MREAP SOLAR PV STRATEGIC ENERGY PROJECT IN SOUTHERN MALAWI: DEVELOPMENT, DESIGN, AND IMPACT

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Background

Malawi is one of Sub Saharan Africa (SSA) countries with a population of approximately 15 million. However, only 9.8% of the population has access to the national grid electricity and access to the rural areas has remained stagnant to less than 1% for a long period of time. Comparatively, the sub-Saharan average is 10% for the rural and 25% overall thus making Malawi one of the least electrified countries in SSA. The lack of adequate electricity in rural areas has the potential to reduce the economic activity of the rural population because people fail to open up business enterprises. As such renewable energy technologies become the hub in provision of electricity to spur economic activities in rural areas. One of the objectives of Sustainable Energy for All (SE4ALL) is to ensure universal access to modern energy and this can be achieved through the use of modern renewable energy technologies.

The solar energy potential in Malawi is ample [7] and its exploitation has the potential to contribute to major reduction in the global emissions of greenhouse gases. Moreover, the use of solar energy for productive use such as irrigation, would aid in reducing poverty. Despite this fact, a contribution towards overall electrification rates is minimal. Even though the deployment of solar PV systems has been increasing in Malawi, solar technologies still meet challenges to remain sustainable.

It is against this background that the Malawi Renewable Energy Acceleration Programme (MREAP) was commissioned by the Scottish Government with the aim of supporting several aspects of renewable energy development, community energy development, rural electrification, biomass and underpinning institutional support and capacity building. The proposal makes the case for multiple sector development activities organized as a single programme with the overall objective to Support Government of Malawi energy strategy by accelerating the growth of community and renewable energy development in Malawi through multiple, targeted and coordinated activities with good potential to provide a platform for that growth.

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Summary of Solar PV Strategic Energy Project

One of the specific objectives of community energy development project was the delivery of 4 Strategic Energy Projects (SEPs) in different renewable energy technologies to further community energy project development.

WASHTED led the SEP focused on Solar PV for rural schools and health centres in Chikhwawa. The installations include Chithumba, Gumbwa, Ndakwera and Dolo. The health facilities and schools were identified through the assistance of the offices of Chikhwawa District Health Office (DHO) and District Education Manager Office (DEMO). The DHO and DEMO selected schools and health facilities by considering their previous pass rates, energy needs and other relevant social indicator such as social connections, trust and participation in developmental projects, standard of living etc. Thereafter, a selection criteria was developed that scored the sites depending on a number of factors that include:

- Availability and reliability of mobile network for technical data transmission through remote monitoring technology
- No likelihood that national grid will be established in the area in the next five to ten years or more
- Availability of self-help energy activities in the communities
- Potential to sustain energy projects in the communities
- Capacity to form and sustain energy committees, etc.

A needs assessment was conducted and established community needs for lighting, powering electronic equipment, telecommunication, water pumping, refrigeration and electric fencing in the identified sites in Chikhwawa.

The total output of the installed solar PV systems in schools and health facilities under the SEP was approximately 5 kilo-Watts-peak (kWp). This comprises of 1,280 Watts-peak (Wp) for Gumbwa, 2 kWp for Ndakwera, 2.10 kWp for Ndakwera and 850 Wp for Dolo. The characteristics of the installed sites are shown in Table 1 and 2 below:

Name	**Type**	**Enrollment Level (2014-15)**	
		Male	**Female**
Chithumba	Primary School	369	343
Gumbwa	Primary School	502	535
Ndakwera	Primary School	858	802
Dolo	Primary School	600	507

Table 1: Primary School Enrollment Level for education facilities

Name	Type
Chithumba	Health Centre
Gumbwa	Health Post
Ndakwera	Health Centre
Dolo	Health Centre

Table 2: Health Facilities

Installed System Specification

Each community energy project had multiple stand-alone power systems that were installed. Though they were not interconnected, they were identical and in close vicinity with each other to enable remote monitoring communications. The following section documents the main characteristics of systems by using Gumbwa as a case study.

Gumbwa System Design

School Classroom Blocks

The system has been designed to run all lighting for 3 hours each night (528 Wh) plus provide 94.29 Wh of AC electricity each day for TV. Three days of autonomy are also accounted for in the design. The system has been installed in two classroom blocks which are being used for students study at night and TV shows.

System specification

- PV Array – 9 x 80 W panels
- Charge Control – Steca 40 Amps
- Deep discharge Deltec batteries - 10 x 102Ah

Staff room

This has been designed to provide 546.3 Wh/day consisting of lighting (374 Wh/day), phone charging (108 Wh/day) and laptop use (64.3Wh/day).

System specification

- PV Array – 3 x 80 W panels
- Charge Control – Steca 20 Amps
- Deep discharge Deltec batteries - 4 x 102Ah

Health Post

This has been designed to provide 735.9 Wh/day for lighting (264.0 Wh/day), phone charging (11.1 Wh/day) and refrigerator use (460.8Wh/day).

System specification

- PV Array – 4 x 80 W panels

- Charge Control – Steca 30 Amps
- Deep discharge Deltec batteries - 5 x 102Ah

Development Process

The Solar PV SEP was designed to build upon previous experiences of Solar PV community energy projects in Malawi. Given WASHTED's previous role in the Community Rural Electrification and Development (CRED) project, this learning from this project was most accessible. Another source of learning came from the MREAP 2012 Evaluation which produced twelve case studies [4], seven of which were Solar PV Community Energy projects. The evaluation brought out some key initial learning on Solar PV systems in Malawi, in particular that projects required improved financial performance, the need for 'appropriate' energy solutions, and general lack of coordination between projects and support organizations. Within MREAP, the new Solar PV SEP had an additional opportunity to collate ongoing learning based on a variety follow-up visits to the CRED sites throughout the programme: new projects were also located in Chikhwawa, a follow-up technical support work stream for CRED projects was commissioned in 2014 [4], and a selection of CRED projects were included within the MREAP Solar PV Sustainability Study [6]. The section below summarizes observations from the WASHTED Engineers that highlight challenges with the CRED Project and potential solutions that would implemented within the MREAP projects. Since sustainability for these projects are dynamically changing, it is critical that ongoing monitoring and evaluations are conducted and shared with other practioners.

Background of CRED

The CRED project was one of three initiatives from the University of Strathclyde's Malawi Millennium Project that had received support from the Scottish Government's International Development Fund. The project arose from a growing interest within the University's Electrical Engineering Department on sustainable solar electricity deployments in the developing world and an ambition to address more of the wider sustainability challenges of solar electricity. The well-established links between the University of Strathclyde (UoS) and the University of Malawi Blantyre Polytechnic provided the opportunity to undertake a project addressing the sustainability issues that undermine renewable energy solutions in Malawi.

A partnership consisting of staff from the University of Strathclyde, Blantyre Polytechnic and the Government of Malawi Department of Energy was subsequently formed and the Scottish Government funding was granted at the end of October 2008 and the CRED project officially commenced in November 2008.

The key principles of the CRED project were to improve the sustainability of rural PV deployments through deployment models focusing on community engagement and empowerment, local responsibility and income generation. Village energy committees backed up by an appropriate support chain of a local field coordinator, local suppliers and local government and academic partners formed the foundation of the project.

Two high level project objectives were identified:

- To increase the opportunities for social and economic development through increased access to reliable, affordable electrical energy in rural communities.
- To develop and increase the capacity of key stakeholders to advance GoM off grid rural electrification programme.

The project efforts towards these objectives were centred around pilot installations in five communities comprising primary schools and health facilities in theChikwawa district that include Mwanayaya, Namira, Mikolongo, Mwalija and Chilongoma.

The above objectives were achieved to some extent however even if a project can be well designed and implemented, it will still be prone to challenges and the CRED project challenges are discussed below:

Community Participation

Project sustainability depends on a high level participation in the community where the project has been deployed. Participation leads to increased capacity for ownership, autonomy and sustainability strived for in the project objectives. However, it was observed that members of the community out with the energy committee had low levels of participation or ownership in the CRED project. The Energy Committee members monopolised control of the solar PV system and were making autonomous decisions without consulting community members. As a result, the members out of the energy committee felt sidelined and did not participate in CRED activities. For instance, activities to do with income generation were monopolised by the Energy Committee even though there

were members in the community that were interested to participate in income generation in a transparent way. One of the possible ways to mitigate on this problem is to empower the community so that the Energy Committee should be accountable to them on all activities taking place at the solar PV

Inadequate Maintenance Funds

Generation of funds for maintenance of the solar PV system was well captured at the design of the CRED project. This included tariffs charged at community level for mobile phone charging and sale of cold drinks, facilitated by the availability of the solar energy installation. The income was kept in a central fund for maintenance and other future uses. However, observation by project managers had shown that the generated maintenance funds were not adequate enough to meet repairs and maintenance of the solar PV system. For example most of the CRED sites could generate funds amounting to MK2, 000 per month through phone charging (MK24, 000/year). This amount would not be adequate to purchase a new battery at the cost of MK60, 000. On one hand, it entails that it would take more than two years to generate funds to purchase a single battery assuming the system does not breakdown.

Transparency and Accountability of Generated Income

Another issue was that transparency and accountability of funds was ultimately not assured. For instance, generated funds became a source of suspicion and conflict amongst the energy committee members and the community at large as highlighted by Picken (2010). Moreover, the members gave themselves incentives for their roles they played as members of energy committees. This was so because some members felt they were doing more activities in the solar PV management than their colleagues and deserved incentives. Of course, this development was discovered during monitoring and evaluation of the project and members who were doing such malpractices were advised that funds generated from the system were supposed to be used on the system for maintenance purposes.

Possible solution: Scalable solar PV to provide significant economic value with proper procedures of collecting income. The income should well be recorded and the funds deposited in a bank with bank deposit slips filled. In addition, any withdrawals should be

accompanied by supporting documents fully signed by authorized members that manage the cash in and out flows of the account.

Formation of Representative Energy Committees

The design of the CRED project took into account the formation of Energy Committees whose responsibility was to manage the solar PV system in terms of operation and maintenance. The Energy Committee was supposed to be nominated by the community. However, it was noted by some members outside the Energy Committee in the community that certain members were self-nominated in the Energy Committees. This had a negative effect in terms of members' participation in the community. For example the village chief relatives would self nominate to be members of the Energy Committee without the approval of the community/Energy Committee itself hence reduced participation in the project activities. Also some Energy Committees comprised of illiterate members who had shown low levels of confidence in their capacity to maintain accuracy and understand their roles and responsibilities in the overall management of the solar power system.

Possible solution: Sensitize the community about the community energy resource and set a day for election of energy committee members within the community with the assistance of local chiefs. Also, explain the roles and responsibilities of the energy committee to the people present during the times of elections. Training for energy committee members should be offered (both at the onset of project operation and ongoing training) should be provided to ensure members are capable of managing the project. Finally, a support organization to reinforce the role and need for desired representation within the energy committee could prevent capture of the committee by any one individual.

Profit Use from Sale of Cold Drinks (Income Generation)

One of the income generating activities in the CRED project was selling of cold drinks. The initial capital put into the business was based on contributory basis from interested members within the community. The issue of 'profit use' within this model had been found to be a potential area for conflict within the community. It was observed that there were low levels of understanding within the community about necessity to retain some of the profits for maintenance of the system. Furthermore, there was distinct divergence in perceptions of profit use and lack of clarity amongst community stakeholders regarding responsibility for decision making pertaining to profits. As a result members within the

energy committee thought it was acceptable to make their own decisions with the funds, rather than to do so with a consensus of the community.

Possible solution: Design projects that clearly state at the commencement of the project that funds generated through the community energy resource will be used for maintenance of the system. Business training should be provided for the committee members to better understand the long-term (3 to 5 years and longer) financial situation of the project and the critical role income generation and savings has towards ensuring sustainability.

Poor Solar PV System Upgrades & Warranties

The CRED solar PV systems installations were carried out by MERA certified solar installation companies. This was an improvement on the status quo in the country and was thought to improve the prospects for long-term sustainability of the solar PV system. However, it was established that out of a total of five CRED solar PV installations, three installations experienced problems with batteries after operating close to three years. At the time of writing this paper, the remaining batteries are functioning normally. Batteries at two non-operational sites were damaged during system upgrades by one of the certified solar companies who initially installed some of the systems. Despite the fact that the installations were within warranty period, the certified installer failed to carry out repairs and maintenance on the system. In addition, the companies were unable to provide timely after sales service despite the fact that CRED Project Managers reported the faults in a timely manner. Also there was no warranty document that was put in place to guide CRED Project Managers on what they would do when such issues arose.

Possible solution: Need to have signed warranties and proper procedures of upgrades. The installers should well define their post installation repair and maintenance procedures before they are engaged. Of course this can be one of the conditions to be taken into account when procuring.

Exclusion of Teachers in Decision Making

In some CRED sites teachers had been excluded in decision making on the activities that are associated with solar PV system everyday use. As a result the teachers felt frustrated at lack of participation and decision making influence. This was one of the major problems because the Energy Committees decisions and activities had significant impacts on teachers, such as use of the school for charging and studying, interruptions to classes hence led to misunderstandings with the school committee.

Possible solution: Election of members in the Energy Committee should include teachers. If no teacher has been included in the election, then they can be taken in as co-opted members.

Design Flaw at Teachers Houses

Teachers' houses at one of the CRED sites had been installed with a simple lighting system of two 9 W DC bulbs connected to 50 Ah 12 V lead acid battery. It was planned that every two days, two batteries of low voltage (between 11 and 12V) were brought to the charging station within the school premises and connected in parallel with two permanently connected batteries. However, the design at teachers' houses did not include low voltage protection to prevent the battery from permanent damage. It was intended that teachers would limit use on their own without a technical barrier such as a charge controller. In actual practice, teachers did not observe the voltage readings from the batteries. Thus, due to this design flaw, some batteries have been damaged permanently.

Possible solution: Need to include the low voltage cut off mechanism in teachers houses to prevent deep discharge of batteries.

Incorrect Recording of Economic and Technical Data

In some CRED sites, the socio-economic data was poorly recorded and confusing. For instance, records for income generation through charging each mobile phone would show MK50 and sometimes MK20 in the log books per charging session despite having a fixed charge of MK50. Also, there had been times when records for income generation had been completely missing in the log books for particular days. However, when data was transferred to the master report, the missed days will have data filled in and nobody knows where the data had come from. Therefore, this led to poor interpretation of results for sites where data was inconsistent and exclusion of some unreliable data.

Possible solution: Civic educate the energy committee members on the importance of recording correct data in the log books. This can be done during skills training workshops or when paying regular visits to the sites. As before a support organization to provide ongoing training could be utilized to reinforce the skills and knowledge of the managing community.

As has been shown, the CRED has provided critical learning for the sector on how a community based project could be designed and implemented for it to remain sustainable. In some areas where the project had not performed well requires improvement and a new

approach to the challenges can be designed to overcome them. It is from this background that the CRED provided lessons on how the MREAP project was to be designed and implemented by taking into account the challenges and successes of project in order to enhance sustainability of the solar PV projects under the MREAP project.

Needs Assessment

According to (Altschuld,2010) a needs assessment is a systematic approach to identifying social problems, determining their extent, and accurately defining the target population to be served and the nature of their service needs. The Solar PV SEP implementation involved a needs assessment by engaging all stakeholders at village level. The first task involved identification of potential sites where solar PV was to be installed. The offices of the District Education Manager (DEM) and that of the District Health Officer (DHO) were contacted to provide a list of potential sites of schools and health facilities where the needs assessment was to be carried out. A total of 22 sites comprising of 11 schools and 11 health facilities in Chikhwawa District were selected to participate in a needs assessment. A questionnaire was designed to capture data from schools, health facilities and the communities (see Annexes 1& 2). Methods and instruments of capturing data included interviews and holding focused groups' discussions. The data obtained through the needs assessment provided priorities for energy needs and their potential applications in the rural communities.

The results of needs assessment identified five centres that were recommended for solar PV installation, including: Ndakwera, Chithumba, Gumbwa, Chang'ambika and Thendo. The sites scored highly based on a number of factors such as existence of self-help activities and ongoing projects, reliable committees and robust security. Furthermore, it was observed that the health facilities and schools were in close proximity, a characteristic which was desirable in easy implementation of the pilot project whose results could have visible impact. In addition, the health facilities in these sites have maternal activities taking place which was another social impact priority area. Annex3summarizes the needs assessment results of schools and health facilities based on weighted indicators.

Site Analysis and System Design

Before deployment of solar PV system in the identified locations, WASHTED solar PV team and the electrical contractor carried out a technical needs assessment in order to verify whether the proposed sites for PV installations will be adequate for proper operation of the system conditions. The sites visited were Gumbwa, Chithumba, Ndakwera and Dolo in Chikhwawa District. These sites include health facilities and schools. There were a number of reasons why a technical needs assessment was carried out including:

- To establish location, orientation as well as mounting method of the PV generator;
- To establish the system component lay out that include PV panels, control board, inverter, charge controller, the wiring routes, cable lengths etc;
- To ensure that PV panel location is free of shedding;
- Determine what equipment will be required during the installation work (e.g. scaffolding or step ladders);
- To verify the community wishes as regards system applications;
- To verify with the community wishes as regard to module type, system concepts and method of installation and desired power; and
- Propose and discuss with the community any alterations required before deployment of the system;

During these visits, it was revealed that all the sites were similar in terms of how PV panels were going to be mounted and oriented (e.g. all rooftops). In some sites efforts were made in order to avoid shading.

This survey established the power demand for the system which is critical in proper sizing. This was based on the size and layout of the building (required to establish the number of lighting points) and other electrical power applications (e.g. phone charging, TV shows, and laptop usage) as demanded by the community. This information propelled the PV team to design a PV system that would meet the requirements of the community at the lowest cost possible.

In order better understand the relative performance of different configurations of system, the team developed two systems: purely AC- and a hybrid AC/DC-based. The idea was to investigate both short and long-term cost benefits of AC- and DC-based PV systems if future evaluations are realized.

System sizing, which consists primarily of matching load demand and the generation capacity of the PV system is summarized in Tables 1(a) and 1(b).System Demand was used

to size both purely AC- and hybrid AC/DC-based PV systems deployed at two sites: Gumbwa and Ndakwera .Other systems in the SEP were sized in a similar fashion.

The rating of the PV array in Watt-peak (Wp) was computed using the total Watt-hour per day (Wh/day). The Wp figure depends on the size of the panel and on the climate of the site location. The climate was considered by evaluating Panel Generation Factor (PGF) which is different in each site location. The PGF is a product of the collection efficiency (64% - assumed value) and average solar radiation in a least sunny month. Taking the average solar radiation in least sunny month to be 4.8kWh/m2/day (Madhlopa, 2003) translates into a PGF of 3.072. This factor is divided into total Wh/day to get Wp for the PV array.

Battery capacity was based on the following assumptions: battery efficiency of 85%, 3 days of autonomy, 50% discharge limit and 12V battery terminal voltage. These computations were necessary and vital in order to avoid over sizing of the PV system which inflates the capital cost of the project. At the same time, the under sizing of the PV system was avoided in order to satisfy the basic power requirements for users, hence, preventing probable system abuse.

	Load evaluation									PV systems sizing								
	Appliance	Qty	Rating (W)	Watts		Duration of Use		Average Daily Wh		PV Energy needed	Wp	No. of Panels	Battery Capacity	No. of Batteries	Amperage	Regulator Size	Inverter size (W)	
				DC	AC	Hrs/Day	Days/Wk	DC	AC									
Class block	Lights (classroom)	16	11.0	176.0		3	7	528.0		1,226.37	399	5	555	6	32.5	40	122.57	150
	Lights (security)	2	11.0	22.0		10	7	220.0										
	TV	1	110.0		110.0	3	2		94.29									
	Total Wh/day							**748.0**	**94.29**									
Health post	Lights	6	11.0	66.0		4	7	264.0		956.67	312	4	433	5	26.0	30	-	-
	Phone Charging	1	5.6	5.6		2	7	11.1										
	Refrigerator	1	38.4	38.4		24	7	460.8										
	Total Wh/day							**735.9**										

Table 2 (a): Load demand evaluation and PV system sizing for Gumbwa site (hybrid AC/DC System)

	Load evaluation							PV system sizing								
	Appliance	Qty	Rating (W)	Watts	Duration of Use		Average Daily Wh	PV Energy needed	Wp	No. of Panels	Battery Capacity	No. of Batteries	Amperage	Regulator Size	Inverter size (W)	
				AC	Hrs/Day	Days/Wk	AC									
Class block	Lights (classroom)	16	11.0	176.0	3	7	528.0	1,176.4	383.2	5	532.3	6	32.5	30	1,050.4	1000
	Lights (security)	2	11.0	22.0	10	7	220.0									
	TV (19 inch - color)	1	70.0	70.0	3	2	60.0									
	Total Wh/day						**808.0**									
Health Centre	Lights (room)	10	11.0	110.0	4	7	440.0	1,252.2	407.9	6	566.6	6	39.0	40	1,118.0	1200
	Lights (security)	2	11.0	22.0	10	7	220.0									
	Lab equip (e.g microscope)	1	50.0	50.0	4	7	200.0									
	Total Wh/day						**860.0**									

Table 2 (b): Load demand evaluation and PV system sizing for Dolo site (AC only system)

SUSTAINABILITY PLANNING

Solar PV Sustainability Framework

Modern economics and social development recognize energy as a cross-cutting and critical input to growth [8]. Currently, rural electrification in Malawi, through government, is restricted to a grid extension with no major off-grid element. Efforts in the recent past in off-grid electricity supply have been led by NGOs and communities and have had mixed sustainability results. Failure in terms of sustainability, which does not have to only be outright failure but also lower than expected performance, means that associated development outcomes will not meet their potential. Whether the government takes a more committed role to off-grid solutions or not, future projects through organizations like Community Energy Malawi and a supportive Community Energy Networks must continue to improve the sustainability model for the sake of the development outcomes, if nothing else. While planners and implementers of solar PV technology are thinking of up scaling solar power, it is all the more crucial that the focus should be to enhance solar PV sustainability at the project and programme levels.

A general sustainability model which highlights the challenges for off-grid projects is shown in Figure 1. Project design decisions which are aimed at optimizing performance the potential project against technical, economic, social, organizational, and environmental factors have implications on how the project operates once it has been implemented. As will be shown in later sections focused on improving the design model to achieve improve technical, social, and organizational performance in particular.

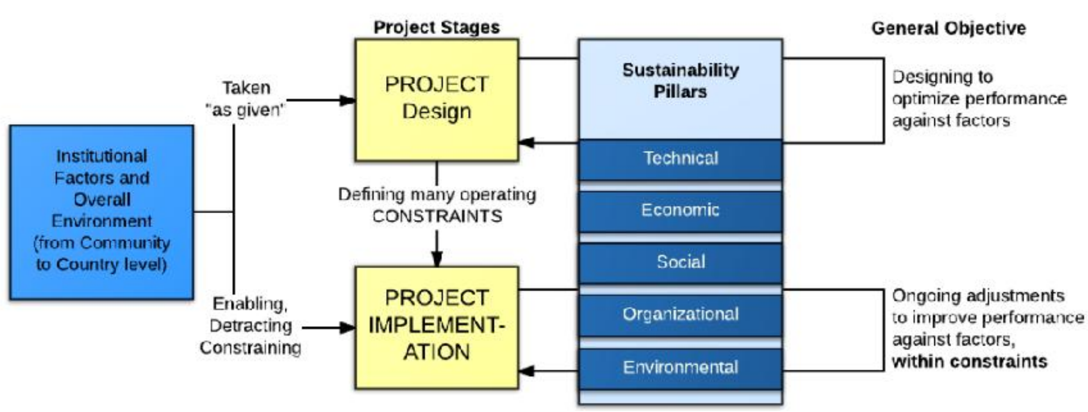

Figure 1: Solar PV Sustainability Model

This includes addressing lack of needs assessment, poor system design, lack of community engagement / buy-in, lack of community training, lack of involving management support structure and technical support mechanisms.

Needs Assessment

The MREAP team conducted needs assessments as a tool that assisted to determine if the conditions to deploy solar PV in Chikhwawa district in southern region of Malawi were available and implementable, and if not to define what would be required to put them in place. It was acknowledged that such a systematic and coordinated approach provides critical input for certified solar installer and team for the identification of key actions that need to be taken to support the achievement of solar PV energy or sustainability. It thus makes it possible to integrate capacity building into the planning process from the outset.

Financial Support Mechanisms

The MREAP project focused on productive use of the solar PV system in order to increase system sustainability. Income generation activities such as phone charging and video showing were incorporated in the solar PV design as a means of generating maintenance funds for system sustainability. Although income generation activities was deliberately designed in the project, little or no any income generation activities were taking place in MREAP sites. However, the DEM and DHO offices were advised to encourage the energy committees in health facilities and schools to generate savings through the use of the solar PV. The savings were to be used at later stage for repairs and maintenance of the system. In addition, it was designed in the project that the district structures that are direct beneficiary of the solar PV system should support the sustainability of the solar PV systems. In this case, the WASHTED team visited the offices of the District Health and Education to be providing maintenance funds for repairs and maintenance of the systems. Although this issue has been discussed with the two offices, implementation has not started yet but WASHTED has initiated the relationship to support the energy infrastructure

Ownership

MREAP team engaged with the communities at all stages of the design and implementation of the project. Local ownership was emphasized as a basic principle of the project design. WASHTED had conducted community training workshop around solar PV as part of capacity building efforts. Communities had clear responsibility for managing and maintaining the

systems. In addition, the concept of an Energy Committee was adopted from the CRED project as a vehicle for community ownership and participation. It was agreed that the composition of energy committee would be exactly as those existing in the communities such as in water, sanitation, health and village development committees in which the representation would take all stakeholders expertise at village level. The following process was agreed for the responsibility and ownership of the systems.

- A formal handover ceremony that would transfer the installation from WASHTED to the offices of the District Education and Health. Thereafter, the same offices would transfer ownership to the community.
- The energy committee would manage and maintain the system on behalf of the community. Regular energy committee meetings would provide feedback and accountability to the community.
- The energy committee would be involved in income generating activities and the offices of the District Education and Health would provide advice on transparency and accountability of revenue collected from the use of the solar PV system.

Community Training

WASHTED solar PV team and selected experts in the renewable energy sector developed nine renewable energy training modules. The renewable energy training modules were designed for conducting renewable energy short courses in the communities. The training workshops were carried out to raise awareness about renewable energy technologies, provide knowledge for design, installation and maintenance of renewable energy technologies to the rural communities in Mulanje and Chikhwawa districts. In all, 150 people participated in the training sessions. In addition, the renewable energy training workshops featured practical training to the participants to reinforce the concepts and also key installation and maintenance concepts.

Management Support Structure

The Management support structure for the MREAP project comprised of WASHTED, community and district structure. WASHTED was responsible for preparing technical drawings and specifications of electrical systems to ensure that installation and operations conform to standards and customer requirements. Also WASHTED carried out supplier

analysis for solar PV materials and equipment so that robust equipment and materials were used for installation. Above all, WASHTED has been responsible for providing advice and direction on how the systems are to be to managed and discuss any issues pertaining to the installations with the selected solar PV installers. In addition, WASHTED has been involved in conducting capacity building workshops around renewable energy technologies to rural communities. Communities are involved in overall management of the solar PV systems in terms of promoting and managing the use of the solar PV system for income generation, minor repairs and maintenance work and data gathering through daily logbook completion which include income generation, system maintenance and use. The district offices of the DEM and DHO have the responsibility of sourcing financial funding for maintenance of the system and providing financial audits for revenue collected from the use of the system.

Technical Support Mechanisms

WASHTED organized a team of solar PV installers to install, repair and maintain the solar PV installations from time to time with assistance of a MERA certified solar installer. Furthermore, the most practical indicator of the performance of the solar PV systems can be obtained from the remote monitoring and data logging software supplied by most inverter manufacturers. The data logging software will record daily, monthly, and annual output for comparison of the actual system performance against the expected system performance. The MREAP project incorporated remote monitoring mechanisms in which data such as battery voltage, battery current, battery state of charge and panel open circuit voltage are recorded to give actual technical performance of the system. This can be seen as preventive maintenance measure and assists in enhancing system sustainability because faults or any malfunctioning of the system can be corrected without major delay. Further information on the remote monitoring data and results can be found in [9].

Robust System Design

Procurement and installation of solar PV systems is the first important step to ensure optimal performance and reliability. The size, model and make, and physical installation of system components are all crucial elements to proper system operation. There are international standards guiding nearly every aspect of the design, manufacture and installation of solar PV systems. Bearing the aforementioned in mind, the WASHTED solar PV team incorporated internationally recognized standards into technical specifications such as

the International Electro technical Commission standards (IEC) for the procurement of materials and installation services. This has been an important first step in achieving system sustainability. The solar PV system design specifications were developed using the technical needs assessment results and solar PV design data sheets. The design specifications looked at the various applications of the system, size and capacity of the health facilities and schools. In order to procure materials and equipment that meets recognized international standards, WASHTED solar PV team carried out a supplier analysis to ensure that the materials and equipment purchased from the proposed suppliers meet the design specifications and warranties and above all the said materials and equipment would be readily available at supplier points in time of repairs and maintenance. The supplier analysis involved on spot testing of the materials and equipment by either using relevant measuring instruments or physical checking of the specifications. Equipment and materials which did not have specification name plates were rejected right at supplier point. Materials and equipment was also checked again when delivered at Polytechnic store room. In other words, we could say materials and equipment were being tracked from supplier point to the time they were being delivered to Polytechnic store room to ensure that solar PV installation should be carried out with high standard and robust materials and equipment. It was observed that most of the equipment and materials delivered at Polytechnic were exactly the ones that we had purchased at supplier points except for few ones which were rejected and returned to the supplier who did not meet the design specifications. The selected equipment and materials have performed well since installation.

SYSTEM INSTALLATION

WASHTED used the expertise from Polytechnic Electrical Engineering Department to install solar PV systems under the Solar PV SEP project in selected sites (see Figure 2). WASHTED identified a certified Malawi Energy Regulation Authority (MERA) electrical contractor through the assistance of the Polytechnic procurement office to be an overseer of the installations and provide guidance where necessary. It was also agreed that the contractor would commission, carry out end user training sessions and above all, carry out post

installation repairs and maintenance of the system for a period of six months,. It was agreed with the solar installer that any repairs and maintenance outside the six months period would attract maintenance fee.

Figure 2: The RM Engineer and Electrical Technician finalizing the solar PV installation

COMMISSIONING

Before the PV system was handed over to the rural communities, the solar PV team and the identified electrical contractor commissioned the system to verify that the installation had been done according to the plans and code requirements and to verify that the performance expectations had been met. This exercise involved visual observations and testing and measurements on the solar PV system hardware in the presence of the Energy Committee (see Figure 3 and 4). This procedure was done to ensure the safety and quality of the installation in accordance with the plans and applicable codes and standards and also for proper operation of the system. The electrical contractor was at the centre stage in carrying out following procedures in the whole process of commissioning:

- Completing final installation details
- Completing a system checkout and visual inspections
- Verifying the wiring insulation integrity and proper termination of conductors
- Completing system documentation and labelling requirements
- Performing initial start-up and operations
- Demonstrating and verifying shutdown and emergency procedures
- Verifying expected output and performance
- Conducting user training and orientation

After the electrical contractor in conjunction with WASHTED solar PV team completed the commissioning process, the installations were signed off as complete and ownership transferred to the offices of the District Education Manager and District Health Officer who in turn transferred ownership to the community in a formal handover ceremony.

Figure 3: Commissioning of Gumbwa Health Post: The Medical Assistant testing the system

Figure4: Commissioning of a Classroom Block in presence of the Head teacher at Gumbwa School

Figure 5: An Electrical Technician testing the solar PV installation during commissioning

MONITORING AND EVALUATION

Project Based Monitoring

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			SCHOOLS						Health Centres / Posts				
			Number of Learners			Number of Teachers			Number of Live Births		Number of Employees		
Location	Type	Date of Start of Operations	Male	Female	Total	Male	Female	Total	Births	Total	Male	Female	Total
Gumbwa	Primary School		502	535	1037	9	2	11					
Gumbwa	Health Post	Dec-13							None	0	2	0	2
Ndakwera	Primary School		858	802	1660	11	0	11					
Ndakwera	Health Centre	May-14							549	549	22	11	33
Chithumba	Primary School		369	343	712	10	0	10					
Chithumba	Health Centre	Aug-14							118	118	13	4	17
Dolo	Primary School		600	507	1107	8	3	11					
Dolo	Health Centre	Nov-14							262	262	22	8	30
		totals	**2329**	**2187**	**4516**	**38**	**5**	**43**	**930**	**930**	**59**	**23**	**82**

Table 3 – Solar PV SEP Impact Counts[3]

Different impacts were provided depending on the type of user. In total 4,516 learners (2329 male, 2187 female) now benefit from classroom lighting which is expected to improve their educational prospects. 43 Teachers (38 male, 5 female) at the schools were able to use the PV systems to deliver night courses, recharge their mobile phones, and use laptops. The health post and health centres have replaced alternative lighting (candles or torches provided by health assistants, 82 in total) with high quality lighting. At the health centres with a maternity ward, we estimate that 930 babies have been born since the Solar PV SEP project has been installed. Though we have not been able to confirm an increase in the numbers of babies born since inception, we suspect that, like other Solar PV projects in MREAP [10], the rate will increase as the community becomes aware of the lighting at the health centres.

[3]Number of learners and number of teachers were derived from current numbers (2014/15 school year) at the primary schools according to school records. The Gumbwa health post does not provide a delivery service so no value was monitored. The health centre employee count was recorded from reports provided by Health Assistants at between Dec 2014 and Feb 2015. Number of live births refers to healthy births for both mother and child and is an estimated figure. Yearly averages were provided by health assistants over the previous 3 years (659, 192, 720 per year at Ndakwera, Chithumba, and Dolo, respectively) which were assumed to be the current rate of births. We then estimated births while the Solar PV system was functioning by calculating the likely number of births over the number of days the systems were operating at the time of this writing (304, 225, 133days respectively).

SUMMARY AND CONCLUSION

It is clear from above that solar PV installation should always incorporate needs assessment exercise. The reason being it assists designers in the estimating the power demand required against the various applications for systems as demanded by the rural communities. Furthermore, based on the data obtained from the needs assessment, PV system over sizing, which escalates the cost, can be eliminated while satisfying the basic power requirements for the community.

Also a comprehensive sustainability planning should always be incorporated in the design process of a project. This would ensure that the PV system remain reliable and sustainable, and the communities maximize the productive use of the system. However, in future sustainability planning should include consultations with policy framers such as Department of Energy.

Renewable energy training should focus on practising electrical artisans and technicians living in the remote areas where renewable energy technologies are deployed. This will enhance availability of technical knowledge and skills for repairs and maintenance around renewable energy technologies in local rural areas.

On one hand, the installation of solar PV system should always consider the procurement process. This involves solar PV supplier analysis so that materials and equipment for PV installation should only be purchased from suppliers who have proven track records of selling not only good quality materials and equipment but those that maintain their availability. This involves selecting suppliers who (i) provide warranties on their products to cover for repairs and maintenance (ii) that is a qualified, responsible and experienced supplier of solar PV systems in the current market (iii) can deliver quality solar PV systems at the most competitive price and (iv) those suppliers whose equipment and materials met the international standard certification.

To maintain quality control and safety standards, it is important that only qualified personnel maintain and repair PV installations. It is not always easy, however, it is vital to identify qualified personnel. However, qualified personnel should always work with energy

committees to ensure that members in the energy committees learn skills on how to repair and maintain solar PV systems.

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ANNEXES

ANNEX 1: SCHOOL

Name of school:

Questions	**Answers**
General information:	
Type of school?	
No. of students?	
Total number of girls	
Total number of boys	
No. of staff?	
Men staff	
Women staff	
How old is the building?	
No. of buildings?	
Total floor area in m^2 ?	
Opening hours? Evenings?	
Any lessons in scientific subjects?	
Is the school closed during weekends and holidays?	
Do the staff stay in during holidays?	
Owner of building?	
The buildings	
Building construction materials?	
Roof construction?	
Roof slope?	
Roof elevation?	
Roof orientation, i.e. is it north, south, east or west?	
Any obstructions from tall trees or other buildings shading the roof?	
Electricity needs	
Please specify what is used for the following application, i.e.: • lighting: • water heating : • water pumping: • refrigeration: • radios • cellophane charging • ventilation, i.e. fans: • air conditioning (if any): • other applications:	
App. how many classrooms (incl. labs) and how many lamps needed in each? Wattage of these lamps? And how many hours per day will these app. be on?	
How many offices and how many lamps needed in each? Voltage of these	

lamps? And how many hours per day will these app. be on?	
No of lamps needed in the kitchen? Wattage of these lamps? And how many hours per day will these app. be on?	
No of lamps needed in each staff flat? Wattage of these lamps? And how many hours per day will these app. be on? And no. of staff flats?	
No of lamps needed in the hall? Wattage of these lamps? And how many hours per day will theses app. be on? Any other appliances, like videos, music equipment, etc.?	
Please specify other appliances available at the school and in the staff flats and their ratings?	
Hot water production / consumption:	
Is there any hot water production? If yes please specify how it is heated/produced and how it is distributed?	
Hot water in kitchen?	
Any hot water in the staff flats?	
Is there a distribution line for hot water to the staff flats?	
Are there any showers? If yes how many?	
Any data for the hot water consumption?	
How much hot water is app. used per day? In litres or m^3?	
General from your point of view:	
Do you see any energy saving possibilities? For instance for the lighting, cooking etc.	
Have you at anytime been looking at the possibilities for using alternative energy sources, such as solar thermal for hot water production, solar PV for lighting or other alternatives? Please specify.	
Any other remarks?	

ANNEX 2: HEALTH FACILITY

Name of facility:

Questions	**Answers**
General information:	
Type of hospital?	
No. of beds?	
No. of staff?	
Do the staff live within the hospital campus? If yes, state how many	
The buildings	
How old is the building(s)?	
No. of buildings?	
Total floor area in m^2 Please specify for individual buildings if applicable?	
Building construction materials?	
Roof construction?	
Roof slope?	
Roof elevation?	
Roof orientation, i.e. is it north, south, east or west?	
Any obstructions from tall trees or other buildings shading the roof?	
Produce sketch of building(s)	
Electricity:	
Please specify what electricity is used for and how much for each application, i.e.: Please specify what is used for the following application, i.e.: • lighting: • water heating : • water pumping: • refrigeration: • radios • television • cellophane charging • ventilation, i.e. fans: • air conditioning (if any): • heating water for sterilisation: • other hospital equipment: • other appliances, :	
App. how many rooms or wards and how many lamps in each room? Wattage of	

these lamps? And how many hours per day are these app. on?	
How many offices and how many lamps in each? Wattage of these lamps? And how many hours per day are these app. on?	
No of lamps in the kitchen? Wattage of these lamps? And how many hours per day are these app. on?	
No of lamps in the operation theatre(s) and laboratory? Wattage of these lamps? And how many hours per day are these app. on?	
No of lamps in the corridors? Wattage of these lamps? And how many hours per day are these app. on?	
No of lamps in the mortuary? Wattage of these lamps? And how many hours per day are these app. on?	
No of lamps in the Laundry? Wattage of these lamps? And how many hours per day are these app. on?	
Please specify other appliances available for instance in the staff flats and there ratings?	
Hot water production / consumption:	
Is there any hot water production? If yes please specify how it is heated/produced and how it is distributed?	
Hot water in kitchen? Hot water in the operating theatre and the lab.? Hot water in the laundry? Hot water in the staff houses (if any)?	
Any hot water in the toilets?	
Is there a distribution line for hot water to the staff houses (if any)?	
Are there any showers? If yes how many?	
Any data for the hot water consumption?	
How much hot water is app. used per day? In litres or m^3?	
Are there any running taps (cold or hot)?	
General from your point of view:	
Do you see any solar energy application possibilities? For instance for lighting, hot water consumption, etc.	
Have you at anytime been looking at the possibilities for using alternative energy sources, such as solar thermal for hot water production, solar PV for lighting or other alternatives? Please specify.	
Any other remarks?	

ANNEX 3:NEEDS ASSESSMENT RANKING

	INDICATORS															
SCHOOL/HF	1	2	3	4	5	6	7	8	9	10	11	12	13	Total	Rank	**LOCATION**
Chipwaila (HF)	0	3	2	0	1	1	0	0	2	2	1	0	-	12	9	Ngabu
Gumbwe	2	1	3	1	2	1	0	2	1	3	0	2	2	20	1	Kapichira
Thendo	2	3	3	1	2	1	1	2	1	0	2	-	-	18	5	Ngabu
Kandewu	2	2	2	1	1	0	0	0	1	3	0	2	0	14	7	Kapichira
Chithumba	2	3	2	1	2	1	1	0	1	2	2	2	1	20	1	Chapananga
Chang'ambika	2	3	3	1	2	1	1	2	1	1	2	-	1	20	1	Chapananga
Gola (HF)	0	3	2	1	1	1	0	0	1	2	2	0	-	13	8	Chapananga
Manderade	2	3	3	1	1	1	0	2	0	0	1	-	1	15	6	Ndakwera
Ndakwera	2	3	3	1	1	1	1	2	1	3	0	0	2	20	1	Ndakwera
Dolo	2	0	0	3	1	1	1	0	0	0	2	-	2	12	9	Ngabu
Mphambe (SCH)	0	3	1	na	na	na	na	0	0	3	-	2	0	9	13	
Nsenjere (SCH)	0	3	2	na	na	na	na	0	2	0	1	0	1	9	13	Ngabu
Saindi (SCH)	0	3	2	na	na	na	na	0	1	2	1	0	2	11	11	Ngabu
TBL (SCH)	0	3	3	na	na	na	na	2	2	0	-	-	1	11	11	

Table 3: Rankings of schools and health facilities based on weighted indicators (Source: Masangwe, 2013)

HF= health facility; SCH= school, na = not applicable

1. Existence of a school and a health centre at the same place
2. Level of community participation in projects
3. Committees found at the facility
4. Existence of projects at the facilities
5. Energy alternatives being used for lighting and powering radios at the facility
6. Existence of a refrigerator at the facility
7. Potential to assist maternal activities at the health centre?
8. Any security committee?
9. Availability of cellular networks
10. current energy services requirements other than lighting
11. No likelihood that national grid
12. Any self-help projects?
13. Enrolment at schools