the technology for different deployment contexts and establish appropriate measures required to make these systems technically, economically and socially viable and sustainable within these contexts. The methodology should identify key risks and barriers associated with the implementation of the technology in Malawi, and determine mitigation measures where appropriate. Ultimately the market assessment will determine if mini-grids have potential to increase sustainable energy access and contribute to poverty reduction in Malawi, and if so, in which locations and circumstances they appear most viable, and what specific measures are required to mitigate any deployment risks and ensure sustainability of the technology.

Ability and Willingness to Pay: This metric is desired by project developers to compare with their cost reflective tariff to give an indication of their mini-grid business plan feasibility. Current ATP is generally determined through village surveys with basic and direct questions posed to potential customers regarding how much energy they use and how much they would be willing to pay for that energy. This is an inherently challenging exercise, as survey field work is expensive, and even once conducted, uncertainty remains in the data collected, as household cannot know for sure how much energy they will use or be able to afford. Additionally, calculating ATP for businesses that do not currently exist face obvious difficulties, and mini-grid developers may find that additional support or guidance on how to engage communities to set up PUE will be required. Unsubsidised mini-grids may be unfeasible in many areas at this time in Malawi, however rural poverty levels have been reducing and ability and willingness to pay will increase over time, making mini-grid initiatives more viable in the future.

Interconnected Mini-grids: Another longer term research area is the interconnection of mini-grids themselves (either with or without the main grid). Such a "mesh network" of interconnected mini-grids offers the opportunity to increase reliability and lower costs, through sharing electricity between grids with different renewable resources and load profiles. Again, a regulatory framework to support such innovation would enhance investor confidence, and robust and detailed research into the technical and economic consequences and requirements is paramount.

6. Further resources on Mini-grids

6.1. Government of Malawi and UNDP GEF

The UNDP under the programme increasing Access to Clean and Affordable Decentralised Energy Services in Selected Vulnerable Areas of Malawi is leading on a 5 year programme to stimulate the mini-grid sector in Malawi. The have supported the development of two mini-grids, the CEM Sitolo one discussed and a hydro mini-grid close to Mzuzu which is at feasibility stage. Furthermore, in partnership with the DoEA, they are collating key information about potential sites, case study data, setting up a mini-grid data repository and advocating for changes in the regulatory environment to stimulate the mini-grid sector in Malawi.

https://info.undp.org/docs/pdc/Documents/MWI/PIMS%205270%20Malawi%20Clean%20Energy%20Mini%20Grids%20Project.doc

6.2. Green mini-grids portal

Green Mini-Grid Help Desk provides a complete information service for developers of green mini-grids (GMGs) in Africa. The website has been developed by Energy 4 Impact (formerly GVEP International) and INENSUS for the Sustainable Energy for All (SE4All) Africa Hub, hosted by the African Development Bank and funded through the Bank's Sustainable Energy Fund for Africa (SEFA). They offer free impartial advice for mini-grid developers and have offered to check over our spreadsheet and feasibility report, provide some feedback and suggest potential funding routes. They're funded by the African Development Bank so everything is for free, although projects need to provide them with some data/info on how our project progresses for their M and E and reporting to AfDB.

http://greenmini-grid.se4all-africa.org/

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8. Appendices

8.1. Appendix 1: Household Surveys

https://drive.google.com/open?id=1Y_IBDk-LNYQvdpTxdmnBNTfaDuPZpIX3

8.2. Appendix 2: Stakeholder Surveys

https://drive.google.com/open?id=1K6hU7uDzK24teZKIXbzUAaDgT5uk5OfF

8.3. Appendix 3: Mini-grid Tools

https://drive.google.com/file/d/1qEGWNkORwNm2ZjTY8_LmJmh74xyY287N/view?usp=sharing