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Powering Isolated Territories and Communities with Hydrogen Energy Systems

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Community Energy Malawi

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Contents

List of Acronyms

CEM: Community Energy Malawi
DC: Developing Countries
DoE: Department of Energy
GoM: Government of Malawi
G20: Group 20 Nations
HySA: Hydrogen South Africa
H2: Hydrogen
IEA: International Energy Agency
GMGs: Green Mini Grids
PV: Photovoltaic
SSA: Sub Saharan Africa

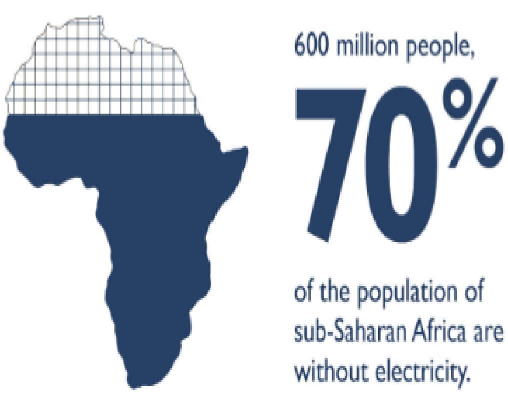
1. Introduction

1.1 Energy Access in Sub Saharan Africa

According to The World Energy Outlook 2018 it is estimated that around 600 Million people lack access to electricity in sub-Saharan Africa. It further states that there are an estimated 585.2 million people lacking electricity, more than two-thirds of whom live in rural areas and are largely reliant on biomass and traditional energy sources to meet their livelihood needs. Under the International Energy Agency's New Policies Scenario – a scenario for global energy that takes into account the agreements made at the Copenhagen climate conference in December 2009 and promises made at the G20 to phase out subsidies for fossil fuels and in the absence of additional, dedicated policies for reducing energy poverty, the percentage of people relying on biomass for cooking in sub-Saharan Africa is projected to decrease in line with the rest of the developing world, by approximately 10 per cent in 2008-2030. It further asserts that despite a projected increase in the electrification rate in 2008-2030, the absolute number of people in the region lacking access to electricity is expected to rise from 31% in 2009 to 50% in 2030; a stark increase in comparison with projections for the rest of the developing world. Sub-Saharan Africa could account for 54 per cent of the total world population lacking access to electricity in 2030 compared to 41 per cent in 2009.

The 2018 Malawi Population and Housing Census of 2018 puts electricity access to 11%. Less than 5% of the rural population has access to electricity. It further points out that biomass fuel is the major energy source for Malawians living in rural areas, supplying 95% of their energy needs while it supplies 55% of the people's energy needs in the urban set up. that the Malawi Energy Policy segments Malawi's energy needs as follows; 83% for household needs, 4% for transport needs, 12% for industry needs and 1% for the service sector.

Figure 1: Electricity Access in SSA and Energy situation in Malawi



There is a strong message emerging from the statistics about Africa's energy access that the energy situation is intolerable and there is need for urgent action to reduce reliance on biofuels, particularly among the poor, through increasing real access to electricity and other modern energy services like mini grids.

1.2 PITCHES - The project

PITCHES builds on the pre-existing Surf 'n' Turf and BIG HIT projects in Orkney as a basis for assessing the market potential for renewable hydrogen systems serving remote communities, including those in sub-Saharan Africa. The overall objective of PITCHES is to demonstrate (at MW scale) that existing hydrogen energy production and storage systems can be used to develop a new energy system to meet transport, electricity and heating needs of remote communities, showing that hydrogen based energy systems have the potential to reduce reliance on imported fuels, reduce carbon emissions, and in future as the technology develops, to reduce energy costs. The PITCHES element of the project explored the replicability of such systems to isolated, off-grid communities, including in Sub Saharan Africa, by testing configurations of the system, and identifying business models which best suit off-grid communities in developing countries. In the developing world, there are many remote communities with little or no grid access - the Energy Africa campaign estimates that 70% of the Sub-Saharan population is without electricity access, and 50% of businesses there view a lack of reliable power as a major barrier to business. Whilst other energy storage technologies, such as batteries, may be more suitable for the smallest communities, integrated hydrogen systems have potential to support medium sized communities with mini-grids, and also the potential in future to support nascent enterprises and industries through providing local transport fuel.

1.3 This report in the context of the wider project

The report consolidates findings by Community Energy Malawi on the mini-grid sector in Malawi and other Sub Saharan Africa Countries. In line with the PITCHES PROJECT Milestones, the report provides information on the status, and case study evaluations of existing mini-grids in SSA. At the same time, the report looks at the opportunities existing in the SSA mini grid sector for new storage technologies, Hydrogen in particular.

2. Current Hydrogen Use in SSA

There is only 1 known hydrogen energy project being implemented in the Sub Saharan Africa region this far with 2 other projects still in the pipeline.

A. Hydrogen South Africa Project (HySA)

The Hydrogen South Africa (HySA) is the well-known of the three known hydrogen energy projects. HySA's core aims are to develop hydrogen fuel cell systems and to undertake research and development of hydrogen systems Through the HySA, Hydrogen Fuel Cell pilot projects have been installed.

B. Uganda Solar-Hydrogen Mini Grid

In Uganda, there are plans to incorporate hydrogen storage systems in 3 government built solar mini grids. The extra power generated by the solar mini grids will be used to generate hydrogen which will be stored and used for powering households and businesses.

Figure 3: Uganda Solar-Hydrogen Mini grid

Source: Green Building Africa

C. African Hydrogen Partnership

The third known project is the African Hydrogen Partnership (AHP) which seeks to turn Africa into a thriving hydrogen economy by enhancing production, adoption and use of hydrogen energy in Africa, thereby reducing greatly the importation and use of fossil fuels. The project will seek to oversee the construction of large scale Power to Gas systems for industrial and transport uses. The hydrogen will also be used to supply electricity to households.

3 Literature Review

3.1Mini Grids in SSA

3.1.1 Summary of mini grids in Sub Saharan Africa

In Africa, the mini grid development sector is developing at a very fast and steady rate. According to a mini-grid market report by Infinergia Consulting, More than 2,000 Mini grid systems have been installed to date. Further, a 2017 report by the World Resources Institute states that Tanzania is a regional leader in mini-grid development. The country has at least 109 mini-grids with an installed capacity of about 157.7 MW, serving 184,000 customers. Nineteen of these systems are fossil fuel-based and they account for 93% of customer connections. In Sub Sahara African countries, most national utility companies operate fossil based mini grid systems as a way of supplying electricity to grid isolated communities and towns. In Malawi for example, ESCOM operates a 1MW diesel plant on the Islands of Likoma and Chizumulu to carter for the island's power needs. A table below lists the available mini-grids and their capacities 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,3 OKW 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	Financed by UNDP, community participation, skills transfer commercialization, and entrepreneurship development

				impleme ntation stage)	strategy
Mthengowathe nga	Roman catholic Church	Solar Mini Grid (50KW)	Domestic and commerci al	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 commerci al	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	Institution al	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 Strathclyd e	Solar Micro-grid (5kW)	Domestic and Productiv e Users	Feasibili ty study complet e	Successful business model relies on CAPEX funding, however smaller capacity means lower upfront costs

Table 1: Summary of mini grids in Malawi

The latest Sustainable Energy for All (SE4All) Global Tracking Framework estimates that the urban-rural divide in access to electricity in Africa is as high as 450 percent (69 urban compared to 15 percent rural access). It further states that the most cost-effective approach for supplying the energy poor isolated areas is by use of renewable mini grid options like wind and solar. There is an abundance of primary energy resource across Sub Saharan Africa. Despite all the potentials, there still exists challenges in this sector. The main barriers to the growth of mini-grids in SAA include gaps in the policy and regulatory framework, the lack of proven business models, the lack of market data and linkages, the lack of capacity of key stakeholders, and the lack of access to finance. In Malawi, Government funding and public budgets are inadequate so current rural electrification rates are low, and preference is given to extending the national grid as opposed to decentralized systems. In addition, rural electrification funds are regulated by a statute that in practice, excludes viable renewable off-grid technologies yet it is widely recognised that universal access cannot be achieved through grid extension alone.

3.1.2 Barriers to Mini grid Development in SAA

A Political, Economic, Social and Technological (PEST) framework complimented with Expert interviews was used to identify barriers to mini-grids in Malawi and other developing countries in Sub Saharan Africa. It is worth noting that the Mini-grid industry is growing and fast becoming the most preferred rural electrification option for developing countries.

Political

Stakeholder interviews revealed that there are legislative, regulatory and policy barriers in as far as governing the mini–grid sector is concerned in Malawi and Sub Saharan Africa in general. Stakeholders noted that preference is given to grid extension by the policy holders while as decentralised energy systems are usually not seen as a viable option to meet the energy needs of the people in the rural and isolated communities. In Malawi for example, the installed capacity for the National Grid is currently at 351 Megawatts against a projected demand of 700 Megawatts and yet the Government of Malawi is still implementing grid extension projects through the Malawi Rural Electrification Programme (MAREP). However, through the Malawi Renewable Energy Strategy (MRES), Government of Malawi states that it is setting across a number of deliberate regulatory and policy changes that will facilitate the growth of the mini-grid sector. It further notes the complex processes that smaller projects have to go through and how mini-grid operators have to comply with largely the same regulations as the large grid operators. Another barrier common across the fold is interference from politicians. Stakeholders noted that politicians tend to politicize developments in their areas to gain political mileage over their opponents and sometimes they even instruct community members not to pay for the energy service as long as the government was involved in its set up.

Economic

Capital investment is one of the main barriers in as far as mini-grid development is concerned. Stakeholders noted that it is very difficult for financial institutions and banks to finance energy projects as most of them are not very much willing to invest considering the sustainability risks associated. Another paramount challenge for Malawi in recent years has been the instability of the currency (Malawi Kwacha) as it has continued to lose value and as such the costs of components has kept soaring. At the same time, stakeholders have been calling for removal of import Value Added Tax (VAT) on all solar products which is yet to come to fruition. The VAT represents a barrier in that it contributes to the high cost of renewable energy products like solar panels and solar batteries. In Malawi however, GoM seeks to provide Fiscal Incentives for private mini grid developers by possibly expanding the Rural Electrification Programme to help fund costs of mini grid costs specifically infrastructure.

Social

With the complexity of implementing, managing and operating a mini-grid project, it is very necessary to have a wide range of skills to successfully manage a mini-grid project. At the moment, it is a big challenge to access project managers and entrepreneurs who are fully equipped and knowledgeable to develop the mini grid business sustainably. With the digitization of most modern energy systems, there is need for a well-equipped human resource to be able to manage modern innovations. In Malawi it has been noted that there is generally a shortage of people fully equipped with technical skills to install and manage solar PV projects and this has led to high failure rates of energy projects across the country. The Malawi Energy policy highlights the need to help in capacity building by introducing a solar PV installation Curriculum in technical colleges so that the number of skilled and certified technicians rises.

Technological

Stakeholders generally noted that there is a huge challenge for most Sub Sahara African countries to have access to modern technologies. This coupled with lack of technology developers poses a huge challenge for mini-grids to operate effectively and competitively in comparison to the developed world. It was also noted that it is very costly for new technologies to be brought to Sub Saharan Africa for use and as such Africa is still stuck with the technology that the rest of the world may have done away with. For example in Malawi, the cost of importing latest and efficient solar batteries is very high such that some solar home system owners opt for car batteries to get the energy service they need.

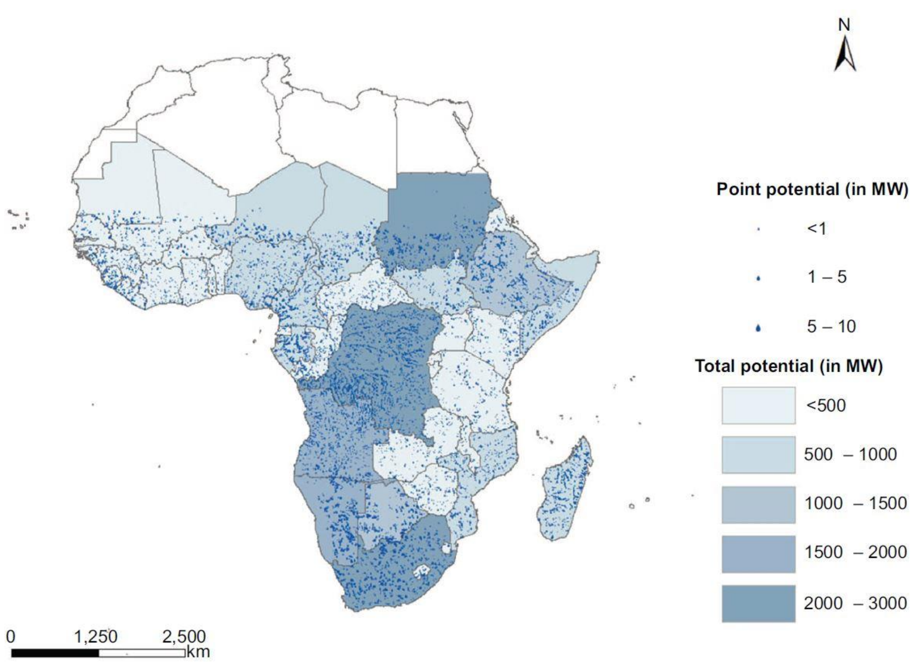
3.1.3 Potential of Mini grids in SAA

The SE4ALL Africa Hub states that improving electricity access for more than 589 Million people living in energy poverty in Africa demands new and innovative solutions. One way of providing electricity access innovatively is the use of renewable mini grids in rural and isolated areas. In cases where the grid is in proximity, the Carbon Trust supports the possibility of integrating mini grids with the national grid in a grid-tied mini grid set up. It is with this dynamism that mini grids as decentralised systems are potentially very attractive in developing countries and are seen as a viable alternative to large scale grid extension.

As shown by the map extracted from a UNDESA report, Sub Saharan Africa has huge potential for mini grid development with most countries having system of capacities between 500 to 3000 Megawatts.

Figure 4: Potential of mini grids SAA

Areas best suited to grid, mini-grid and stand-alone systems, Sub-Saharan Africa



Source: UNDESA 2016

Though most renewable energy mini-grids do not face the risk of interrupted fuel supply or fuel-cost increases, their effective generation capacity may vary according to weather and season. Electricity storage, in batteries, is one way to overcome this variability, particularly for solar and wind systems. Another way is to combine different sources of energy in “hybrid” schemes, commonly solar or wind combined with diesel; hybrid solar-wind and solar-biomass systems can also be found. Hybrid renewable diesel systems are more economic than diesel only.

3.1.4 Mini grid Business models for SAA

According to a resource paper by the SE4ALL Mini grid help desk (year), Mini-grid business models vary and there are different strategies used to make them a success. Some of the strategies include demand management, promotion of productive end use, electricity quality, tariff design, revenue collection and end user finance. It continues to say that there is currently no proven business model for mini-grid development in Africa.

The World Bank and UNDP describe business models based on ownership where as other organizations also describe business models based on subsidies and technologies used in generation. However, most Sub Sahara African countries describe their business models based on ownership. It is regarded as a decisive element on what to base the business model of the mini grid on.

Community-based model

Community based mini-grids are usually common in cases where the prospective community is very distant to the national grid or they do not possess much economic attraction for private operators. This leads to the community seeking grants from prospective funders to help them build, own and operate a mini-grid system to meet their energy needs. Community owned mini-grids are very common in developing countries since interest from the private sector or utilities is generally low. It is a very common way of promoting community empowerment as there are high involvement levels for community members at all levels (Inception, Implementation and management and monitoring). However, the model is not easy to sustain in a set up where illiteracy levels are high. It gives high chances of technical failures as the people may not be too conversant with the technicalities of the systems. Therefore, a community-based model requires substantial technical assistance with regard to the system design and feasibility studies as well as training in operation and maintenance and assistance in management support during the lifetime of the project.

Private sector-based model

In this ownership model, an independent Power Producer (IPP) builds, owns and operates the system as a utility company supplying power to a community. This business model is structured to make economic sense and the tariff structure is designed to sustain the business while providing the energy service to the community. It is estimated that there are around 700 electricity generation plants in developing countries that have been financed, constructed, and are operated by independent power producers. Despite the high possibility of government involvement and interest in supporting IPPs with public financial support, IIPs are better placed to guard against political interference. An example of this ownership model is Community Energy Malawi’s Sitolo Mini-Grid which is funded by UNDP with support from the Government of Malawi. Similarly, Bondo Micro-Hydro scheme in Mchinji follows this ownership model.

The utility-based model

This model is very common when state owned utility companies run mini-grid operations in isolated areas where grid extension would not be achieved. In Sub Saharan Africa, most state owned utility companies operate diesel generated mini grid systems. In Malawi for example, state owned Electricity Generation Company (EGENCO) runs two mini grid systems in Likoma Island and Chizumulu Island. The advantage for this model is that the people enjoy a national tariff system despite the fact that the cost of energy is relatively higher when the cost of diesel and Operation and maintenance of diesel generators is considered. The demerit of this model however is that local involvement is usually very minimal as the utility company comes with their own technicians whereby curtailing skills transfer. Also, State owned utility companies are prone to political interference which has a large bearing on the sustainability of projects.

Hybrid business model

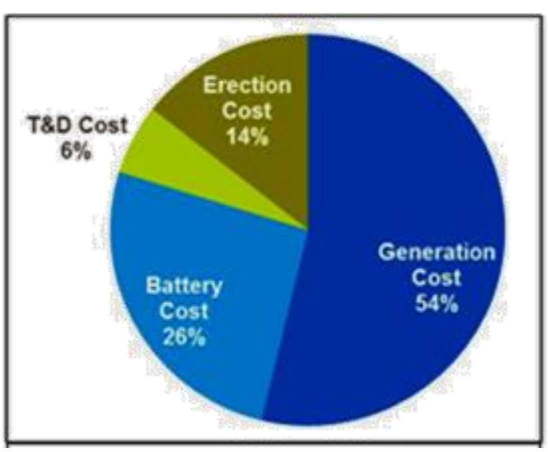
This model is a combination of different business models so as to benefit from the advantages of each model. It seeks to minimize on the challenges each model has. For example, a utility company may construct and own all the necessary mini-grid infrastructure and let a community energy committee operate the mini-grid. By doing so ensuring that there is high community involvement and ensuring skills transfer. Also, Malawi has recently unbundled the Electricity Supply Cooperation of Malawi (ESCOM) into two separate generation and distribution entities, EGENCO and ESCOM respectively. For the case of Likoma and Chizumulu Islands, the two entities work together to ensure reliable supply of electricity in the two Islands.

3.2 Common issues with storage across mini grids in SSA

High Initial CAPEX:

Storage batteries are a central part of mini-grids functionality, because they can store energy when there are good wind speeds or when the sun is shining, and provide it across the mini-grid when there isn't enough sunlight and or Wind. Unfortunately, they also represent the single most significant Cost in the CAPEX usually going as high as 26% of the mini grid costs in the Developing Countries. For the Sitolo Mini-Grid which community energy Malawi is constructing in Mchinji, battery costs have taken up to 40% of the initial costs.

Figure 5: Typical Cost Breakdown for Solar Mini grids in SAA

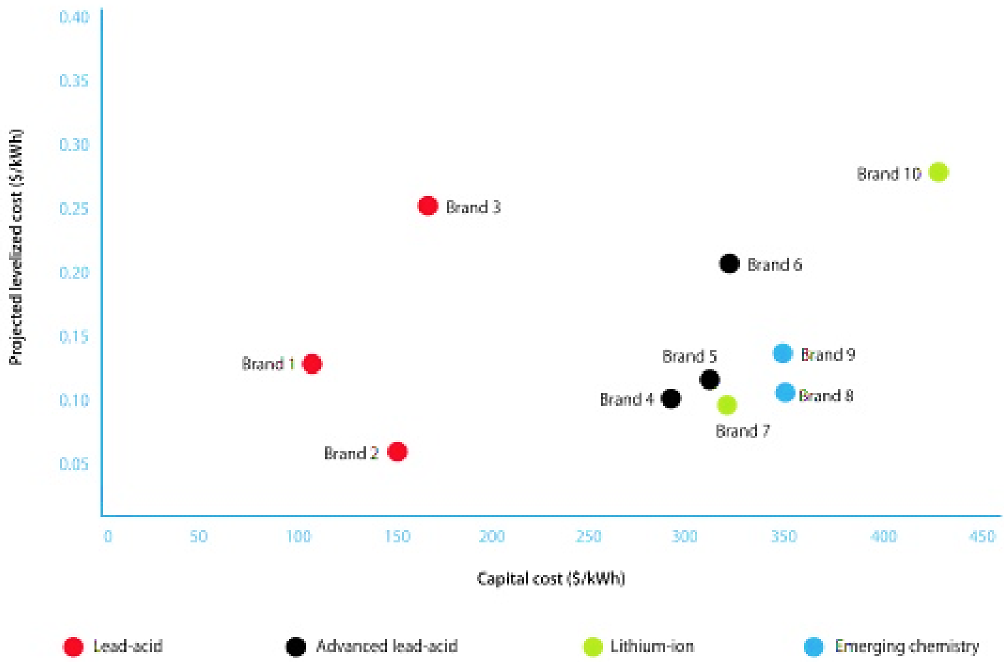


There are several storage batteries used across mini grids in Africa's developing countries. Lead-acid batteries often have advertised lifespans as long as 10 years. In reality, however, they tend to underperform and/or fail much sooner. If they are discharged below 50%, remain in an extended state of partial charge, or are exposed to the high ambient temperatures common through much of Sub Saharan Africa where Temperatures average around 64 degrees year round, their lifespans and performance diminish. The capital cost of typical lead-acid batteries used in SSA, at the lower-end of the cost spectrum of lead-acid batteries available around the world, is $150/kWh, with a levelized cost (based on advertised lifespans) of about 15 cents/kWh. However, because actual lifespans of the batteries are much shorter than advertised, the levelized cost can be two to four times higher than anticipated. By comparison, "advanced" lead-acid batteries—still new on the global market, and currently too expensive for the typical mini-grid application demonstrate much stronger performance and longevity. Lead-acid batteries, if not handled properly, can also lead to environmental contamination and adverse health effects.

While the underlying chemistry required to improve conventional lead-acid batteries, to achieve the enhanced performance, is not complex, there has historically been limited market demand for it. The vast majority of lead-acid batteries are used in automobiles, for ignition. Hence, they are optimized for high power in a short burst, rather than high energy (i.e. relatively low power over a long period of time).

The other often mentioned battery technology for mini-grids is lithium-ion, used heavily in consumer electronics and more recently, in electric vehicles (EV) especially in South Africa. From the point-of-view of technical performance, lithium-ion batteries are a more ideal choice for mini-grids. Below is a summary of findings from mini grid battery usage survey of the various mini-grid batteries in the SSA market.

Figure 4: Common Battery Technologies for mini grids in SAA



3.3 Opportunities for Hydrogen with Mini-Grids in Malawi and Sub-Sahara Africa

3.3.1 Expert Opinions

There exists a huge potential for use of hydrogen energy applications in mini grids in SSA some of which have been explained below.

Primary resource Availability: Experts noted that Sub-Sahara Africa has got an abundance of renewable energy resource ranging from Solar, Hydro, wind and geothermal. Electricity from renewable energy can be used to split water into hydrogen and oxygen through electrolysis.

Mini grids preferred to grid extension: Mini grids are appearing to be a very practical solution to rural electrification as compared to Grid Extension which is capital intensive. With the growth of the mini grid sector, more storage technologies are being explored especially for solar and wind powered mini-grids which are seasonal. Storage technologies like hydrogen can be used to store energy for use when the mini grid is not producing enough to supply the users. The International Energy Agency (IEA) estimates that 140 million people in Africa will gain access to electricity through mini-grids, yet unlike off-grid solutions, the promotion of mini-grids appears to lag mainly due to high CAPEX. IEA further states that mini grids can provide electricity in rural and remote areas, where populations are dispersed and per capita electricity consumption is low, at much lower cost than central grid extension. They require smaller capital investment than grid expansion, making it easier to secure finance.

Emerging and existing favorable energy investment policies: According to the African Progress Panel, many African countries have set ambitious targets for increasing energy access or for advancing other elements of the energy transition. Governments are amending electricity laws and improving regulatory frameworks, clearing a path for investors. Independent power producers are increasing the involvement of the private sector and showing how to scale up renewable power generation capacity.

Mini grid adoption rates surging: Mini-grid systems are becoming a major investment area for most SAA countries. Africa is rapidly adopting and adapting them, particularly to meet the needs of areas that are remote or neglected by the grid. Off-grid and mini-grid power by renewable sources of energy has a crucial role to play in meeting the three great energy challenges that African governments face: providing all their citizens with access to secure and affordable energy services; building the energy infrastructure needed to drive inclusive growth and create jobs; and limiting carbon emissions.

Demand for Modern Energy Technologies like Hydrogen: The average African (excluding South Africa) uses just 160kWh/year. Africa is geared to lead the world in building sustainable energy systems that couple efficiency and equity. Demand for modern energy is set to surge in Africa, fueled by economic growth, demographic change and urbanization. As the costs of renewable energy sources fall, Africa will leapfrog into a new era of power generation.

3.4 How Hydrogen could support a Mini Grid in Malawi

3.4.1 Likoma Island Diesel Mini Grid System, Malawi. (Case Information Provided by Department of Energy-Malawi)

Likoma Island is the larger of two inhabited islands in Lake Malawi, in East Africa, the smaller being the nearby Chizumulu, that together make up the Likoma District. Although both islands lie just a few kilometres from Mozambique, they are both exclaves of Malawi surrounded by Mozambican territorial waters. Likoma is densely populated, with about 14,500 inhabitants dispersed in a dozen settlements.

Likoma Town and the town of Mbamba host busy markets. As Likoma is a relevant tourist destination, there are a few hotels, lodges and hostels. Access to Likoma is currently by boat or charter aircraft. The island's main mode of transportation is provided by the MV Ilala/MV Chilembwe steamer boat that circumnavigates Lake Malawi, stopping over at all the main settlements on the coast and the islands. In addition, the MV Chambo links the island with the town of Nkhatabay Bay on the west side of the lake once a week.

Energy supply at Likoma Island

The state-owned Electricity Supply Corporation (ESCOM) uses three diesel generators to power Likoma Island. Two 3-phase 400 V 250 kVA gensets run synchronously with a third on standby. The mini-grid was established under the Malawi Rural Electrification Programme (MAREP) which is a socio-economic programme of the Malawi Government. The consumers pay for the electricity at the Post Office, where they can purchase prepaid units.

Source: en.wikipedia.org; malawitourism.org, turnkey-visit.com

The generators are switched on only from 7 a.m. to 12:30 pm and from 2pm to 10 pm during week days and 7 am to 12:30 pm and 2 pm to 10:30 pm during weekends. Electricity supply may not be available for successive number of days when logistical challenges of bringing the diesel (by boat) become severe. These blackouts affect the functioning of health services, telecommunication, clean water supply and the island's tourism and accommodation providers. The hospital and those business and homes that can afford it use their own generators but are prone to the same logistical fuel supply problem. An issue posed is the high cost of diesel. With sales of about USD 7,000 per month, this means that ESCOM is operating Likoma at a loss, selling at only 11% of the cost. To keep costs manageable, power is supplied for only 14 hours a day on the island.

Figure 5: One of the 3 Diesel Generators in Likoma

Source: A. Nkoloma (Global Group); C. Zalangera (Mzuzu University*). Photo:* A. Nkoloma (presentation)

Some social amenities and services, including surgical procedures at the hospital, suffer from the power shortage. Likoma Island could easily be transformed into a high tourist destination if electricity would be available 24 hours a day. There is one main hospital, St Peter's (which needs energy for medical equipment, lighting, and catering services for patients), one boarding secondary school (Likoma), one community secondary school (Chipyela), nine primary schools, and a community library. The main energy needs in education services are for lighting, refrigerators, and computers for teaching. Likoma Island also has a water treatment plant and two telecommunication towers using electricity from the diesel generators.

Renewable energy as a cheaper, environmentally friendly alternative to power the mini-grid

ESCOM acknowledges that the current system is expensive (augmented by the high cost of transporting the diesel) and not sustainable and is considering other options, such as solar and wind. In 2014, a techno-economic feasibility study was carried out (doctoral thesis research, see text box) on solar and windgenerated electricity. Supplying electricity for 24-hours with diesel generators would raise the operation and lifecycle costs by 44% compared to the costs of 14-hours supply schedule. The study shows that the power provided on a 24-hour basis by a solar PV-diesel-battery (with or without wind turbine) would be cheaper than the 14-hour electricity supplied today.

Possible Hydrogen Application in Likoma/Chizumulu Government Mini-Grid

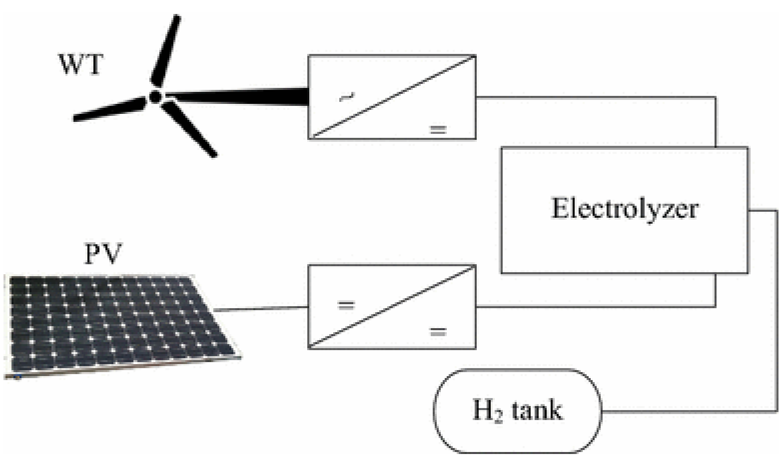
As stated earlier, Likoma and Chizumulu Island Mini grids use diesel generators to supply electricity to households, business centres and institutions. The power runs for 14 hours of the day and it is switched off at night to cut costs. In a techno-economic feasibility study for Likoma and Chizumulu Islands, C. Zalengera notes that it is feasible for the two Islands to run on photovoltaic and wind hybrid. The cost of producing photovoltaic and wind-based electricity could be between USD 0.44 and USD 0.56 per kWh, depending on the interest on capital finance, which is considerably less compared to USD 0.89 per kWh for diesel-fired electricity. Thus, PV-wind-diesel hybrid systems could reduce the subsidy spent by the government on grid electricity on Likoma Island from USD 0.80 per kWh by about half. Currently, the Diesel Generators use about 32,000 litres of fuel a month. This implies, at a cost of USD 1.9 per litre of diesel, a monthly fuel bill of about USD 61,180. The power generation cost is estimated to be about USD 0.89/kWh, but ESCOM sells the power at an average of USD 0.085 per kWh, according to its national tariff system.

Overview

As a way of supporting the proposed solar-wind hybrid system which are both time specific, Hydrogen energy can be used to store electricity, producing it by electrolysis using the extra power produced by diesel/ wind/ solar PV electricity, and thereafter storing it through fuel cell technology. For transport applications on the Island, Hydrogen can be used for fueling District Council vehicles which currently operate on petrol/diesel. At the moment, Likoma Island has got 13 vehicles operating (all on fossil fuel). Electrical Vehicles and hybrid vehicles can all benefit from the produced hydrogen to cushion the effects of erratic and costly fuel supply on the two islands.

Likoma and Chizumulu Islands have got access to vast amounts of clean water which can be used for hydrogen production. For production, both Islands would have an electrolyser device that would enable gaseous hydrogen production that can be stored in a hydrogen tank and then it can be transferred to the end use points and other relevant supply chain options.

Figure 6: Possible Schematic Diagram of a solar-wind-hydrogen hybrid system



Stakeholder Opinions

Officials from the Department of Energy Affairs (DoEA) and Electricity Generation Company (EGENCO) support the idea of using hybrid systems to ensure a cleaner and more efficient supply of electricity in the 2 islands. At the moment, EGENCO incurs very high operation costs because of fuel transportation costs.

Nevertheless, the cost of electricity for the island is still uniform with the rest of the country which means that the mini-grid operates at a loss. DoE opines that it will be of paramount importance for the Islands to have reliable electricity supply systems because the Diesel Generators being used at the moment are not fuel efficient and they don't offer reliable supply due to high breakdown rates. A feasible way to enhance the reliability of the mini-grid would therefore be efficient storage systems that can be used when need arises. DoE supports the exploration of Hydrogen Fuel Cells as a way of ensuring sufficient electricity supply thereby achieving SE4ALL agenda. On their side, EGENCO says they are open to utilizing cleaner systems for power generation in the two islands stating that this would help them cut on high operation costs they incur with diesel generators. EGENCO was quick to state the need to build the capacity of engineers in Hydrogen Energy Management considering that the technology will be the first of its kind in Malawi.

3.1.2 Sitolo Mini-Grid Project

Community Energy Malawi (CEM) is installing a **solar mini-grid** at **Sitolo Village**, which is situated 18 km from Mchinji Boma (and 12 km from the national grid), to generate and distribute power. Sitolo village is not included in the national Malawi Rural Electrification Programme (MAREP). The village covers 3 Village Group Headmen (Sitolo, Kuluzeze, and Faifi) under Traditional Authority Mlonyeni.

Sitolo village has 300 households and 1 primary school and 1 clinic. The 80-kW solar PV facility will initially connect 150 households, grocery shops, a salon and barber shops, one bar, a maize mill, the local school and health clinic as well as six street lights. In future, the system coverage could include more households and other productive uses (such as milk cooling and metal workshops). Also, CEM Trading may start a rolling programme of selling solar pico-products and battery charging in an '**energy hub/kiosk'.**

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

The Project will involve the installation of an 80-kW solar mini grid complete with a 3-km radius transmission (11 kV) and distribution (400/230 kV) system targeting 150 households. This project is supported by UNDP working in close collaboration with Department of Energy Affairs with CEM offering on the ground implementation supervision of the deliverables.

The project engineering design is done by Mzuzu University (Energy Department). A first modelling, based on the estimated peak demand of 28 kW and energy production of 300 kWh per day, an 80-kW system may not be able to meet all of the peak load (84%), even if the maize mill is not included. The system would cost USD 435,000 including equipment (with 164 batteries of 3300 Ah), accessories and installation, of which half would be 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 of USD 435,000, 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) suggests a higher household demand (by including refrigeration). The village maize mill would represent the largest single load on the system. In the village expectations are high and local mobilization for the mill is well-established with the building for the business under construction. Without load management, it would take system capacity requirements beyond the 80-kW threshold. 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 18km on foot to similar facilities. Currently, the load demand is being studied, in particular how the mill can be accurately included.

Sitolo village	Demand kWh/day	Total load kW
New demand assessment		
Households (100)	454.20	26.65
Shops, bar (3)	25.95	2.58
School, church	10.55	2.31
Clinic	4.41	0.29
Maize mill	181.05	15.16
Public lighting	3.60	0.30
Total	679.76	47.29
First demand assessment		
With maize mill	190.77	16.94
No maize mill	255.81	15.14

Source: CEM-commissioned reports

80KW Sitolo Solar Mini grid

Source: Community Energy Malawi

Possible Hydrogen Application at Sitolo Mini-Grid

It is worth noting that the mini grid system at Sitolo will operate with a single power source without backup or a hybrid arrangement. Since solar energy is not dispatchable and largely depends on the availability of the solar resource at a particular time, the system might not supply the required electricity to all the users at a particular time. Therefore, a combination of two or more renewable energy technologies would be more competitive in as far as electricity supply is concerned. In this case, using the solar PV electricity to aid in operating an electrolyser to generate hydrogen gas to be stored for use at peak demand would be an ideal solution to manage scenarios where the mini grid is not generating more energy for use especially at night hours or when high energy consumption loads are in operation.

Sitolo Miini-Grid will operate on 100% renewable energy which means that energy storage is a prime component of the system to ensure efficient and sufficient energy suppy even when the solar resource is low. Just like in Eday, Kirkwall and Sharpinsay where the extra energy resource is used for runnng electrolysers to produce hydrogen for storage, a similar arrangement would work at Sitolo. Water is available in the area through the Bua River, one of the big rivers in Malawi and has its source in Sitolo, which can then be treated for use at the Electrolysers. The produced hydrogen can then be compressed in storage units and then transported to the energy generation site for use in sitolo.

Curent Storage system Overview

The Mini Grid system at Sitolo will operate with a battery storage system of 940 KWH Lead Carbon battery solution. The storage system has costed 162,416.88 USD, representing approximately 40% of the total CAPEX. Battery replacement has been projected to be done after 8 years of operation. This entails that there is need for appropriate energy managememt considering that batteries are a significant element in cost of electricity over he systems lifetime.

Sitolo Mini-grid Storage system

Source: Community Energy Malawi

4 Barriers to Hydrogen Energy Use in Malawi and other Sub Saharan Countries

To establish the existing barriers to implementation and use of hydrogen systems in Malawi and other Sub Saharan Countries, Community Energy Malawi has consolidated expert opinions from policy holders, regulators, the academia and project funders from Malawi, Tanzania, Zimbabwe, Zambia and Nigeria. The list of experts is attached in annex 1 and the questionnaire which was used has also been attached in annex 2.

For Sub Saharan countries to become a successful Hydrogen Energy economy, the key limitations that were highlighted are as follows; Technology costs, Lack of local Expertise to manage systems, Technical issues, Safety and Environmental issues and Legislative Policy.

4.1 Technology Cost

The Energy experts generally agree that the costs of bringing the technology might not be cheap considering that is relatively new even in the developed world. However, the experts note that hydrogen systems can greatly reduce running cost for community mini grids operating on diesel, whose Operation and Maintenance costs are deemed very high. All experts pointed out that the initial CAPEX for hydrogen systems may be too high to attract funding opportunities. For Malawi to implement a hydrogen energy technology, electrolysers and other components would have to be imported from the developed world, in this case ITM Power being a known supplier of such equipment. Further to this, repairs would also have to be imported considering that Malawi does not manufacture such equipment.

4.2 Capacity to manage Hydrogen Systems

The experts noted that there is a huge knowledge gap on Hydrogen applications at the moment. The members of the academia further highlighted that despite institutions of higher learning having comprehensive curricula on Renewable Energy Technologies, Hydrogen Energy Technology is not embedded in the same for large scale projects. This has a huge bearing on the capacity of prospective local project managers if such project were to be implemented. As a way of overcoming this barrier, the experts highlighted that capacity building initiatives would help equip people with the required skill sets to make sure the technology thrives in Malawi and other Sub Saharan Countries.

4.3 Technical/Design Challenges

Stakeholders also reported that commissioning of a Hydrogen system would require a lot of custom modelling and design which poses a massive technical challenge. Even though hydrogen has been used for several years for other parts of the world, the technology is still a new phenomenon in Sub Saharan Africa region. As such, it was generally proposed that pilot projects have to be implemented in areas where there are favorable conditions. The pilot projects will enhance learning and information sharing in anticipation for larger and complex projects. For instance, hydrogen (Electrical Vehicles) projects for transport in Malawian cities was specifically referred to as a starting point to further raise awareness of the technology and reduce dependence on fossil fuels.

4.4 Safety Concerns

Experts note that hydrogen is an element with a low ignition point. This raises some safety concerns in terms of the high flammability of the hydrogen in fuel cells, transport vehicles and storage areas. Experts called for extra caution in implementing such a project to ensure that all necessary safety measures are taken into consideration. Also, the engineers will need to ensure their designs and are safe and reliable.

4.5 Legal and Legislative

At the moment, there are no specific laws in place that would govern the hydrogen energy industry in Malawi. Even legislation of LPG is complex in Malawi resulting in low penetration of the technology. This is a challenge in that the process to get generation licenses would be a bit complex. However, Malawi Energy Regulatory Authority (MERA), a statutory body mandated to regulate the energy industry notes that new and innovative projects are welcome. MERA further states that with the help of other stakeholders like the Malawi Bureau of Standards (MBS) and the academia, they always move with time and that in such cases, new standards are introduced to govern new innovations and technologies.

5 Recommendations

The project has noted the following recommendations going forward;

Conduct pilot projects. This aids in generating knowledge and learning in the local context. Pilot projects will aid in identification of essential modelling parameters for hydrogen and mini-grid project in general. At the same time, pilot projects will help in breaking other barriers especially putting in place legal and regulatory framework to govern hydrogen energy development in Malawi and other sub-Saharan Africa countries. To maximize learning from the pilot projects, effective monitoring and evaluation tools have to be employed to form a basis for scaling up projects and future projects in general. The Malawi Commision for Science and Technology, the Malawi University of Science and Technology, the Mzuzu University's Institute of Energy Systems or Testing Centre for Renewable Energy Technologies (TCRET) are among possible partners in Malawi. The same can be the case in other countries where the academia can be more adept to initiate such pilots.

Need for capacity building. There is need to provide a platform for people in Malawi and other Sub-Saharan countries to build their capacity in operation, maintenance and management of Hydrogen Energy systems. Such platforms as conferences and data sharing can enhance the development of hydrogen energy technologies in Malawi and other developing countries.

Need to build up knowledge about Hydrogen energy. There is generally lack of knowledge of Hydrogen as an energy source for both electrification and transport. There is need therefore to champion awareness messages as well as practical examples of that showcase Hydrogen energy as a viable option for storage and transport. These initiatives can be designed to portray hydrogen energy as a technology that can help reduce some of the energy challenges facing the developing countries across Sub-Saharan Africa.

Information Access to Policy Holders and Funders. There is need to consolidate lessons from different successful Hydrogen Energy projects that can be shared with different policy holders and project funders. Such information as CAPEX and other Operation and Maintenance of already existing projects are essential for prospective projects in Malawi and other Sub-Saharan countries.

6 Conclusion

The idea of using hydrogen as a storage technology is an ambitious and altruistic notion. It is not, however, without its challenges ranging anywhere from the current technology and cost, to infrastructure and safety. With the increase in use and adoption of mini grids coupled with the soaring costs of batteries across developing countries of SSA, there exists a huge potential for Hydrogen Energy technology to be used as an alternative storage options for mini grid systems across Sub Saharan Countries. .

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Annexes

Annex 1: List of experts interviewed

Joseph Kalowekamo, Department of Energy Affairs, Malawi

Said Banda, Department of Energy Affairs Malawi

Emmanuel Mjimapemba, Programme Manager, UNDP, Malawi

Wilfred Kasakula, Malawi Energy Regulatory Authority

Dr. Collen Zalengera, Mzuzu University Energy Studies Department. Malawi

Mrs. Joyce Chivunga Jere, Malawi University of Science and Technology, Malawi

Ms. Likonge Makai Mulenga, Copperbelt University, Zambia

Mr. Ifeanyi Orajaka, CEO, Green Village Projects, Nigeria

Mr. Reginald Mapfumo, HIVOS, Southern Africa Hub, Zimbabwe

Ms. Annie Wachera Wambungu, Strathmore University, Kenya

Annex 2: Guiding Questions during expert interviews

PITCHES (**Powering Isolated Territories with Hydrogen Energy Systems**) is an EU funded project which Community Energy Scotland (CES), Community Energy Malawi (CEM) and partners are working on. Through PITCHES we wish to address the business opportunity provided by the significant untapped potential of renewable energy in isolated territories in countries throughout the world. In such regions there are barriers to exploiting the full renewable energy potential, as electricity grids are often weak (lacking capacity to transmit or export the potential energy) or non-existent, so that communities cannot use the local resources and instead rely on expensive imported fuels. The intermittent generation of most renewable resources also means that electricity storage is required for local communities to use all of the potential energy.

There is potential for the application of hydrogen (and other energy storage technologies) to secure the following benefits for isolated energy systems:

- Reducing reliance on imported fuels through integration of renewables
- Reducing energy costs
- Creating additional revenue
- Reducing carbon emissions
- Stabilising the grid to ensure supply

The purpose of this questionnaire is to obtain your views on hydrogen and energy storage and if they could be used to provide or improve access to local renewable energy for isolated territories in your country. The objectives are to:

1. Gain an understanding of the potential for renewable energy in your region/country
2. Identify the main barriers to using renewable energy in isolated territories and the role of energy storage in realising that potential
3. Understand current access to electricity in isolated territories and utilisation of micro-grids, and plans for extending access to electricity
4. Assessment of the potential market for Hydrogen, understanding the barriers and proposing solutions to the barriers

Questionnaire

CES and CEM are sending this questionnaire to contacts all over the world to get local knowledge and opinions from different countries on micro-grids, energy storage and hydrogen. Please answer this questionnaire with your opinions either on a country or geographical region with isolated territories with which you are familiar.

1. Name
2. Occupation
3. Which region or country are you providing information/opinions for in this questionnaire?

4. Describe the availability of access to electricity in the region / country.
5. Are micro-grids being used to provide access to electricity in your region / country?
6. Are there plans to increase the use of micro-grids in your region / country?
7. What are the main barriers to using renewable energy in your country / region?
8. What is most of the electricity demand used for in isolated territories in your region / country?
   a. Commercial
   b. Domestic
9. What do people most need energy for in isolated territories in your region / country? (Please rate 1st, 2nd, 3rd with 1st having the highest energy demand)
   a. Transport
   b. Electricity
   c. Heat (includes cooking)
   d. Other (Please state)……………………………………………
10. Which of the following types of energy storage technologies are being used in your country for energy storage for micro-grids
    a. Battery
    b. Hydrogen
    c. Flywheel
    d. Pump storage
11. Are you aware of existing applications and use of Hydrogen for energy storage in your country / region?
12. Please estimate the number of micro-grids in your country and their size?
13. Are there plans for the development of medium-sized micro-grids in your country? Please give details
14. What are the barriers to developing micro-grids in your country?
15. Where does most of the electricity supply come from in your country (e.g. import or own generation)?
16. The production of Hydrogen requires access to water. Please comment on the availability of water in isolated territories in your area to produce Hydrogen.
17. Are there any regulatory or practical barriers to implementing Hydrogen in your country?
18. Are you aware of any research, statistics or reports you can point us to for further information on micro-grids, renewables or hydrogen in your area?