Community energy in Malawi

An annotated bibliography

CESET
Community Energy and the Sustainable Energy Transition in Ethiopia, Malawi and Mozambique

An annotated bibliography on community energy in Malawi

This annotated bibliography is one of a three-part series produced by the CESET team. The annotated bibliographies provide an opportunity to:

1) Survey the body of published research in the area of community energy in Malawi, Ethiopia and Mozambique;
2) Review key insights and considerations already well documented in the literature as of July 2020;
3) Explore areas overlooked in current debates to date and that may help to identify critical gaps.

The methodology employed consisted of literature searches in databases with the terms' community energy' and 'energy policy' paired with each country. Those references were then reviewed and organized according to a reading guide. Please not that these annotated bibliographies take stoke of the literature available on each country as of July 2020. These are meant to be living documents that will be regularly uptaded by the CESET team as more work on the topic gets published and as the project evolves.

If you are aware relevant work and references missing from the bibliographies, please feel free to contact us: ceset@sheffield.ac.uk

This annotated bibliography focuses on Malawi.

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Theme list

1. Malawi overview

The Republic of Malawi is located in South-east Africa. It has a total area of 118 484 km2 and a population of about 15.6 million inhabitants, with an annual growth rate of 2.8% (NSO, 2009). It shares borders with Zambia, Tanzania, and Mozambique. Malawi's population is expected to double by 2050, from 15.7 million in 2010 to 36.6 million in 2050 (Rivard and Reay, 2012). Malawi is one of the least developed countries in the world, ranking 168 out of 174 countries. About 50% of Malawians earn less than US$2 per person per day. The deforestation rate in Malawi is 2.8% per year and is the highest in Africa. Agriculture employs 84% of the entire country's labor force. The major export crops are tobacco, tea, sugarcane, and cotton. The agricultural sector is composed mainly of smallholders who rely on rainfall for irrigation and hence are vulnerable to the effect of climate change (Murray et al., 2016). Malawi's surface water resources come from Lake Malawi and the Shire River. Malawi's small rivers are suffering the effects of climate change, becoming dry during the dry season (see Kaunda, 2013, for a detailed description of the country's climate and water resources).

2. The energy sector in Malawi

General overview

Various studies have assessed the energy situation in Malawi (for a comprehensive overview of Malawi's renewable and non-renewable energy mix, see Taulo et al., 2015). These studies all highlight the country's reliance on firewood. According to Barry et al. (2011), over 95% of Malawi's primary energy supply and 90% of total energy comes from biomass, mainly in the form of firewood and charcoal for cooking. According to Kaunda (2013), the remaining energy comes from petroleum (6%), electricity (3%) and coal (2%). About 90% of Malawi's urban population relies on firewood as the primary fuel. Firewood provides cooking energy to 43% of urban and 96% of rural households (Kaunda, 2013, p. 7). Households' demand represents 80% of the country's total energy demand (To et al., 2017; Kaunda, 2013). Electricity offers cooking energy for only 2% of Malawi's households, mostly used in urban environments (38% of the urban households) (Kaunda, 2013). Electricity shortages also pose critical challenges for the population's health, in addition to those of air pollution from burning charcoal and firewood. For instance, Suhlrie et al. (2018) showed that healthcare facilities could not function without electricity. They underscored the lack of functional lighting in facilities offering child delivery and night time care.

Several studies have attempted to map out Malawi's energy generation capacity for different energy technologies (for a review, see Zalengera et al., 2014). The current installed generation capacity is 351 MW (Mhango, 2015), which mainly consists of hydropower plants along the Shire River (98%) in the south of the country (To et al., 2017; Zalengera et al., 2014). Hydropower plants are operated by the state-owned Electricity Supply Corporation of Malawi (ESCOM). Malawi's grid infrastructure suffers maintenance issues with an estimated loss of 18% to 22% of electricity generated as a result of technical failures on the transmission and distribution networks (To et al., 2017). Deforestation, population growth, climate change impacts, and recent discoveries in coal power generation pose additional energy challenges in the country (Rivard and Reay, 2012). Taulo et al. (2015) identified the following energy challenges in Malawi:

- rapidly rising electricity demand and insufficient power generation capacity;
- high oil import bills;
- lack of investment in new power generation units;
- raising demand due to urbanization;
- high transmission and distribution costs and transmission losses;
- poor power quality and reliability;

- heavily subsidized pricing;
- insufficient focus on alternative energy sources; and
- lack of access to modern electricity for a large segment of the population.

Malawi has the potential to exploit several renewable energy resources, including hydro, solar, and wind. However, for the most part, renewables remain underexploited (Taulo, 2007, 2015) due to several challenges. Zalengera et al. (2014) highlight the following issues hindering the development of the renewable energy sector:

- financing remains an issue for both large and small scale energy projects because of their dependency on donors grants and international development partners, and the use of funds attached to stringent conditions;
- human resources and training for the development, implementation, operation, and maintenance are lacking for both large scale energy systems and smaller-scale solar home systems. Malawi relies on maintenance expertise and skills sourced from other countries;
- limited coordination and competing priorities across government departments which prevent adequate regulation and governance of the energy sector.

The next sections review the literature dealing with specific energy sources (renewable and non-renewable) and their role in Malawi's energy mix.

Geothermal

The country's location in the East African Rift System (EARS) means that it has potential reserves of geothermal energy (Dulanya et al., 2010; Zalengera et al., 2014). There are approximately 55 geothermal spots in Malawi, but three major ones identified for detailed investigation are Chiweta, Mwankeja, and Nkhotakota (Taulo et al., 2015). Dulanya et al. (2010) examined hot springs with potential heat-generating capabilities, calling for further exploration of their exploitation. To date, geothermal energy in Malawi has not been exploited at a large scale, despite its local significance. For instance, hot springs are used by nearby villages to bathe and wash clothes.

Fossil fuels

Taulo et al. (2015) provided an overview of fossil fuel production and consumption in Malawi. The country imports 97% of its petroleum-based products and is hence very vulnerable to market fluctuations (see also Rivard and Reay, 2012) – the remaining 3% are sourced from locally produced ethanol fuel. Domestic consumption is driven by the transport sector (representing around 90% of total liquid fuel consumption). Consumption will to grow with road infrastructure development and vehicles consumption, with transport and products' transit through Tanzania (Dar Corridor) and Mozambique (Nacala and Beira Corridors). Rising oil prices in the past years (at least until COVID-19) have contributed to further the country's dependency on its external partners and posed significant budgetary challenges.

Coal is the country's most abundant fossil fuel resource (coal mining in Malawi started in 1985 in the Rumphi district). Coal deposits have been found in 15 dispersed locations in the country, the most significant being at Ngana in the north, where total proven reserves have been estimated at 16 million tones but could reach as high as 70 million tones. According to the same study, coal consumption is driven by industrial demand, particularly for heat processing in the tobacco industry and textile and sugar production.

Wind

Several studies investigated the potential of wind energy resources in Malawi, but data remains insufficient for comprehensive planning. In their review of Malawi's energy landscape, Taulo et al. (2015) stress that wind has historically been used at a small scale to supply water for livestock and irrigation in rural areas. They argued that wind can be used at a small scale for water pumping, in combination with adequate storage facilities (to mitigate against intermittent supply). The authors also highlighted that existing evidence from Malawi's Meteorological Department tends to indicate that low wind speeds mean that it is unlikely that wind resources can "*can contribute significantly to a firm power generation*" (p. 28). However, the Malawi Renewable Energy Acceleration Programme sought to generate additional evidence on the potential of wind energy development, as discussed by Zalengera et al. (2014):

> "*Major developments in the Malawi's wind energy is the work of the Malawi Renewable Energy Acceleration Programme (MREAP) which identified two sites for potential wind farms in Mzimba and Rumphi districts by use of WRF Mesoscale Modelling and constraints mapping [26]; installation of wind masts for detailed wind speed measurements at the identified sites was planned for April 2013. The government continued to install small wind turbines to a capacity of 10 kW as part of hybrid systems with solar PV for rural electrification projects*."

Existing research has paid more attention to other forms of renewable energy, including solar and hydro. The suitability of wind for small scale applications (including water pumping and irrigation) deserves further attention, as illustrated by the MREAP deployment of wind technologies as part of hybrid systems with solar PV.

Solar

Several papers have explored the potential of solar energy technologies to address energy access gaps in Malawi, particularly in rural areas. In 2012, around 7000 PV systems were installed in Malawi, most of them in a state of disrepair or not fully functional (see Dauenhauer et al., 2020). In 2011, the government of Malawi launched the Malawi Renewable Energy Acceleration Programme (MREAP) to develop an integrated approach to rural electrification. MREAP supported off-grid technology deployment and community involvement in renewable energy management and operation (see also section 5).

Beyond this specific program, existing studies cover different types of solar technologies, from LED lanterns to water purifying systems, microgrid and solar home systems.

Adkins et al. (2010) looked at the introduction of solar LED lanterns in rural areas. The study focuses on a market-led program mobilizing local economic actors such as vendors and cooperatives to sell lamps to village households without subsidy. It explored issues of enterprise development, community interactions and also includes a survey of LED users, assessing savings compared to kerosene use, and making a case for market-led LED strategies to be scaled up in off-grid communities across Malawi. The study demonstrated the gaps and synergies between different systems of off-grid energy provision (serving different usages). It explores how community energy systems emerge within broader ecosystems of off-grid energy supply and the local economies, and how they can leverage the existing market provision of spare parts and mobilize skilled labor for maintenance.

Looking at developments in solar, wind, and hydro technologies in the Dezdra District, Eales et al. (2017) found that pico-solar products have the highest potential for widespread uptake. The paper made this claim based on the modeling of the technical and financial feasibility of solar microgrid development. Pico-solar systems can address low-income households' needs and provide low capacity, small scale solutions for populations facing energy access gaps. Solar home systems and systems that use solar energy for productive uses offer additional opportunities for energy access. In contrast, wind and hydro systems were found less relevant by this study because of limited resources available and a lack of local capacity to implement them. Beyond pico and solar home systems, Eales et al. (2018) argued that with less than 12% of the population connected to grid electricity networks nationally and only 1% of the rural population connected to the grid, solar microgrid emerge as cost-competitive method to increase energy access. The financial viability of solar microgrid is a key challenge in Malawi because capital expenditures are high and the market for solar products is less developed than in other countries (particularly given the large number of low-income users). The study concluded that microgrid should be managed as social enterprises but did not provide further details on this type of business model. Future research should look into how different business models can support the uptake of micro-grid in areas that lack energy access.

Mafuta et al. (2012) investigated the possibility of using remote sensors and solar power to manage irrigation systems in Manja Township, City of Blantyre. Despite technical difficulties in implementing these fully automated solar powered water irrigation systems, the study found that they could constitute viable and cost-effective options for small scale farmers in Malawi. Longwe et al. (2019) examined the integration of community management structures into the design of solar water pumping projects. They explored how community involvement can help ensure the long-term sustainability and maintenance of solar water pumping systems. The study compared ten projects (part of Water Mission) in the Kasungu, Lilongwe and Blantyre districts in 2015. In these projects, installation, monitoring, and evaluation were done in collaboration with the communities, and the systems were handed over the beneficiary communities at the end of one year post installation. The study is particularly relevant for CESET as it describes how solar water supply projects were designed and implemented alongside community-focused capacity building activities.

Morse et al. (2020) looked at the potential of solar water disinfection systems in rural areas (using solar radiation to purify water), exploring how community engagement and participatory work could ensure that energy solutions are embedded in rural communities' needs. The study is particularly insightful for CESET because it discusses issues of co-creation and users' engagement to design context-sensitive interventions. It also provides a methodology to engage with users from determining the prototype to piloting and evaluating interventions. The study showed that users exhibit a preference for systems that can be manufactured and repaired locally, as the program engaged with local manufacturers to develop the technology. The study also highlights the importance of understanding local gender dynamics when designing particular interventions, as women are often responsible for water collection and management.

Hydro

Hydroelectricity only accounts for a minor part of Malawi's energy mix (Rivard and Reay, 2012). Still, it represents the largest source of electricity produced in the country – 98% of Malawi's installed electricity generation capacity (To et al., 2017). Hydropower plants are aging and are difficult to maintain. For example, Kaunda (2013) noted that "*the current 24 MW Nkula A hydropower plant was installed in 1966*." As a result, hydroelectricity supply remains unreliable across the country.

Malawi is also vulnerable to hydro-climatic variability and dry extremes for the supply of electricity (Falchetta et al., 2020). Small off-grid hydro projects could provide electricity to remote communities taking advantage of Malawi's many rivers (Taulo et al., 2015). Kumambala and Ervine (2009) explored the potential of small-scale hydropower for multipurpose schemes providing energy, irrigation, and water supply. The paper provided an analysis to help to decide on the location of a small scale hydro scheme in the highlands of Malawi. It concluded that small hydro constitutes a relevant energy source for off-grid communities, and can improve "*self-reliance and the use of natural resources*" (p. 539). Kaunda (2013) also argued that decentralized hydropower generation could contribute to improve energy access and augment supply capacity, particularly for rural populations. The study provided an inventory of potential sites and already existing installations showing that the Northern parts of Malawi have a higher potential for small hydropower generation. The paper also discusses the potential to link energy provision to local manufacturing systems, arguing that there is some local capacity (particularly in universities) to build the turbines and generator. However, broader capacities for manufacturing, maintenance and installation of small hydropower plants are lacking across the country.

Studies on the potential of small-scale hydroelectricity in Malawi remain limited. Yet, the rare studies that exist show that the country's many rivers could be harnessed for community energy projects, either for hybrid systems mixing hydro, solar and wind, or as part of strategies promoting different technologies (including small scale hydro, solar PV, etc.) for different usage.

Fuelwood/biomass

Several studies have documented the relationship between fuelwood and charcoal consumption and deforestation in Malawi (Hudak and Wessman, 2000; Jagger and Perez-Heydrich, 2016). Some studies have investigated rural communities' biomass consumption and its impact on welfare, particularly the well-being of women. Using survey data, Bandyopadhyay et al. (2011) linked biomass scarcity to the loss of well-being for women living in rural communities across the country, as poor women tend to spend more time collecting fuelwood when biomass is scarce. Das et al. (2017) looked at the health outcomes of biomass cooking fuels for women in rural Malawi, surveying 655 households. The study linked various respiratory diseases to the burning of firewood with symptoms such as "*shortness of breath, persistent cough, and phlegm*." The study concluded that improving access to high-quality biomass fuels in the short term is a condition to improve health outcomes.

Improving health outcomes requires a transition to clean energy for cooking and the dissemination of clean cookstoves (Jagger et al., 2017). Such a transition is also needed to address deforestation (Barry et al., 2009) and can help harness biomass energy more efficiently. For instance, O'Shaughnessy et al. (2014) stressed the feasibility of expanding the use of an off-grid electricity-producing biomass cooking stove. The technology integrates a generator to charge it, or to store electricity in a lithium battery to charge LED lights and mobile phones in the Balaka District of Malawi.

Several studies have examined the drivers of the adoption of improved cookstoves. Orr et al. (2015) showed that households led by women and with more economic resources were more likely to adopt improved cookstoves. However, the study also stressed that the adoption of improved cookstoves does not necessarily go hand in hand with lower fuelwood consumption or reduced frequency of collection. Barry et al. (2009) noted that involving local champions and designing products similar to the cookstoves that users are familiar with makes it easier for people to use and maintain improved cookstoves. The study showed that an improved cookstoves program should go hand in hand with capacity-building activities focusing on the use and maintenance of the technology. This should include a range of skills such as "*kitchen management, cooking practices, and firewood management*" (Barry et al., 2009; p. 123). On the supply side, the study notes the importance of local manufacturing capacity and resource availability (in this case, the improved cookstoves are made out of clay). Note that against other materials in the broader literature on cooking and cookstoves, these studies assume that kitchen management and cooking practices can be taught to those who do the cooking in the household- an assumption that is by no means warranted within the literature.

Finally, one paper explores the impact of Malawi's policy ban on charcoal (Zulu, 2010). It shows that the charcoal ban does not necessarily lead to an increase in electricity usage, particularly in cities such as Lilongwe. Poverty, electricity access challenges, and reliability issues mean that even in the context of the ban, charcoal remains a preferred energy source and increases wood consumption. The paper also stresses the difficulties in implementing the ban and the need to move away from charcoal bans to support, instead, sustainable farming and forestry practices to address demand. Community-based forest management (CBFM) could support the commercial production of woodfuels, alongside with

> "*licensing for revenue and ecological sustainability under CBFM or concessions within and outside selected reserves, an enterprise-based approaches for poverty reduction,*

smallholder/private tree-growing, wood fuel-energy conserving technologies, improved electricity supply and agricultural productivity."

Two studies (by the same authors) have investigated the fuelwood supply chain and sustainable agroforestry practices. They explore the role of agroforestry fuelwood technology in offering a sustainable approach to sustainable forest management, highlighting the importance of farmers' training and the promotion of environmental governance (Toth et al., 2017) and discussing how the management of private and communal woodlots can increase sustainable fuelwood supplies (Toth et al., 2019).

3. Malawi's energy challenges

According to 2013 figures, approximately 7% of all Malawians have access to electricity. In urban areas, 30% of the population has access to electricity, compared to 1% in rural areas (Frame et al., 2013; To et al., 2017). As the majority of the population relies on biomass and fuelwood for cooking and lighting, women and children bear the burden of wood collection. Indoor air quality is a pressing public health challenge (Taulo et al., 2015). While trying to facilitate universal energy access through rural electrification program, the government also faces the challenge of maintaining an ageing national grid.

Energy challenges in urban areas

While scholarship on energy access in urban areas is lacking, a fragmented body of work has highlighted specific energy challenges related to biomass and charcoal use:

- Manda and Wanda (2017) look at how firewood and charcoal burning contributes to the production of everyday risks related to indoor air pollution in Karonga's informal settlements.
- Smith et al. (2017) interviewed people living in three communities supplying charcoal to Zomba, a medium-sized city in Southern Malawi, and showed that the production of charcoal had opposite effects. Many charcoal producers received benefits from it, whether this was direct (financial) or indirect (increased social network, improved access to goods and services, opportunities for diversification). However, many interviewees did not think it was a desirable livelihood because the work is illegal, stigmatized, hard, and dangerous. Most producers engage in these activities to obtain a one-off payment for expensive items, to respond to income shocks, or to meet seasonal financial needs. Women are forced into charcoal production more often than men because they have fewer livelihood options. The study also stresses that Malawi's charcoal ban threatens these livelihoods.

One study examines the role of particular stakeholders (hotel owners) in supporting sustainability transitions: Khonje et al. (2020) explored how the hotel sector in Lilongwe can accelerate the uptake of sustainability innovations in the field of energy efficiency and energy use, alongside other innovations in waste and water management – but the study does not focus specifically on renewable energy uptake.

Energy challenges in rural areas

The previous sections have discussed some of the critical challenges faced by rural communities living far off the grid and solutions deployed to address energy access gaps in rural areas. Malawi is one of the most densely populated countries in the world. The agricultural sector employs almost 90% of the population, and 85% of the population resides in rural areas. Households in rural areas use biomass from firewood as the main source of energy. Deforestation is a crucial problem. The government (Malawi Department of Energy) implemented several programs to improve energy efficiency to limit deforestation. Such programs include, for example, the distribution of efficient stoves as part of the Programme for Biomass Energy Conservation (ProBEC) (Barry et al., 2009, already discussed in the previous section). The next two sections discuss more extensively rural electrification strategies and policies in Malawi.

4. Renewable energy development

Various studies have explored Malawi's energy policies and the extent to which they are able to support renewable energy transitions. Malawi's 2003 National Energy Policy aimed to decrease the reliance on biomass to 50% of the energy mix by 2050, shifting energy consumption from traditional energy sources to modern energy, including electricity, renewables, and liquid fuels (Rivard and Reay, 2012). The National Energy Policy follows national development objectives (Frame et al., 2013), such as the Malawi Vision 2020 Plan, which sets out the country's development objectives (To et al., 2017). The Vision 2020 Plan highlights three critical issues for the energy sector in Malawi: the monopolistic structures and poor management of electricity services (that makes them too expensive and unreliable), the dependence on imported petroleum products, and dependence of the population on fuelwoods. The national utility (ESCOM) is in charge of urban electrification and the Department of Energy Affairs is in charge of rural electrification (To et al., 2017). The National Energy Policy provided a general framework for the following regulations:

- The Energy Regulation Act establishes Malawi Energy Regulatory Authority (MERA), which oversees the electricity, liquid fuel and gaseous fuel markets, including technical regulations and pricing;
- The Rural Electrification Act sets up the Rural Electrification Fund;
- The Electricity Act permits private investments in the electricity sector;
- The Biomass Energy Strategy supports sustainable biomass usage and limiting deforestation.

The four-years programme Promotion of Alternative Energy Sources Project (PAESP), launched in 2006, promoted alternative sources of fuel and their technologies for cooking and other thermal applications in the household sector, as a means to reduce environmental degradation and deforestation. It focused on various technologies, including briquettes, ethanol stoves, and biogas (Kaunda, 2013). In 2012, a feed-in-tariff policy was introduced for energy generated from renewables to encourage private sector investments (Zalengera et al., 2014). Several government plans have sought to enhance energy access through off-grid energy deployment, particularly in rural areas. In 2011, the Malawi Rural Electrification Programme (MAREP) was implemented by the national operator ESCOM, led by a steering committee composed of the University Strathclyde (UK) and the Government of Malawi Department of Energy Affairs and implemented jointly with the Japan International Cooperation Agency (for an in-depth review of the program, see Frame et al., 2013). The program includes a strong Community Energy Development Programme, which is discussed in more depth in the next section.

International institutions such as the World Bank, UNDP, and donor agencies such as DfID have invested in energy access programs and infrastructure development. NGOs such as Solar Aid and other charities actively contribute to off-grid technology deployment and rural electrification. Thus, multiple actors have implemented renewable energy projects since early on. However, there was not a systematic strategy to learn from different off-grid projects (Frame et al., 2013) and there is no integrated approach to off-grid technology development in Malawi (apart from the MAREP). Zalengera et al. (2014) reviewed different options for the promotion of renewable energy in Malawi, including solar, wind, biomass, hydro, and geothermal and identified barriers to renewable energy development, including unreliable financing mechanisms for large scale energy projects, limited capacity for implementation and maintenance, lack of coordination among local institutions, and unclear regulation enforcement. Chirambo (2016) discussed avenues to address the renewable energy financing gap specifically. The author highlights options such as guaranteeing power purchase as means to attract energy investments, and concludes that the country can use a combination of (adapted) price guarantee scheme, cross-subsidies, and environmental taxes to support the development of renewable energy technologies, notably through climate finance.

5. Community energy in Malawi

Barry et al. (2011) looked comparatively at renewable technology adoption in Rwanda, Tanzania, and Malawi. Although the study did not explicitly focus on community energy, it examined how different technologies fit community energy projects and how communities themselves respond to those technologies. The research in Malawi focused on efficient stoves and efficient tobacco barn adoption, a program led by the Department of Energy Affairs with support from the Programme for Basic Energy and Conservation (ProBEC), financed by GTZ and Southern African Development Community. Their study found that the maintenance of different technologies over their lifecycle presented barriers to uptake. Simple maintenance protocols and training for both users (especially women) and technicians could help to ensure the sustainable use of renewable energy technologies. The study also reveals the importance of identifying and enrolling local champions in the projects. These champions help disseminate the technology and share knowledge with their peers about how to use it, repair it, and maintain it. The study also stressed the importance of working hand in hand with local communities to determine their needs, their capacity to use the technology, and the benefits that they are expecting from it. The availability of land and finance also drives the project's success. The type of funding deployed in renewable energy projects impacts technology use and uptake. For instance, most rural poor households do not have access to credit: rural communities pay cash, and when they lack such cash, and have to pay with materials and their own labor. Different projects have experimented with the use of subsidies, credit loans, or just providing the technology for free as a means to facilitate the adoption of renewables.

Frame et al., 2013 have investigated the opportunities and challenges of the Malawi Rural Electrification Programme (MAREP), initiated in 2011. This evaluation was therefore implemented in the early stages of the program. It focuses on evaluating the approach adopted by MAREP stakeholders for project evaluation and learning. It does not constitute an evaluation of the program as such, but of the approach taken to assess its aims and impacts on knowledge exchange, stakeholders involvement, and capacity building. The paper offers a brief overview of the different scales at which off-grid renewable energy are deployed in Malawi, including:

- individuals benefitting from efficient cookstoves and pico-solar systems (e.g., LED lighting);
- households acquiring solar home systems and solar thermal systems through a small network of commercial suppliers;
- community-level infrastructures such as solar PV or solar thermal deployment for schools and health centers, funded by international donors, governments, NGOs and charities;
- mini-grids (e.g. hydro microgrid or hybrid solar-wind systems serving off-grid communities);

MAREP, implemented by the national operator ESCOM, constitutes a significant policy development from a community energy perspective because it rests on an integrated approach to the deployment of hybrid renewable energy systems (solar-wind) across different villages in the country. The program also aimed to generate new evidence to inform renewable energy policy in Malawi. It focused explicitly on energy access through the development of community energy through a dedicated Community Energy Development Programme (CEDP), led by the organization Community Energy Scotland, and comprising of various initiatives:

- The Mulanje Renewable Energy Agency (MuREA) is deploying a micro-hydro mini- grid with capacity 75 kilowatts serving 400 households.
- The University of Malawi Polytechnic (WASHTED) is deploying solar PV systems for community service infrastructure (schools and health centers) in Chikwawa district.
- Mzuzu University (TCRET) is deploying biogas digesters for then farming households and one orphan care center in Mzimba district.
- Conce Universal is deploying an efficient cook-stove distribution network in the Balaka district, linking a new cohort of stove promoters to existing production centers and targeting wood fuel reduction in 100 villages.
- Sustainable forestry management programs have expanded to eight new areas. Solar PV systems are to be implemented in five primary schools.

MAREP used a variety of technologies, ownership models, financial models, and models of community involvement in each of these projects. At the time of writing (2013), the authors pointed at the lack of data on community energy projects failure and sustainability issues (e.g., operations and maintenance, financial management). In 2016, the same team of researchers addressed this gap through three studies evaluating community energy projects in Malawi.

Dauenhauer et al. (2016a) assessed the sustainability of 43 solar PV projects in Malawi (commissioned by MREAP), most of those implemented in Primary Schools and Health Center. The study focused on the project, system, and room level – most projects use renewable energy technologies to provide energy to different rooms in a particular building. The study assesses the technical, economic, social, and organization sustainability of the projects. The majority of solar community projects failed to deliver positive impacts. At the time of the study, 38% of systems had lost all service. This was due to issues related to the technical design of the products (e.g. 44% of systems have undersized PV arrays, 83% of systems have undersized battery banks), limited financial viability (only $1/5^{th}$ of projects have a bank account and the majority of projects do not report any income); and limitations in the skills required to manage community projects (e.g. lack of revenue/budget book keeping; lack of community involvement in the ongoing management of the projects; lack of access to technical and financial skills training, absence of maintenance arrangements, etc.). In addition, the study finds that projects are often located far away from markets supplying replacement parts (e.g., bulbs) limiting communities' capacity to maintain the solar PV system over time.

The second study led by Dauenhauer and colleagues (2016b) focused on evaluating MAREP's CEDP (2012-2015). It assesses the sustainability of community energy projects by looking at their technical, economic, social, and organizational sustainability and by exploring how community-based organizations (CBOs) were involved in each of these dimensions. For instance, CBOs were invited to take part in the development of community energy projects' business models (e.g., the identification of locally relevant revenue-generating activities) in collaboration with project officers in the District Executive Committees (local authorities). CBOs were also responsible for the overall project and asset management, and they shared responsibilities for the operation of the project with local operators (often newly created voluntary energy management committee), which are also in charge of revenue collection and liaison with CBOs. More broadly, CBOs participating in the program received support by Community Energy Malawi (also providing training, information sharing, etc.). The study concludes that community energy in the MAREP CEDP program offered "*a significant improvement in the sustainability prospects of the associated community energy projects at the cost of higher investment in the development process*," with around 20.439 Malawians benefitting from the program and CBOs benefitting directly from capacity-building activities. However, they also noted that "*the systematic challenges to sustainability for off-grid systems in Malawi require an ongoing support mechanism for communities, ostensibly through [the creation of] a district energy office*" supporting and facilitating the coordination of community energy projects. The study stresses the importance of support from local governments to develop CBOs' capacity to maintain and operate the system, and to develop a business model and revenue collection strategy that support the long term financial viability of community energy projects, as the financial and technical skills required to operate community energy systems remain high for communities themselves.

In a more recent study, Dauenhauer et al. (2020) investigated the sustainability outcomes of 65 off-grid solar PV projects serving rural public facilities in Malawi, examining their technical, economic, social, and organizational variables (the paper also provides an extensive review of the sustainability of off-grid technology deployment in other countries across Sub-Saharan Africa, Asia, and Latin America). The overall aim of the study is to provide insights into good practices for project developers so that they can use those in the planning stages of their projects. Solar PV projects are defined as (p.5) "*a group of solar electricity assets (one or more individual systems) for which a distinct management team is responsible for its ongoing operation and management*." The study compares projects developed through the MREAP (CEDP and Strategic Energy Projects) and projects that were not developed as part of the program, to assess whether MREAP projects were more sustainable than other solar PV projects. The paper found that most projects were unsustainable. Specifically, the study concludes that:

- Social sustainability was often weak because of the limited engagement of the local community (e.g. community members do not meet regularly and have a limited stake in the project);
- Organizational sustainability was also weak because of the sketchy management structures, and minimal technical, managerial and financial training provided (although CEDP projects tend to provide more training and support to community members than Strategic Energy Projects and non-MREAP projects);
- Financial sustainability, a key factor for the success of the projects, was weak because even the more secure projects only covered 37% of the expected operations and maintenance costs. Most projects do no identify reliable revenue sources. In general, projects do not have a bank account (apart from CEDP projects), and basic maintenance arrangements are lacking. Clear operation and maintenance budgets are found to be lacking in the majority of projects;
- Technical sustainability was hindered by poor standards, lack of load profiles for first-time electricity users, and components of deficient quality. Systems usually do meet users' needs and demands (most systems are undersized for both battery and panels).

The authors concluded, in line with their other studies, that the sustainability of solar PV projects depends on having clear financial and organizational frameworks and local government support. In the case of CEDP projects, the higher performance was found in terms of selecting CBOs with pre-existing experience of local development projects; the co-development of business plans with CBOs and training (financial management and technical skills); and early on recognition that communities would own the project and would need to ensure its financial viability. These different studies have focused on solar PV technologies but also offer relevant insights for community energy more broadly. They tend to deploy the same sustainability framework across the different studies and only to offer ex-post, one-off evaluation. Understanding the diversity of technologies, governance arrangements, and what works and does not work at different stages of the project thus remains a blind spot of current studies.

6. Key insights

The interest in community energy in Malawi links to several projects that have experimented with community energy systems. This interest is motivated by the lack of alternatives and the extreme challenges found regarding energy access in this country. One thing to note is that there have been already systematic, comparative studies of diverse systems of community energy looking at the diversity of models, technologies, and governance arrangements deployed for community energy in the country. Engaging with this work will help reassess their findings in future community energy programmes, but will also help expand previous methodologies and analytical frameworks. As noted in the earlier sections of this annotated bibliography, existing work on community energy has consisted of ex-post, one-off projects evaluation looking at the sustainability of community energy systems through surveys and comparative studies (of mostly solar PVs) in rural Malawi. CESET can help advance this work by assessing the diversity of technologies, governance arrangements, financial models, and meanings of energy systems' sustainability in different contexts (geographical, social, cultural). Various studies in Malawi (investigating solar PV systems, improved cookstoves, wind, and hydro energy) have stressed the need to link energy strategies and technologies to existing local manufacturing networks. Such link needs detailed consideration as community energy systems need to be designed not just in relation to the community they serve, but also in the broader context of local formal and informal economies within which they are embedded. Both the supply and maintenance of energy systems are likely to be determined by the existence of a local market for spare and replacement products and by the presence of skilled labor to repair and adapt the technologies to changing usages.

Most work on renewable energy deployment has been focused on rural areas, and there is a significant gap to address with regards to energy consumption and barriers to access in urban areas.

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