Malawi Renewable Energy
Acceleration Programme (MREAP)

MREAP is led by the University of Strathclyde and funded by the Scottish Government. It has operated over 2012 - 2015.

University of Strathclyde Glasgow

Sustainability of Solar PV Institutions in Malawi

Dedicated Study

MREAP Strand: Institutional Support Programme (ISP)

Produced By: Damien Frame and Peter Dauenhauer, University of Strathclyde

Received: July 15, 2015

Abstract: The sustainability challenges of off-grid community energy projects using solar photovoltaics in Malawi have been widely acknowledged. However, little formal evidence has been produced regarding the factors that affect the sustainability of these projects. Under the MREAP, a study was commissioned to generate more conclusive evidence around the sustainability challenges of the current stock of schools, health centres, and other rural public institutions. An original data set consisting of performance data from 5 sustainability 'pillars', consisting of economic, technical, social, organizational, and environmental has been captured for 43 systems in rural Malawi. The results confirm existing anecdotal evidence and suggest that the majority of installed projects can be considered 'unsustainable' and at risk of failure in the near future. Many projects are now unsupported, are partially or completely non-functional, and are without reliable and effective means to resuscitate performance. Projects are ranked (relatively) in terms of overall sustainability and factors for improved sustainability are discussed. Our analysis demonstrates the complicated interactions between sustainability pillars and highlights the need for a holistic approach to project design and implementation.

MREAP is led by the University of Strathclyde and funded by the Scottish Government
For more information visit: http://www.strath.ac.uk/eee/energymalawi/
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The Scottish Government
Riaghaltas na h-Alba

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Abstract

The sustainability challenges of off-grid community energy projects using solar photovoltaics in Malawi have been widely acknowledged. However, little formal evidence has been produced regarding the factors that affect the sustainability of these projects. Under the MREAP, a study was commissioned to generate more conclusive evidence around the sustainability challenges of the current stock of schools, health centres, and other rural public institutions. Under this study an original data set consisting of performance data from 5 sustainability 'pillars', consisting of economic, technical, social, organizational, and environmental has been captured for 43 systems in rural Malawi. The results confirm existing anecdotal evidence and suggest that the majority of installed projects can be considered 'unsustainable' and at risk of failure in the near future. Many projects are now unsupported, are partially or completely non-functional, and are without reliable and effective means to resuscitate performance. Projects are ranked (relatively) in terms of overall sustainability and factors for improved sustainability are discussed. Our analysis demonstrates the complicated interactions between sustainability pillars and highlights the need for a holistic approach to project design and implementation.

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Executive Summary

Background

The survey reported here was carried out in 2014/15 as part of an extension to the Malawi Renewable Energy Acceleration Programme. Through the initial scoping and evaluation stages of MREAP, sustainability of off-grid PV systems was identified as a major issue for community renewable energy development in Malawi. The distinct lack of an evidence base from which learning can be drawn to inform stakeholders deploying renewable energy systems in Malawi and wider policy making was also highlighted. MREAP sought to build on available knowledge to promote sustainability within community energy projects deployed by the Programme and also initiate more robust evidence gathering to grow the knowledge base available to the sector. The sustainability study is an action deriving from an MREAP Programme Steering Group discussion around the existing installed base of off-grid PV systems at schools and health clinics around Malawi and in particular the perceived poor sustainability and lack of learning from these deployments.

The motivation of the survey was to better understand the types of systems previously installed in Malawi, identify which systems were still functioning and to gain insights as to performance across all aspects of sustainability. The approach to survey design was based on the concept of sustainability pillars (technical, economic, social, organizational, and environmental) each of which has a distinct section in the survey with relevant indicators and questions.

Conclusions

Specific conclusions with respect to pre-defined study questions are outlined below.

To what degree are systems performing as expected?

Overall, the system technical performance is poor. There are numerous systems in a state of complete failure or not meeting expected performance. An interesting aspect of the data is that the expected performance of lighting systems is mainly described as either completely not meeting expectations or fully meeting expectations. It is difficult to say if this is a wholly accurate representation of the system or an indication of difficulty in the questioning process to articulate and capture varying degrees of satisfaction. Nevertheless, large numbers of systems can be said to be not meeting expectations.

Summary of system performance issues:

- 38% of the systems have completely lost all service
- 58% of room lighting is not fully meeting expectations
- 43% of batteries are showing ‘bad’ battery health indicator
- 31% of the mainly CFL installed bulbs are not working

What components are used in system design?

The standard components that comprise PV systems (PV panels, Batteries, Charge Controller and Inverter) are found to be prevalent in system design as expected. However, there are significant numbers of obscure brands and hence doubts over component quality. The poor practice of inverter direct connection to batteries is common. Light bulbs are primarily CFL and experience high failure rates.

Sizing and quality of PV system components is critical to appropriate design. Standards in this respect appear to be lacking. The analysis strongly infers that although the Malawian renewable energy sector is regulated and there is an accreditation process of installers and suppliers, there are still serious issues with the supply chain and design process. Design and installation is often below standard and the overall technical sustainability is poor. Specific suppliers and installers are not identified in the survey therefore this issue cannot be linked to the use of non-accredited suppliers.

The ultimate responsibility for ensuring appropriate technical standards for PV installations lies with MERA, however with numerous local and international organisations working with communities across Malawi there is significant chance of proper process being bypassed. In many cases this may be simply a case of the consumer being unaware of how to ensure they are purchasing an appropriate solution. Whilst it is not feasible for all consumers and communities to be fully conversant in PV system design methods and be able to verify their system has been designed properly, the MREAP community energy toolkit emphasises the importance of using MERA accredited suppliers and this should be sufficient in principle. It should therefore be the aim of the sector to ensure that all MERA accredited suppliers are using suitably robust design standards and components. Likewise efforts to better inform consumers (in this case purchasing agents for institutional level PV systems) on minimum quality requirements would allow for better choices during procurement.

What factors are linked to high system performance?

High system performance is assessed as the working state of the system and its ability to meet expectations. Performance overall has been identified as poor. There are no exemplar projects that allow a comparative analysis of factors linked to high performance. For the many systems in a state of failure, the multi-faceted nature of sustainability and the limited scope of this retrospective study makes identifying specific underlying reasons for that failure difficult in most cases. However, it is clear from technical analysis that system design, and battery bank sizing in particular, is a critical factor and can be linked to more robust and higher performing systems. Nevertheless, there is also evidence of systems that are technically weak that are maintaining a high level of performance through regular repair financed externally that quickly returns systems to working order after failure.

Which systems can be described as "most" sustainable and why?

We define the most sustainable projects as those scoring highest within the sustainability rankings. In essence, the ranking defines a project as highly sustainable if it meets usage expectations, has relatively strong financial performance, is embedded and accepted within the community, and has the skills available to manage the project. It is essential that the systems are sufficiently technically reliable to maintain a level of performance that available financial resources can support. i.e. project finance can fund the necessary life-cycle costs, and most critically, 3-5 year battery replacement. The encompassing sustainability issues of community engagement, social and organisational structures are also of importance, however in the surveyed systems, insufficient to guarantee sustainability on their own. Although there are a number of surveyed systems that rank highly in all respects, their long term outlook is limited due to the lack of sufficient revenue and forthcoming requirement for battery replacement. Based on the survey responses, even a highly trained, organised and motivated community will be unlikely to maintain their system in the long term without a high standard of technical installation and a degree of external financial support for life-cycle costs. Therefore, it is not clear that an equal weighting across the pillars is appropriate. Furthermore, there may be an absolute minimum requirement for each pillar depending on the particular operational model, a nuance we have only brushed the surface of.

Recommendations

Ensuring the use of technically robust design standards and component choice is required for improved technical sustainability. Mechanisms to achieve this should be a priority for the sector and the role of all stakeholders in this should be considered (GoM, MERA, funders, suppliers, communities, etc).

For Community Energy Practitioners

- (Timeframe: immediately) Project design should be based on a sustainability pillars approach. Best practice for all sustainability metrics should be referenced and used to justify a fully sustainable project design prior to implementation. To improve learning, a common set of sustainability indicators should be included within project monitoring and evaluation.
- (Timeframe: immediately) Project designers to consider the role of district authorities in the sustainability of PV systems for schools and health clinics. The study suggests that even projects with apparently good sustainability assessments begin to struggle without external support of some sort. District support has been helpful, but sporadic. It could be made more effective by formalizing respective roles between community and district. Furthermore, linking up and demonstrating the impact of interventions to district objectives could provide the district with more leverage to invest and support such initiatives more widely.
- (Timeframe: immediately) Projects must include long term maintenance costs in project design and explicitly include a facility for this. Even the most successful community led income generation schemes surveyed have not been able to generate and save sufficient revenue for 3-5 year battery replacement.

For Academic Institutions

- (Timeframe: next 3 years) The study shows that previous community solar PV deployment appears to be highly dependent on limited-time donor-based funding that has not been shown to be particularly sustainable. Promising variations on the 'community energy' model need to be robustly tested and conclusions drawn proving long-term sustainability performance of these models.
- (Timeframe: next 3 years) An interface of regular knowledge exchange and policy briefings should be led by academic institutions to ensure government is utilising best practice and can plan for systematic issues such as district management of rural infrastructure.

For Government of Malawi

- (Timeframe: next 3 years) MERA to consider approved component list and to publish on-line design standards that accredited suppliers must comply with.
- (Timeframe: next 3 years) Investigate models where district authorities can partner and support community energy projects for education and health infrastructure, taking into account the cost structure and technical support requirements of deployed PV systems.
- (Timeframe: next 3 years) Support and promote the supply chain for LED light bulbs for renewable energy systems.

For Scottish Government

- (Timeframe: next 3 years) Require a lifecycle costing approach and model in place for any community energy systems funded

- (Timeframe: next 3 years) Require a sustainability pillars approach to project design with appropriate M&E that enables analysis of sustainability performance for any community energy systems funded
- (Timeframe: immediate) Disseminate results from MREAP and encourage similar approaches to M&E that enable further evidence to be gathered on sustainability performance

Further Work

Despite the limitations of this retrospective survey, many insights as to the sustainability of off-grid PV systems in Malawi have been obtained. It is clear that a more systematic approach to monitoring technical and economic performance of off-grid projects in addition to social and organisational sustainability indicators from project inception, rather than retrospective one-off surveys, would allow more robust research into causes of poor sustainability and potential solutions. Given recent initiatives in Malawi to establish M&E systems for community energy projects and remote-monitoring for off-grid PV systems, the opportunity exists to establish, maintain and grow a valuable data set to serve as the foundation for the ongoing refinement of understanding on best practice for sustainable off-grid PV systems in Malawi.

Acknowledgements

This study was part of the Malawi Renewable Energy Acceleration Programme and was funded by the Scottish Government. The authors thank the field teams at WASHTED, Mzuzu University and Concern Universal Malawi and Renew'n'able Malawi for their dedicated effort and input throughout all stages of the study process. We also acknowledge the motivation from the wider MREAP team in identifying the problem and inspiring this study. Finally, we thank the communities that contributed their time, information, and energy to answer all our questions!

1 Introduction

1.1 Energy Access in Malawi

Globally, nearly 1.3 billion people lack access to electricity. The sub-Saharan African country of Malawi currently supplies only 9% of its population overall [1]. Compared to other African countries, Malawi's rural electrification ranks relatively low at only 5% (see Figure 1). Those with access currently experience blackouts on a regular basis. For public institutions such as primary schools, the situation is equally grim. UNESCO reported only 10% of primary schools and 52% of lower primary schools had access to electricity in 2012 [2].

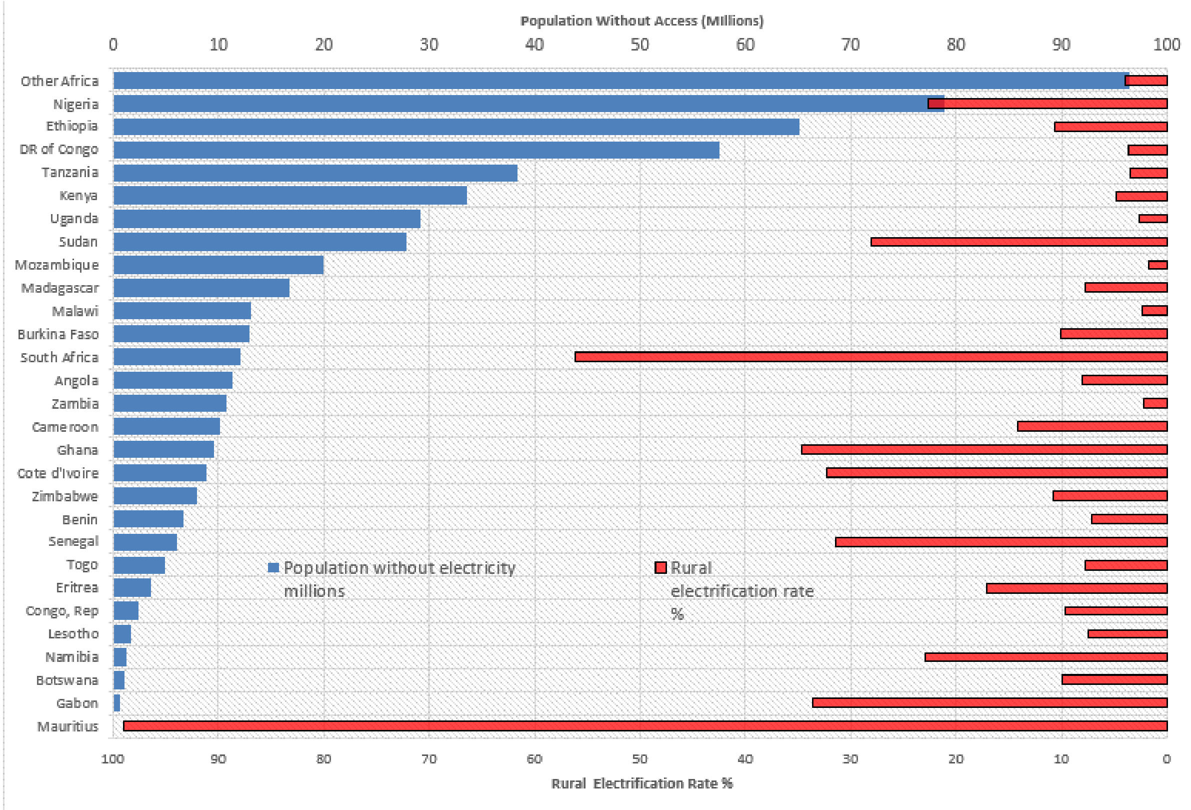

Figure 1: Sub-Saharan Africa Population without Access and Rural Electrification Rates (Source: [3], reformatted by authors)

For many developing countries, where the extent of the grid is limited, off-grid solutions such as stand-alone PV systems are the only real near-term option for basic services such as lighting and charging of mobile phones. Although they do not match the quality of supply (in some cases) of a grid-connection, they nevertheless provide important benefits and often to the poorest. The provision of basic electrical services to remote schools and health clinics is a popular application of solar PV. The International Energy Agency (IEA) are expecting up to 70% of future energy access to come in the form of mini-grids and other off-grid systems [3]. This implies 840m people connected through off-grid[1]. With this level of emphasis, it is critical to ensure the project-level sustainability of the new projects coming online and address weaknesses from existing projects.

[1] Though due to population growth, by the time they are connected, the number will be considerably larger.

1.2 MREAP perspective: motivation for studying sustainability

The Malawi Renewable Energy Acceleration Programme (MREAP) is a coordinated multi objective development Programme funded by the Scottish Government over 2012-2015 [4].

The issue of how to effectively address sustainability of off-grid community energy projects in Malawi has been a consistently recurring theme throughout MREAP. A scoping study for "support mechanisms for community energy" in Malawi, commissioned in 2010, strongly identified community engagement and support mechanisms as a sustainability measure though it did not identify research of sustainability factors as an explicit recommendation [5]. Building on this learning, MREAP's approach (especially with respect to the Community Energy Development Programme) emphasized community engagement, capacity building, and support as elements deemed critical to a successful and sustainable community energy project [6].

As MREAP commenced, an evaluation of the sector was undertaken [7]. As part of the evaluation, 12 case studies were developed covering the 3 regions of Malawi and included a range of renewable energy technologies (RETs) that were being used at the community and household level. These case studies were complemented by key informant interviews and a round table with members of the Government of Malawi in March 2012. In addition, the evaluation piloted an inventory of RETs that collated information from more than 270 installation sites which were undertaken by more than 30 development programs or projects spread out across Malawi's 28 Districts. Though wide in scope, many projects included in the inventory had only high level descriptive information. The main findings from the inventory and case study analysis indicate that poor technical sustainability in the areas of design, agreed usage, maintenance process, and monitoring are compounded by a lack of appropriate community engagement and long term economic planning. In addition, it found a distinct lack of an evidence base from which learning can be drawn to inform stakeholders deploying RET in Malawi and wider policy making.

The technology and impact focus of community projects in MREAP were primarily determined via a thorough community engagement and needs identification process. Many of the projects chose solar PV applications for schools and health posts as community priorities. The potential benefits of such services are well accepted and evidenced by previous Government and donor initiatives to deploy solar PV in off-grid locations. However, as a public service with no obvious business model, on-going support of such systems place an onerous burden on already stretched local government health and education burdens and much of the observed sustainability issues are evident in previous installations.

Following the consensus among the MREAP partners and sector colleagues at the Programme Steering Group Meeting in November 2013 that rural community based Solar PV projects continued to face sustainability challenges, a study was proposed to learn more about the factors behind project success and failure [8]. On the whole, attendees agreed that further exploration into all of the factors of the sustainability nexus would benefit the sector as a whole and develop a stronger evidence base than provided by the Scoping Study, Evaluation, and other anecdotes that were available. The focus was agreed to be school and health clinic systems. As a result, this study has been proposed under MREAP and was funded by the Scottish Government through an extension of the Programme in 2014.

1.3 Defining Sustainability

Due to its ubiquitous use, it is useful to adopt a working definition of "sustainability" here as: "the perceived potential for a system or project to endure, build a self-perpetuating capacity within a community, and ultimately reach the end of its predefined life span or evolve into another beneficial form" following [9].

Figure 2 outlines a general framework for consideration of sustainability and connects up the relative role of the project design and implementation phases. This represents the conception of sustainability used in this study. Because the project is strictly constrained by the project design phase, sustainability itself will be linked the decisions made on the design earlier on. Finally, the whole project sits within a set of institutions (i.e. legal, governance, economics, etc.) that enable, detract, or constrain the project as the case may be.

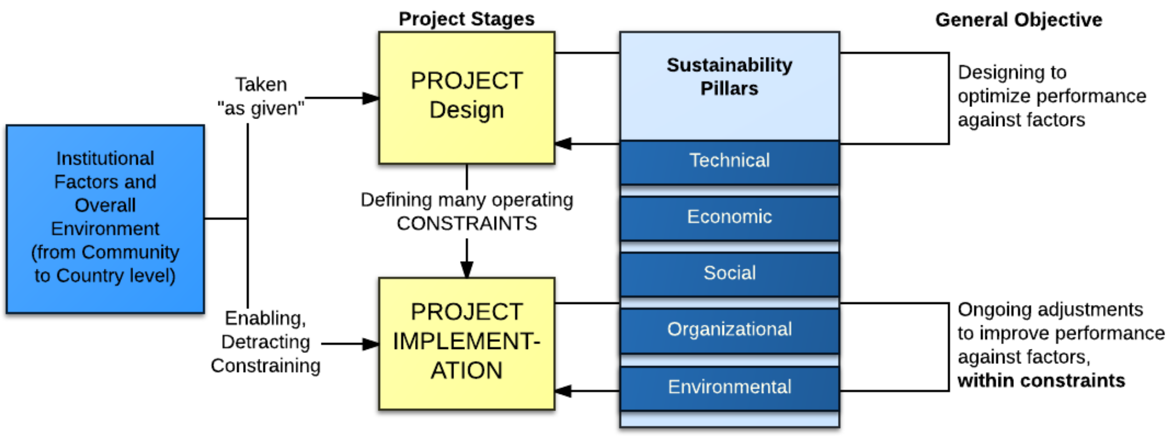

Figure 2: Sustainability Pillars and Project Design

Within the Solar PV Sustainability Study it is used as the framework for analysis and evaluation of sustainability factors in retrospect, that is, after the project has been installed and is operational. The approach to survey design was to capture a set of indicators from included projects that were related to the various sustainability pillars that ultimately allows for comparison and further analysis. Each sustainability pillar (technical, economic, social, organizational, and environmental) has a distinct section in the survey with relevant questions. In analyzing the results we review responses for each indicator individually and then undertake a ranking process, scoring projects against each of the indicators.

A full discussion and background is provided in APPENDIX - Conceptualizing Sustainability.

1.4 Study Objectives

The motivation of the survey was to better understand the types of systems previously installed in Malawi, identify which systems were still functioning and to gain insights as to performance across all aspects of sustainability. With momentum growing for internal policy makers to encourage future off-grid projects, learning from past results is critical for their success.

Four key study questions were used to shape the survey:

1. To what degree are systems performing as expected?
2. What components are used in system design?
3. What factors are linked to high system performance?
4. Which systems can be described as “most” sustainable and why?

1.5 Report Structure

This report has been structured to present the results of the survey with respect to the sustainability pillars described above. Sections 2 and 3 will describe the methodology in further detail, Section 4 introduces the projects and provides some high level overview results, Sections 5 – 8 present detailed results for each sustainability pillar. Section 9 discusses social impact. Section 10 introduces a sustainability ranking for the projects and interpretations. The first three study questions are primarily addressed in the Technical Sustainability section (5). The final question is addressed by assessing the survey results for all sustainability pillars in Section 11. Sections 12 and 13 provide discussion and conclusions and set out recommendations and directions of future research.

2 Method

2.1 Data Sources

Data was gathered through interviewer led surveys held at 43 individual projects. The survey was developed through a collaborative effort between RENAMA and the University of Strathclyde. The survey consisted of 8 sections including basic project information, data sources available at the project, "sustainability pillars" (technical, economic, organizational, social, environmental), and impact data.

The survey was reviewed by the field partners (Washted, Mzuzu University, Concern Universal) and trialed by two field partners prior to deployment. Following the trial, the survey was revised with minor changes. Surveyors from all field organizations were trained to ensure questions and interpretations were well understood. Furthermore a guidance document was produced for surveyors.

Each field partner had a defined area of operation: North, Central or South. Field partners were responsible for conducting the survey at a mix of sites selected by the field coordinator (RENAMA) drawn from the Energy Project Database [21]. Projects from this database had only basic information recorded: name, location, contact number – so were relatively unknown. All sites were to involve off-grid solar PV electrification of either a primary school, secondary school, or health centre. Several locations could also be chosen by the field partner, but the intention was to diversify the selection of projects so no more than 3 could come from one specific area or implementing organization. Projects selected by the field coordinator were at random from the database.

The selection of projects that were surveyed unfortunately cannot be assumed to be a random sample. The objective of the selection approach was to balance the logistical and budget constraints with the desire to include a diverse portfolio of projects throughout Malawi. The Energy Project Database does not include the comprehensive set of projects in existence in Malawi, indeed MREAP had identified this issue during the 2012 evaluation [22]. Despite these limitations, the results do provide a depth of information previously unavailable on the sustainability of projects throughout Malawi. This information and analysis has both a direct value for community energy practitioners, and the approach itself can be considered for future analysis.

2.2 Survey Implementation

Surveyors were given guidance on how to introduce the study objectives to the respondents with a script, in Chichewa, in order to reduce inordinate setting of expectations and a process for informed consent. During delivery, the surveyor would use a structured questionnaire while seeking answers from the respondent, typically a project lead on site. Elements of the survey which were purely observational (i.e. observed number of panels and manufacturer's capacity rating) could be recorded without the respondent. In practice surveyor teams that included more than 1 individual split up to conduct the questionnaire with the respondent concurrent to gathering observational data.

Due to the length of the survey, it was suggested to surveyors to allow for up to 4 hours to complete the full survey. Respondents were offered refreshments and it was suggested that breaks between survey sections be provided, if needed. Surveyors were to attempt to complete the survey in full during a site visit but were allowed to follow up after the site visit concluded. In some cases this included following up with contacts provided by the main respondent, such as contractors involved or local non-governmental organization partners.

The surveying period was November 2014 in the central region and April 2015 in the North and Southern regions.

2.3 Data Entry

Following surveys of the 45 surveyed projects, 43 returned a completed questionnaire. Field partners were responsible for data entry into Excel based forms. Of these 43 projects, data quality issues prevented the inclusion of two secondary schools from the Northern Region and one TDC from the Southern Region resulting in the final data set consisting of 40 projects across the regions. The total number of systems assessed in the 40 projects was 113 and the total number of lit rooms was 219.

Although 40 completed surveys were taken forward for analysis, none were 100% complete across all data fields as, due to the natural variation between system types, the level of access granted to the surveyor and the knowledge of the respondent, not all data points were registered for each system. Throughout this report, the number of observations is provided alongside each statistic. For example, where a result is presented as a percentage of systems or percentage of rooms, this value is a percentage with respect to the total valid data entries for this data field, not necessarily a percentage of all systems or rooms.

2.4 Data Analysis

The completed survey data was entered into spreadsheet templates by the field partners. A regional surveyor report was also completed by each field partner based on their individual experience conducting the survey. This report was structured both to explore issues with the process of conducting the survey and to elicit analysis from the field partner that would ultimately be considered in the final analysis.

As a formal database design and build was not within the scope of this project, data analysis was undertaken via Matlab and bespoke scripting. All spreadsheet data was read to Matlab and stored in a data structure that allowed querying of specific questions and some basic statistical analysis.

2.5 Limitations

This section discusses limitations to the study and expected implications. Limitations include the selection approach, capacity, logistics of enumerators, and potential respondent issues.

Firstly, the selection process was designed to select a variety of projects types such as: varying age, geographically distributed, size of system, and type of institution. Field partners were allowed to select a small number (less than three) projects, while the remainder were suggested by the field coordinator who populated a list from the CONREMA database. The suggested projects were separated by region (North, Central, and South) and passed to the respective field partner. This database is in a nascent stage and typically has only basic information on projects. The CONREMA database does not track all projects nationally, so we do not have the full population of projects to sample from. As such, the selection process is not randomized, though this limitation was known at the start of the study. The reader should be aware that conclusions can therefore only be drawn on the sample of selected projects.

Second, the understanding of the survey by the enumerator may have resulted in error due to mis-interpretation or mis-communication. The design team conducted at least 2 training sessions with each field implementer to clarify sections and come to consensus on question/response meanings. Furthermore, a pilot was completed by each implementation team. Despite these measures, after data entry there were some internal inconsistencies of data that required exclusion of parts of the data set and furthermore suggest that enumerators required more training. One example was system usage information indicating a system is fully functional while follow up questions would otherwise indicate the system is in the state of a failure. After the first phase of data entry, any inconsistencies were discussed with enumerators and adjusted or, if we had low confidence, excluded.

Another prime example requiring clarification was during the interpretation of sections with missing data. Throughout the survey, many sections and questions did not have answers. Where appropriate options were given for "other" and "don't know" to capture this possibility. However, enumerators tended to prefer to leave sections blank when there are no possible answers. For example, many projects lacked any sort of financial model so the whole section was left blank. Similar to the previous section, in these cases we confirmed the enumerator's interpretation of and how it should be coded.

Accuracy of respondent answers is another area of potential limitation. The survey involves sections requiring the enumerator to directly gather data (e.g. recording system components) and sections where the enumerator asks question to respondents available on site. Several challenges were experienced here.

- First, availability of qualified respondents was not always secured. In this case we generally received sparser data sets when these respondents were not able to answer all the questions. In some cases, we followed up with several respondents to confirm an answer (such the technician who installed the project or a local NGO who kept records).
- Second, since many projects were relatively older, full project information was often unknown by *current* staff. Many rural facilities have staff that move frequently and replacements are unaware of inception information, in particular, capital costs, contractors, and funding sources. This could also affect time-sensitive answers such as whether theft or total system failure was ever experienced by the project.
- Third, respondents may have had difficult in recalling information even when they were present and could therefore provide an answer. We attempted to reduce this recall burden by optionally allowing respondents to estimate (i.e. what is typical monthly income? OR what was last month's income?), or offering the option to not answer if respondents were uncertain. Furthermore, enumerators indicated that, in person, they felt reasonable confident in the accuracy of the responses we received.
- Fourth, it is possible that respondents may have answered questions to satisfy the surveyor. The survey took at minimum 2 hours to complete and for larger projects up to 4 hours. During design we identified respondent fatigue this as potential risk and designed the option to take breaks in between sections. It was also suggested that enumerators provide a light refreshment to the respondent if desired.
- Fifth, there is reason to believe that hidden biases could have influenced answers. For example, the respondent, assuming that funding opportunities would be forthcoming, could have provided responses that put the project in a better light. Likewise there could be an incentive of project managers for hiding thefts or abuse of position such as through not reporting financial performance. As the range of potential biases is quite high, we do not attempt to respond to the comprehensive list. The approach to minimize this included an opening statement clarifying the objectives (and limit of involvement) of the study. Sections often had more than one questions that would allow for consistency checks of the answers. Finally, enumerators were asked whether they thought, in person, there was any indication of respondent deception; which returned as negative. As a result we have assumed that answers were truthful and free of bias.

Third, as a result of the physical distance between field surveyors and the analysis team, an enumerator reports was designed to capture specific feedback from the enumerators. This was meant to better understand the study process as well as capture the enumerator's analysis for their regional data.

Finally, the environmental sustainability section had to be excluded from all data sets as we suspected, based on qualitative answers and enumerator reports that it was misinterpreted to mean "global" environmental sustainability rather than specific local effects as intended.

2.6 Availability Survey Instruments and Data

Annexed to this report are several useful tools as well as the survey instrument that is shared for other researchers to extend and improve the approach taken here. Users are encouraged to contact the corresponding authors for questions and to explore potential collaborations.

Available tools:

- Solar PV Survey (Annex 1)
- Survey Guidance (Annex 2)
- Excel based Data Entry form (Annex 3)
- Field coordinator Report (Annex 4)

Data will be available for research purposes upon request from the authors and is also available via the CONREMA database managers.

3 Overview of Projects Surveyed

3.1 Projects, Systems and Rooms

Table 1 provides a breakdown of the surveyed projects, detailing the type of project and the numbers per region. The projects are mainly Primary schools and Health Centers, this is deemed to be representative of the national picture of off-grid PV installations. The three 'Other' projects were two Teacher Development Centers and a Youth Club.

Two southern health centers are actually Mission Hospitals that also utilize ESCOM power with PV as a switchable standby power source. As such, most data was not relevant for comparison with the other projects.

No.	Type	Central	North	South
17	Primary Schools	8	6	3
5	Secondary Schools	2	2	1
18	Health Centers	6	5	7
3	Other	0	0	3

Table 1: Project Types

The term 'project' refers to the site location where a PV installation has taken place, e.g. at a primary school. In most cases there are numerous individual PV systems within a project that provide a range of services to the stakeholders. The majority of systems are installed on a per building basis.

In addition, each system may provide a range of services to a number of rooms within that building. The questionnaire was therefore designed to capture data at project level, system level and room level, as shown in the questionnaire extracts for a school with one classroom and three staff houses (see Figure 3, Figure 4).

1.01	**Number and ID# of Systems in Project** *(example: #1 Store Rooms & Vaccine Fridge, #2 Teacher Battery Charging, #3 Phone Charging & Lighting Classroom 1+2) – if more systems than rows, add on the backside in same way; clearly indicate question number.*	1.02	**When did the solar system(s) start operations?** (Month, year; if different dates, mention per system
Number (#)	*System Description*		
1	Classroom		2014
2	Staff House		2014
3	Staff House		2014
4	Staff House		2014

Figure 3: System Data Entry Example

System #	Room #	Room Type				AC / DC		Total # of light sockets/ fittings	Number of working lights
		Classroom / Maternity Wing	Office	Staff House	Other	AC	DC		
1	1	x				x		7	7
1	2	x				x		1	1
2	1			x		x		1	1
2	2			x		x		1	1
2	3			x		x		1	1
2	4			x		x		1	1
2	5			x		x		2	2
3	1			x		x		1	1
3	2			x		x		1	1
3	3			x		x		1	1

Figure 4: Room Data Entry Example

4 Technical Sustainability

In this section, the results drawn from analysis of the technical sustainability data are presented and discussed. Technical sustainability is the ability of the system to operate reliably and provide the expected level of energy service for the planned system life-span. The initial design of the system is critical. It must be based on an accurate understanding of expected service requirements and robust assumptions around solar resource and component efficiency. For example, should the solar resource be over-estimated, the daily energy demand under-estimated and PV panel and battery efficiency over-estimated, the system will quickly fail to meet expected service standards and battery degradation is likely. Quality and reliability of components is also a major factor for technical sustainability.

Each project has a variable number of systems that include classroom blocks, delivery rooms, offices and staff homes. Each system is analyzed as a single entity and can range from a single panel and battery home system to a multi component system powering multiple classroom blocks.

4.1 Overview of Technical Issues

Off-grid solar PV systems follow a common design and component choice format. Solar PV panels are connected to Battery Storage via some protection and control electronics usually in the form of a Charge Controller unit. Lighting and other electrical loads will normally be connected to the system via the charge controller. If AC power (grid style supply) is required, an inverter will be required to change from DC supply to AC supply.

PV Panel Orientation: The solar PV panels must be positioned at the correct angle and facing in the correct direction to achieve maximum conversion of the solar energy into electrical energy. For static systems in Malawi, panels should be facing north with a tilt angle of approximately 25 degrees[2].

Battery Health: Batteries commonly used for PV systems are quoted to have lifespans from 5-15 years[3], however this is highly dependent on the operating temperature and how heavily the batteries are used[4]. Protection from the environmental conditions and appropriate ventilation are the essential minimum requirements for a lead acid battery bank. 3 years could be a realistic expected lifespan for batteries in PV systems in Malawi.

Component Choice: PV Panels, batteries, charge controllers and inverters are imported and distributed in Malawi by regulated suppliers[5]. Imports of established brands from Europe, South Africa and China are well established. The importance of reliable, high-quality components is paramount to the technical performance of the system.

PV system design: The first stage in the design process is to estimate the average daily energy requirement (load) in Watt-hours (Wh). Using this 'design load' the PV array and battery bank are sized using the appropriate design equations. The PV array sizing aims to meet the average daily load whilst accounting for system losses and inefficiency. The battery bank sizing aims for a battery capacity that can deliver the average daily load (adjusted for losses) without dropping below a chosen level of charge, for a chosen number of days without being recharged (days of autonomy). What

[2] Optimum Tilt Angle for Photovoltaic Solar Panels in Zomba District, Malawi http://www.hindawi.com/journals/jse/2014/132950/
[3] http://www.ra-un.org/uploads/1/6/7/1/16716340/evaluation_of_battery_storage_technologies.pdf
[4] http://solarray.com/TechGuides/Batteries_T.php
[5] http://www.meramalawi.mw/documents/Regulated%20entities-nov-2014.pdf

varies between design approaches are the assumptions made on solar PV resource, required days of autonomy and system efficiencies. The balance to be made is between cost (increased size of system) and sufficiently robust assumptions.

A simple PV system design process is summarized below.

1. Estimate the average daily load in Watt hours
2. Find the required PV panel array daily output by multiplying daily load by an efficiency factor (assumed as 1.3 here)
3. Find the required Watt peak output of the panel array
   a Divide the required panel Watt hours by the local Panel Generation Factor[6] (PGF assumed to be 3.7 for Malawi).
4. Find the required battery bank capacity in Amp hours
   a Divide the average daily load (Wh) by the system voltage to obtain Amp hours
   b Include efficiency factor (multiply by 1.3)
   c Scale by the maximum discharge rating of the batteries (assumed 80% here)
   d Scale by the chosen number days of autonomy (3 days)

Solar PV design resources contain a range of approaches and assumptions. The assumptions made here are those recommended and used within the MREAP program, adopted from the more conservative, high standard design methodologies available [20]

4.2 System Age

Systems were established over a considerable range of dates from 1998 to 2014 (Table 2). A third of these were installed in 2010 (due to 4 particularly large school and health clinic projects in 2010 with numerous systems). 70% of systems included in the survey were installed prior to 2012. As such, 70% of the surveyed systems could expect to have experienced, or be currently experiencing battery issues.

Year	1998	2003	2006	2007	2008	2009	2010	2011	2012	2013	2014
% Systems	4%	2%	14%	7%	3%	2%	33%	5%	8%	8%	14%

Table 2: System Establishment Date (number of systems observed =94)

4.3 System Components

The initial sections of the questionnaire capture basic information on system technical characteristics. The results from these sections indicate that the most basic requirements of a PV installation (secure PV panel mounting and correct orientation along with secure and well ventilated battery bank enclosures) are not ubiquitously met.

The number of unventilated battery banks should be of particular concern as is the level of suspected tampering.

Summary of Basic Installation Measures

- 77 of 82 systems are north facing
- 79 of 81 systems are roof mounted
- 56 of 66 battery banks have a solid enclosure, 20 of these are unventilated
- 23 of 71 systems show signs of tampering

[6] The PGF is a function of the site location's 'peak sun hours' and assumptions on system efficiency

Component Details

A summary of the components deployed within the systems is provided in Table 3. Number of observations are shown in parenthesis.

The results indicate that well-known, quality brands are the most prevalent PV system components, however high numbers of 'alternative' brands are also evident. The judgement of brand quality is based on the survey team's combined experience of solar PV installation. In addition to the 36% Raylite and 30% BP Solar results shown in Table 3, 23% of battery brands and 25% of PV panel brands observed have been categorized as 'other'. In particular, Inverter brands appear to be a range of imported brands with unknown reputation and quality.

Component	Batteries	Panels	Charge Control	Inverter
Brand	Raylite	BP Solar	Steca	Power
% of Systems in bin	36% (73)	30% (83)	45% (77)	36% (47)
Rating	96-120 Ah	75-120 Wp	8-15 Amps	200-300 W
% of Systems in bin	58% (74)	43% (95)	52% (67)	52% (46)
Number	1	1	1	1
% of Systems in bin	50% (92)	53% (104)	79% (99)	46% (113)
Missing	8% (49)	0%	1.1%(55)	19% (37)
Health Indicator Bad	43% (40)		3% (33)	
Inverter connected direct to battery			67% (70)	
No Inverter				53% (113)

Table 3: Summary of System Components

Component ratings indicate approximately half of systems are single panel, single battery systems, implying a high penetration of home systems around school and health center installations. There is relatively low incidence of missing components, indicating that theft rates are low. The component most likely to be missing is an inverter which, as an easily removable component that can be utilized flexibly outside of the system, is an unsurprising result. Inverters are not ubiquitous across the systems, 47% of systems are DC only – implying a focus on lighting as the priority service. Battery health appears to be a major issue with 43% of the observed battery banks displaying a poor health indicator[7].

4.4 Performance of Lighting Systems

For every system that included a lighting service, the following information was recorded for every room that contained lighting:

- Room Type
- Power supply = AC or DC
- Number of installed light fittings
- Number of working lights
- Bulb type = CFL or LED
- Bulb power rating in Watts
- Actual usage of lights in that room (hours per day and days per week)

[7] Good quality deep cycle batteries have a 'Magic-eye' window built-in that provides an indication of state of charge for one of the battery cells. This is an approximation, but a good first pass test of battery health.

- Expected usage of lights in that room (hours per day and days per week)

The results are summarized in Table 4 below. Of 598 installed bulb fittings, 416 (or 70%) contain working bulbs. As would be expected, LED lights as an emerging technology have a low penetration and most lights are CFL technology. Bulb power ratings are in the expected range for energy efficient CFL bulbs. Interestingly, not all systems have utilized the standard DC lighting approach, with 20% supplying lighting with AC power via an inverter. Although this may have implications in the power quality and reliability required from the inverter (i.e. higher cost), AC powered light bulbs are more widely available from non-specialist retailers.

Lighting Data						**Number of Observations (rooms)**
Bulb Type	CFL	LED				
% Rooms	95%	5%				173
Bulb Power Type	DC	AC				
% Rooms	81%	19%				178
Bulb Rating (W)	<8	8 to 11	>11			
% Rooms	13%	75%	12%			194
Bulbs Working	0%	1-99%	100%			
% Rooms	44%	8%	48%			213
Expected Days per Week	5	6	7			
% Rooms	3%	1%	96%			193
Expected Hours per Day	<2	2 to 4	5 to 11	12	>12	
% Rooms	6%	54%	10%	20%	10%	192
Number of Bulbs Installed		**598**		**Number of Bulbs Working**		**416**

Table 4: Lighting statistics for all rooms in all systems

Comparison of the numbers of bulbs working versus installed fittings on a per room basis produces an interesting result (Figure 5). It appears that rooms will mainly have either all bulbs working (48% of rooms) or no bulbs working (45% of rooms). This can partially be attributed to household installations with small numbers of light fittings where an all or none situation may be likely. In addition, it has been observed by the project team that where light failures start to occur within a project, working bulbs will be repositioned in priority rooms to provide a good quality service in at least one room as opposed to partial service in multiple rooms.

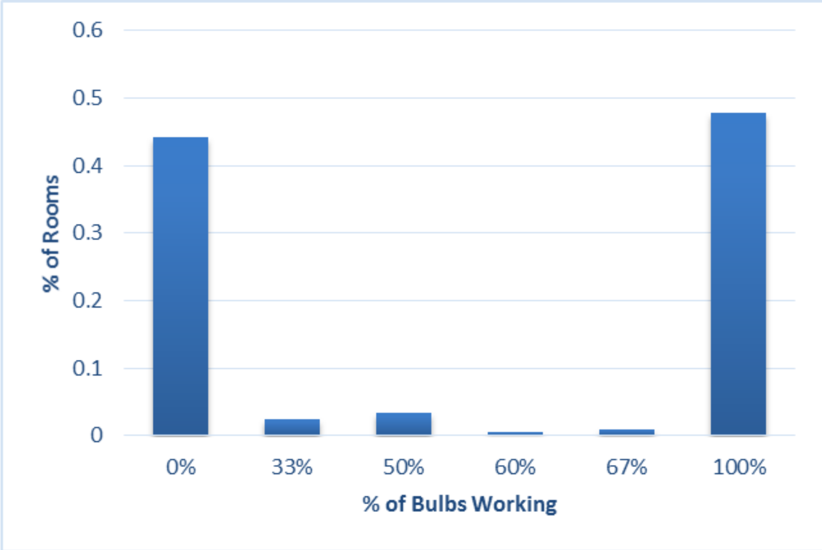

Figure 5: Numbers of bulbs working versus numbers of installed fittings

The data on expected usage reveals that lighting is almost always expected to be utilized 7 days per week. Hours per day usage figures are concentrated in the range of 2-4 hours and around 12 hours. This aligns well with standard design of lighting for 3 hours in the evening for social and business use and 12 hours a night for external security lighting.

Figure 6 displays data for the expected weekly house of lighting. These values are derived by multiplying expected days per week by expected hours per day for each room. This approach is common to the established methods used in PV system design to calculate average daily usage. Excepting the security lighting (84 hours), an approximate bell curve is produced with a mean around 21 hours (7 days at 3 hours).

7 days at 3 hours of use is a fairly common design assumption. However, electrical design standards often utilize at least a 90% confidence factor for load estimation. As a point of interest, for our data, it appears that roughly half of the systems would be considered undersized when compared to the standard design assumption for PV lighting of 7 days x 3 hours.

Any design assumptions that imply working week (5 day) usage for e.g. school blocks, offices, health posts, should be carefully qualified. This data would suggest that a more robust lighting load estimate would be 7 days at 5 hours per day.

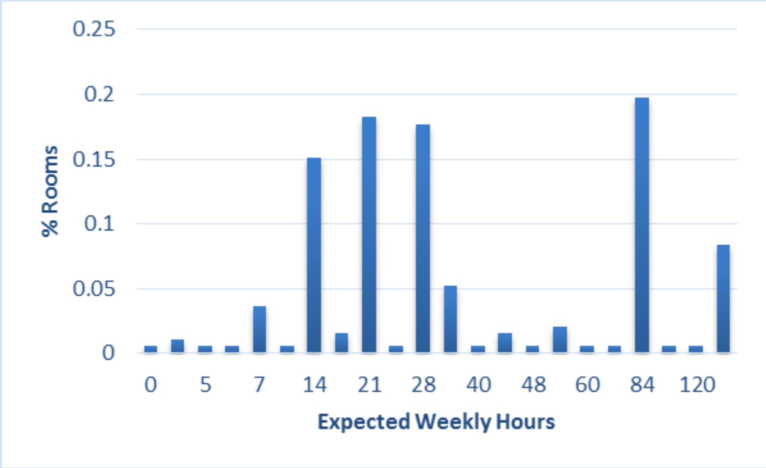

Figure 6: Accumulated expected usage in a week

As a measure of system functionality, we compared the expected weekly usage with the recorded actual usage on a room by room basis (Figure 7). The results reflect the statistics for rooms with bulbs working, in that performance is mainly polarized as either entirely meeting expectations or completely failing to meet expectations.

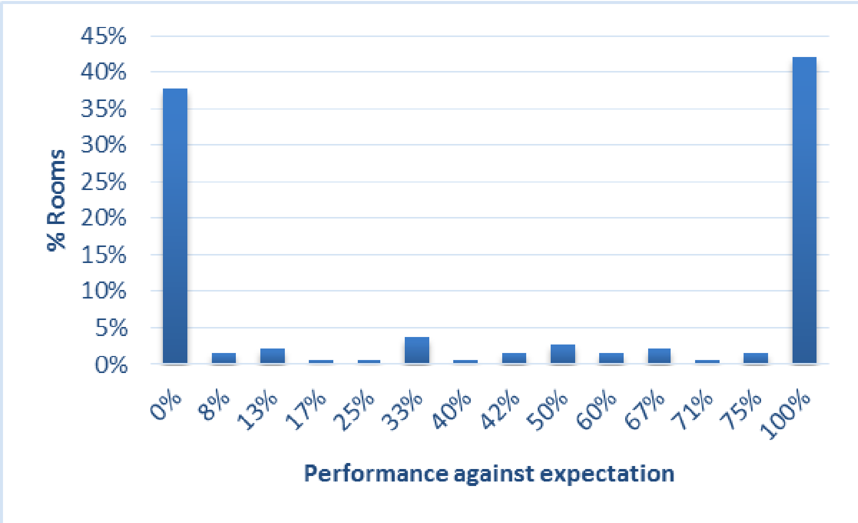

Figure 7: Actual performance versus expected performance

When plotted against age (Figure 8), a trend of poorer performance in older systems is observed. 70% of systems were installed prior to 2011 – more than half of these (65%) are not meeting expectations. However, a significant portion of older systems are still meeting expectations, indicating that age is perhaps not the main factor in sustainable system performance.

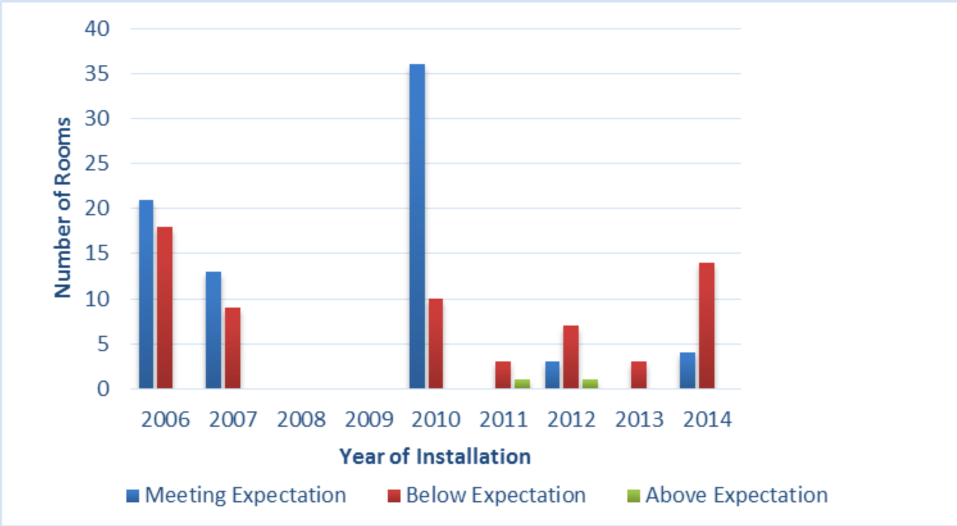

Figure 8: System performance by year

4.5 Analysis of System Sizing

The survey data provides the expected usage (or electrical loading) of the system as well as the installed components that are attempting to meet that load. By applying established PV system design methods, as described in Section 5.1, an estimate of the required system sizing can be obtained from the expected usage data. The actual installed system size can then be compared to the estimated requirement and the 'fitness for purpose' of the systems can be assessed.

Figure 9 and Figure 10 display the estimated fitness for purpose of the PV array size and battery banks for each system as the ratio of installed capacity to estimated required capacity. In both cases there are systems that appear to have dramatically oversized or undersized capacity. Given the data for this estimation is based on a respondent response and subject to the limitations presented earlier, there is a fair likelihood of error in the provided data[8]. Nevertheless, the majority of results appear sensible and it is a significant finding that large numbers of systems appear to be undersized[9].

As a result, 44% systems have undersized PV arrays and 83% of systems have undersized battery banks.

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[8] In the most extreme cases the entered data is incomplete or incorrect (entered as a voltage rating rather than a power rating for example).

[9] For the purposes of this analysis, consistent respondent overestimation of expected use would bias the result towards the systems being considered "under sized". In many cases it is also likely that expectations over time have increased. However we argue that the current usage expectations are now most relevant to the sizing exercise and a good design process should have properly assessed future expectations.

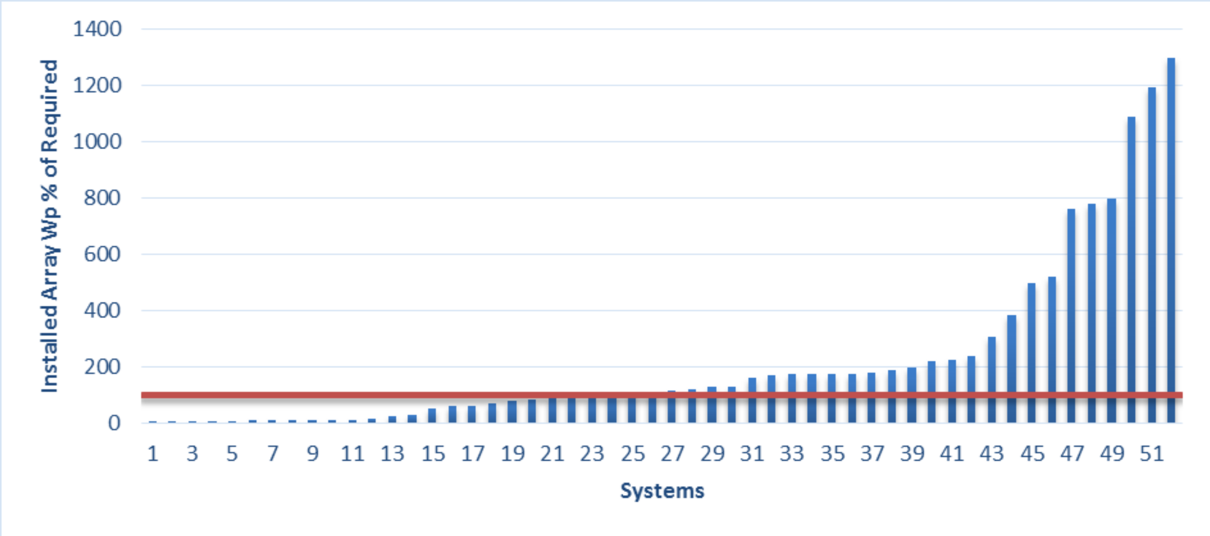

Figure 9: Ratio of installed PV array size (Watt peak) to estimated required size

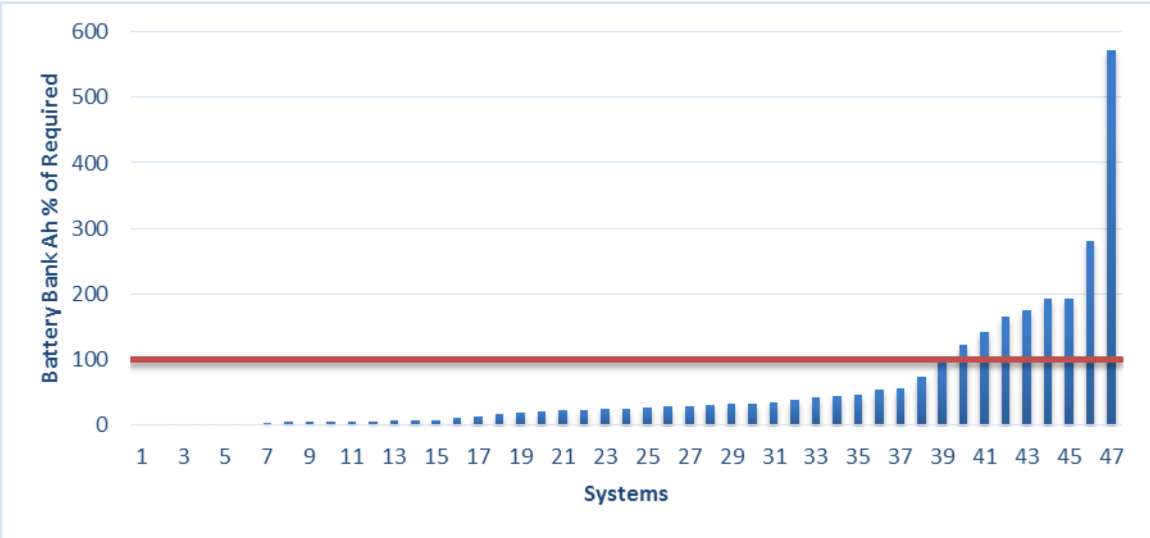

Figure 10: Ratio of installed battery bank size (amp hours) to estimated required size

4.6 Sustainability Symptom Analysis

In addition to data on system components and system usage, the survey also sought to capture particular symptoms of poor technical sustainability as an additional insight to the user perception of their system performance. The symptoms are described below and the results are summarized in Table 5.

All service lost: System is in a complete state of failure.

All lights lost/All power lost: Option to identify partial loss of service. This indicates a fault specific to a particular load type.

Lights/Power in day only: Some services work, but only during sunlight hours. This indicates that the PV panels are supplying power, however a failure in battery storage means no energy available at night time.

Lights/Power for short time at night: As above, however the battery failure is not complete and can provide a limited service.

Symptoms	% Systems
All service lost	38%
All lights lost	7%
Lights in day only	7%
lights for short time at night	12%
All power lost	4%
Power in day only	5%
Power for short time at night	5%
% Systems with any Symptom	45%
Number of systems observed	74

Table 5: Technical Sustainability Symptoms for Central Projects

45% of systems have experienced some kind of symptom with their lighting or power service, however most significantly, 38% of systems have lost all service.

5 Economic Sustainability

In this section the survey economic data is presented and discussed. Economic sustainability concerns the continued financial well-being of the off-grid project. This is determined by understanding the full cost and income structures and assessing the ability to meet operation and maintenance costs (short-term and long-term) in addition to respond to unexpected system failures. As a qualitative survey without access to retrospective financial accounts, the key factors for assessing economic sustainability were identified as the presence of any financial management structures or process and a qualitative estimate of typical monthly income, operation and maintenance costs.

The survey asked, at a project level, for an estimate of typical monthly income and expenditure. Figure 11 shows the headline economic sustainability indicators. Only 11 projects (27%) have any kind of income at all. Of these only 6 (15% of all projects) also have a bank account.

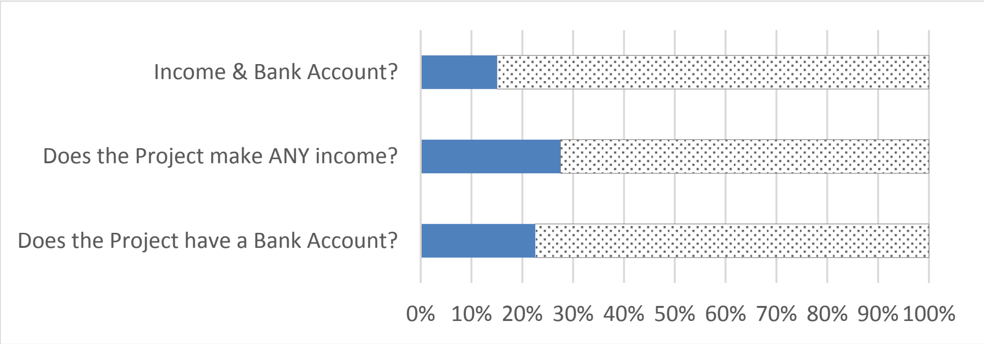

Figure 11: Project Economic Sustainability Indicators (blue = yes)

5.1 Project Income

For the full 40 projects, the mean and median monthly income was 1,832 MW, and 0 MWK respectively. We restrict the data set to projects which have a recorded income. 11 projects provide detail on income, a similar number of projects provided data on monthly operation and maintenance costs, although not necessarily the same set of projects in each case. Some of the projects report significant costs but little or no income; an interesting observation which either points to a hidden income source supporting the project or a sustainability risk.

From the restricted data set, a representation of the monthly finances is provided below (Figure 12-Figure 14). Monthly income and costs range from 0 to near 20,000 MWK. Mobile phone charging dominates income generation sources and expenditure on equipment is primarily on light bulbs and inverter replacement.

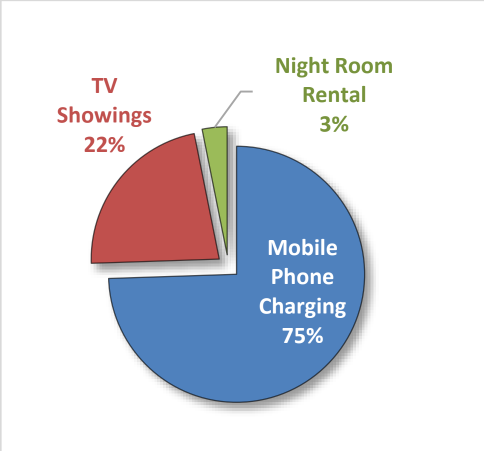

Figure 12: Recorded Income Sources

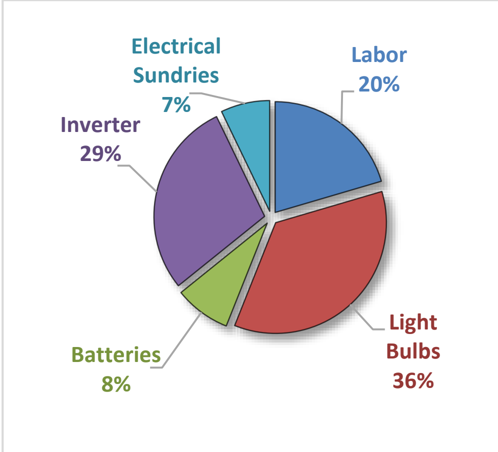

Figure 13: Recorded Expenses

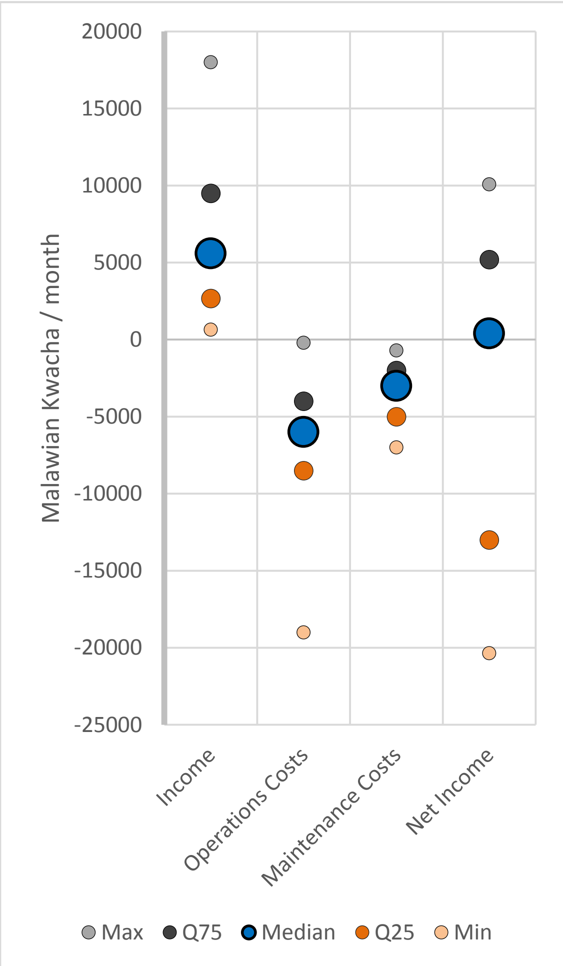

Figure 14: Recorded Income and Cost Ranges

The data available does not support a particularly robust statistical analysis, therefore some specific case studies are used here to discuss sustainable economics for these types of system in Malawi.

Project 10

Project 10 is a rural full Primary school in Dedza district with a solar PV system installed in 2013, providing lighting and power in the Headmaster's office. The system has been operating reliably since installation. An energy committee manage the system and operate a formal income generation scheme from mobile phone charging with a formal logbook system to record sales. The 2014 records of income and expenditure are shown in Table 6. All income for the year is generated from approximately 5000 mobile phone charging sales. Core costs to the income generation scheme are security guard salary and phone charger replacements. It is also evident that the funds also support more general school activities. With revenues healthy and a positive balance obtained for the year, economic sustainability appears to be good. However, even for this relatively economically healthy project, there still remains some cause for concern in that creating a suitable level of reserves is not fully prioritized. Reserves of approximately 100,000 MWK will be required for a battery replacement and more immediately should the inverter fail, insufficient funds remain to replace the unit and all income generation would stop.

Income		Costs	
mobile phone charging	149,680.00	security guard	60,000.00
		phone chargers	24,000.00
		Buckets	1,750.00
		Refreshments	2,000.00
		Transport	8,000.00
		Paper	8,000.00
		Notebooks	1,000.00
		Land	5,000.00
	149,680.00		109,750.00
		Balance	**39,930.00**

Table 6: Project 10 Financial Summary 2014

Project 22

Project 22 is a rural full Primary school in Mzimba district with a solar PV system providing lighting to a school hall installed in 2011. A school committee manages the system and undertakes income generation activities. Logbook records were not being kept and only estimated monthly figures were available, as shown in Table 7. Based on these figures, the school should have an annual surplus of MWK 48,000. With over 3 years in operation the system should have built up approximately MWK 150,000 in reserves. In fact the committee report a bank account with a balance of “above MWK 100,000”. Despite a fairly onerous cost burden for lightbulb replacement, this system appears to be approaching economic sustainability, however the lack of financial records is a cause for some concern. The diversification of income sources is critical, if TV/Stereo/Radio shows were not offered, monthly net income would be zero.

Income		Costs	
Mobile phone charging	9,000	security guard	6,000
TV/Stereo/Radio shows	4,000	Replacement light bulbs	3,000
	13,000		9,000
		Balance	**4,000**

Table 7: Project 22 Average Monthly Financial Summary

6 Social Sustainability

Although the social sustainability pillar for energy projects can encompass many potential indicators, the key factors for the PV systems surveyed in this work were identified as the level of community involvement and contribution with the inception and ongoing management of the project i.e. 'buy-in' and 'engagement'. Incidence of theft was adopted as a measure of the wider community sense of ownership. Finally, the projects inception activities were tracked to understand how communities are engaged by implementing organisations.

6.1 Inception Activities

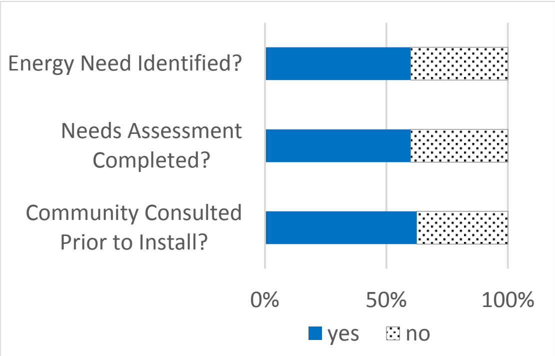

Figure 15: Inception Activities

Figure 15 shows the level of engagement by implementing organisations was provided prior to project inception. Our data indicate that 27% of the communities were not consulted prior to installation of the project. Respondents were asked whether a needs assessment was completed with the community with just over half responding 'yes'. Of these, roughly half of the needs assessment specifically identified an energy need. While it is possible that current respondents simply do not recall the pre-installation activities (some projects are quite old), it is clear that a significant number of projects have a limited pre-project community engagement process.

6.2 Community Engagement

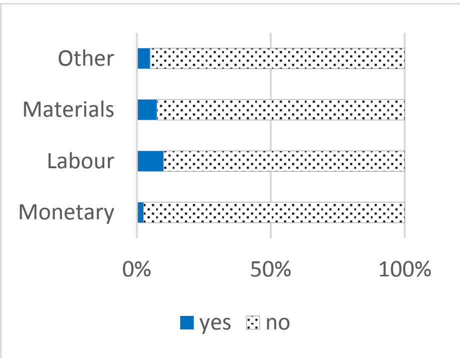

Figure 16: Community Contribution

Community engagement levels in terms of involvement and contributions is shown Figure 16. Contributions of any sort of by the community to establish a new project are found to be extremely low. This is perhaps surprising given it is commonly thought that most project require at least some form of even nominal community contribution to show it is committed to the prospect.

6.3 Ownership

Ownership of the surveyed PV systems is primarily via community committees (50% of projects) (Figure 19). 20% of projects are dominated by one individual and 18% of projects have no management structure at all. Management meetings (Figure 18) are monthly if at all (80% of projects have no meetings). Only 22% of projects have oversight by local district government (Figure 17).

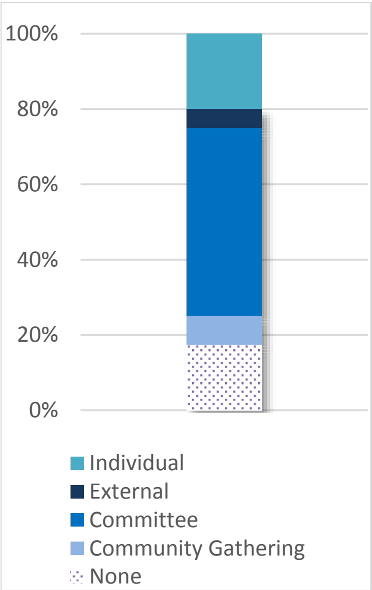

Figure 19: Decision Makers

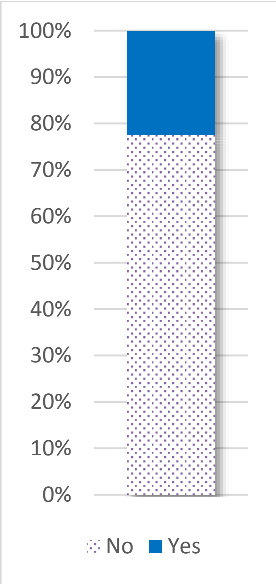

Figure 17: District Involvement

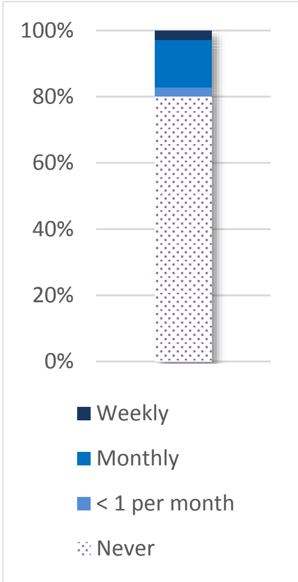

Figure 18: Meeting Frequency

In addition to the management structure, the involvement of local stakeholders was tested as an indication of wider community engagement. A large number of projects (21) have no stakeholder representation in the ongoing management of the project. Where stakeholder representation occurs, there is mostly only one stakeholder group (Figure 20, Figure 21).

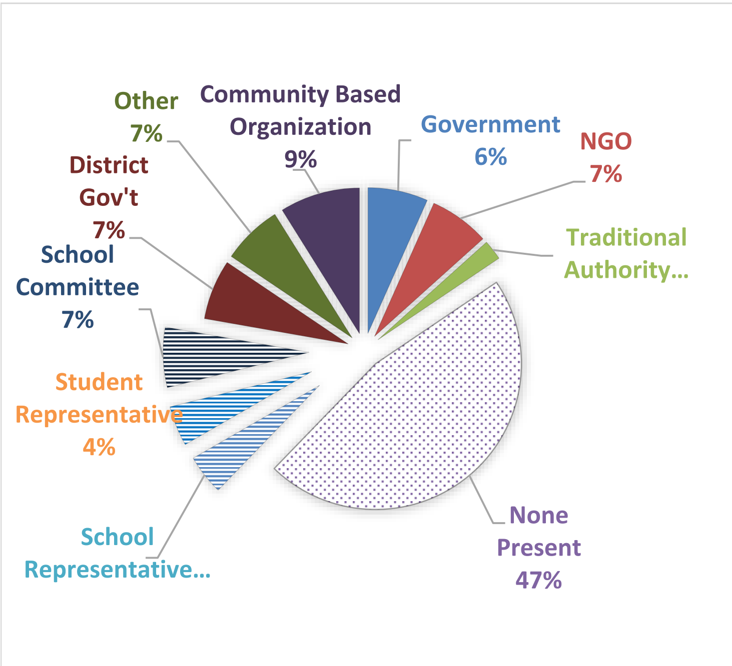

Figure 20: Representation of Stakeholders

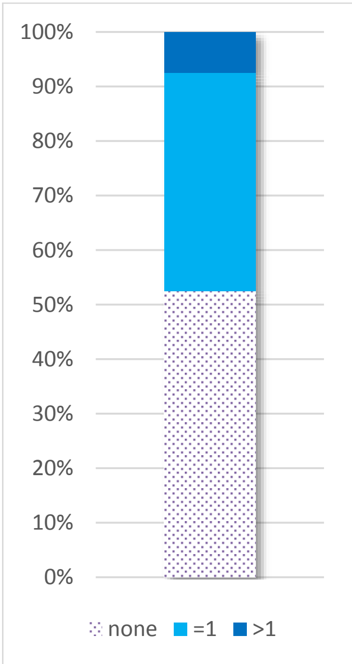

Figure 21: No. of Stakeholders

6.4 Theft and Breakdown

The survey attempted to capture the decision making process by which the owners would respond to major events: theft and complete system breakdown. Unfortunately, data on the process of decision making following these major events was very limited and therefore cannot be presented. However, respondents did provide high level information on prevalence of theft and perception of whether it was resolved (Figure 22). There is a low but significant number of equipment thefts: 28% of all projects. Of these, only 18% of respondents felt it was resolved adequately (i.e. thief brought to justice).

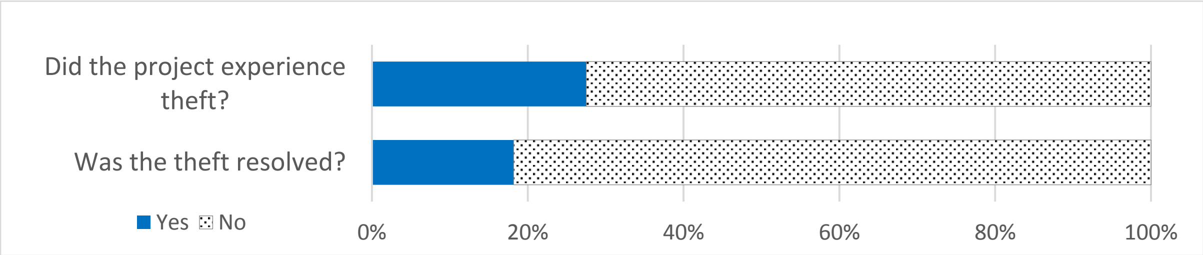

Figure 22: Theft

Figure 23 shows the responses on whether the system in the project have *ever* failed and, of these, if it was repaired. We interpreted the results to correspond to the main/largest system in the project (i.e. primary school or health system), given a project could incorporate multiple asynchronous electrical systems. As we would expect, the systems identified as "completely failed" and "not resolved" are comparable to breakdown rate in the technical sustainability section. This question is useful however as it has a historical element: over the lifetime of the surveyed projects nearly 80% had at least 1 total system failure and a fair number do not get fully repaired (28%).

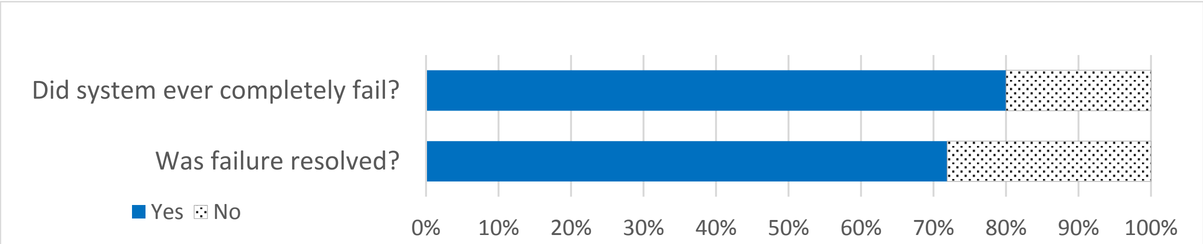

Figure 23: Breakdown

7 Organisational Sustainability

The organisational sustainability pillar is primarily concerned with the capacity of the organisation (or individuals) that is managing the system. The presence of Technical, Management and Financial skills along with appropriate training strategies are necessary throughout the project lifetime and as a result capture the essence of organisational sustainability. Suitable maintenance skills and practical resources are also core components.

Figures 24-26 highlight that the required skill sets are lacking in many projects. Training at install was received by less than half of the projects and very few have any ongoing training. Financial skills and training are particularly limited.

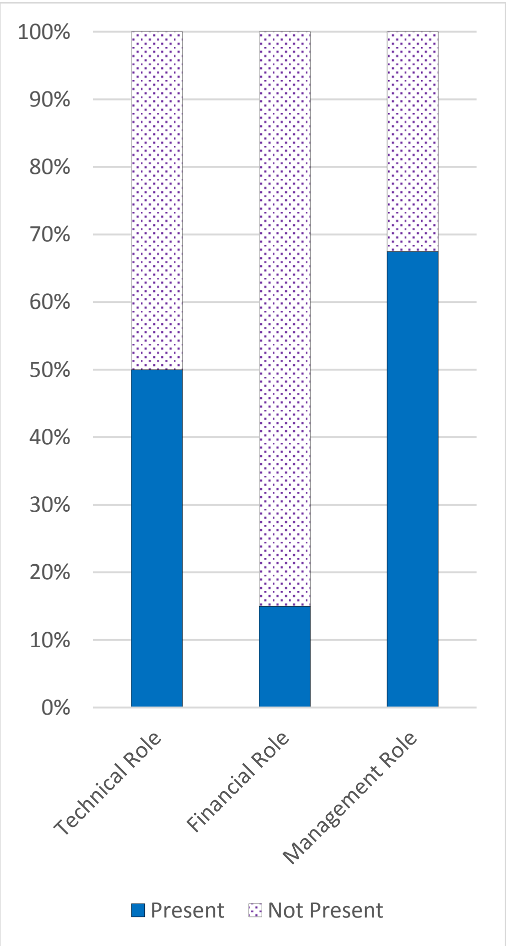

Figure 24: Roles present in Project

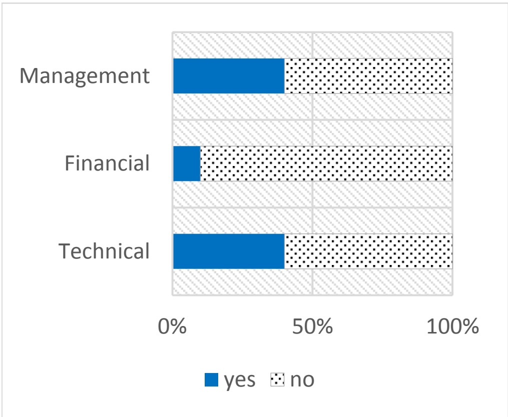

Figure 25: Training Delivered before Installation

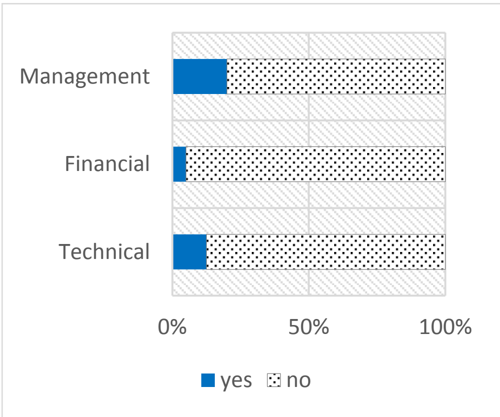

Figure 26: Ongoing Training Delivery

As shown in Figures 27-29 nearly half of all projects have no ongoing maintenance arrangements in place. This would incorporate both internal and/or external maintenance provision such as through a PV contractor. More than half have no process of handover training should a management team member leave. The simplest maintenance requirement for a PV system is to replace light bulbs. 31% of systems have no spare bulbs on hand and have no knowledge of where to obtain bulbs. 50% of projects are aware of where bulbs may be purchased, however the location is greater than 20km away.

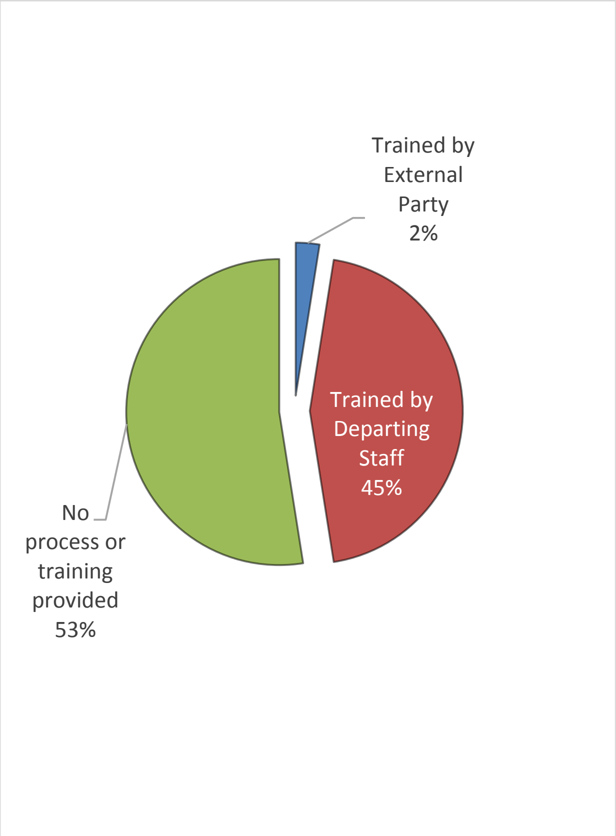

Figure 27: Handover Training

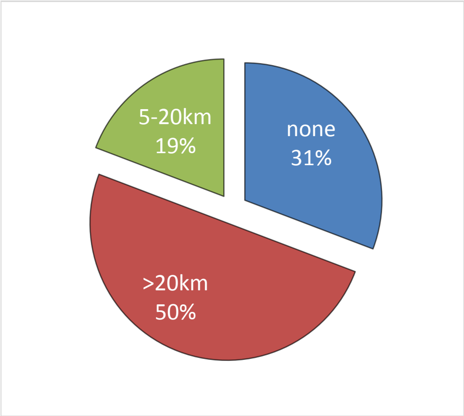

Figure 28: Spare Bulb Availability

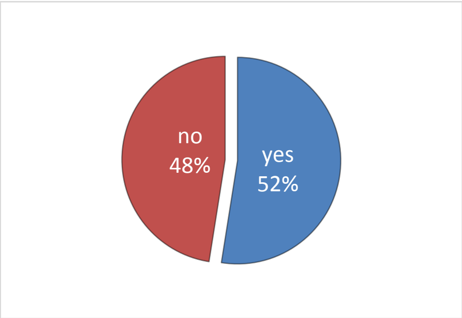

Figure 29: Maintenance Arrangement in Place

8 Social Impact

The surveyed PV systems were all community based projects with an objective of achieving a positive impact on the local community. In the majority of cases the objective is improving infrastructure at primary schools and health centres, where the implicit assumption is that lighting and power will improve educational attainment and health outcomes in the community. In the surveyed projects, no specific monitoring of the impact was being undertaken. Although measuring impact was not specifically within scope of this study, understanding the level of social impact where possible was deemed a valuable additional exercise to provide insight as to the value a community may attach to a system.

Data was requested from Primary schools regarding educational attainment in terms of numbers of students performing well enough in leaver exams to be offered places at secondary school. At health centres, records of birth rates and mortality of mothers going into labour were requested. The information returned has allowed some insights to be drawn regarding school performance, however health centre data was insufficient to allow any meaningful analysis.

For each primary school the records were examined to find the total number of children going on to secondary school each year and the total number of children who sat leaver exams. These figures were used to provide an annual percentage of students going to secondary for each surveyed primary school. Each school's annual data set was arranged with respect to the year of PV installation in order to allow a standard comparison of results before and after PV installation. With the data aligned around Year 0 (PV install) the total percentage of students going to secondary across all schools was found for each year relative to PV install and plotted in Figure 30. Not all schools had records available and those that did had varying numbers of years available. In addition, some of the schools have retained a working system for years after PV install while some have been in a state of failure for many years. With such incomplete data derived from a small set (13) of primary schools, no robust statistical analysis on the impact of solar PV on educational attainment is possible. The results for six of the most complete data sets is shown in Figure 30.

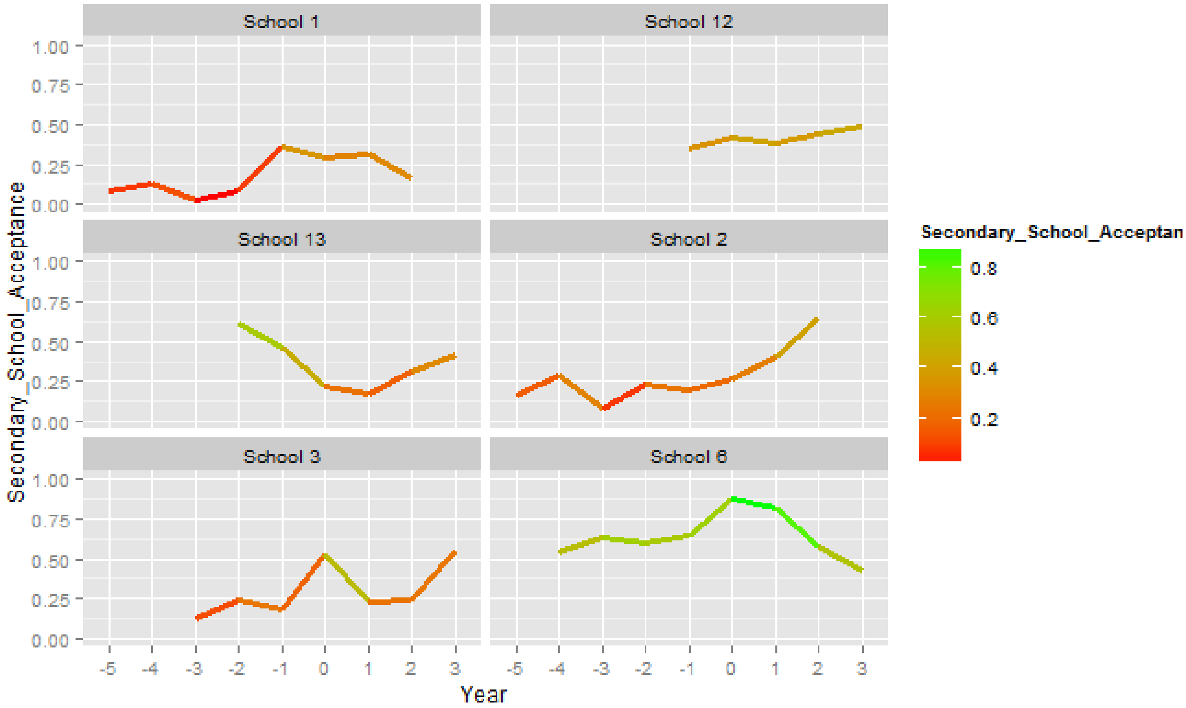

Figure 30: School Performance - % of pupils going on to Secondary School

The data, unfortunately, do not enable any strong conclusions to be drawn. Some schools do exhibit a gradual increase in secondary school enrollment rates, yet others have confusing trends. It was out of scope in this study to examine causal factors to improvement in academic achievement[10]. However, some insight as to the interaction between access to lighting and impact can be draw out as case studies for discussion.

School 6

School 6 is a rural full primary school in Lilongwe district. Records are available from 2006 to 2013. Solar PV lighting was installed to a classroom block and Headmaster Office in 2010. For the 4 years prior to PV installation, performance was relatively stable at around 60%. Following PV install, performance jumps to 88% then decreases year on year to 49% in 2013. The system is currently in a complete state of failure as of 2014. Prior to this, the survey indicates regular evening study classes and a healthy revenue generation scheme from mobile phone charging. The survey reports regular theft of lightbulbs and reliance on the original contractor (>20km distant) to supply spares. Interestingly, in the years that follow PV install, overall school attendance goes up. From the quantitative and qualitative data for this school, the following narrative appears reasonable: “A well organised and reasonably well performing school prior to PV install. PV services provide an immediate benefit to staff and student performance resulting in a boost in exam results. Attendance starts to increase. PV system reliability issues start to occur. Benefits from PV reduce and exam performance

[10] One would expect that availability of a school feeding programme, availability of sanitation facilities, and household economic situation may all be critical factors towards a pupil’s educational performance. Literature reviews from 1990-2010 and notes that availability of desks, low teacher absence rates, and teacher knowledge in taught areas improve educational outcomes [23]. In Sri Lanka, Aturupane et al [24] examine and find a number of key factors such as education of parents, nutrition levels and, notably, availability of electric lighting.

decreases. With increased attendance and dropping performance, overall percentage of students going to secondary drops sharply”.

School 2

School 2 is a rural full primary school in Balaka district. Records are available from 2005 to 2012. Solar PV lighting was installed to an office block and staff houses in 2010. For the 4 years prior to PV installation, performance fluctuates between 8% and 30%. Following PV install, performance ramps sharply for 2 years until records stop in 2012. Although recent problems have arisen with the system batteries, system reliability is reported to have been good from 2010 to 2012 and an active committee with health income generation schemes are evident. The lack of data from 2012 makes further interpretation difficult, however, although performance fluctuated prior to PV install, a pronounced rise in performance of students is evident post PV install. Interestingly this has occurred without lighting a classroom block, only office and houses that facilitate staff preparation time and a small amount of evening student study.

Additional Impact

The survey also investigated the community perception of services that the PV systems were providing (Figure 31 Figure 32). From these responses we can see that in addition to the expected acknowledgement of improved education and health services, improved communications is the most widely perceived benefit (65% of projects).

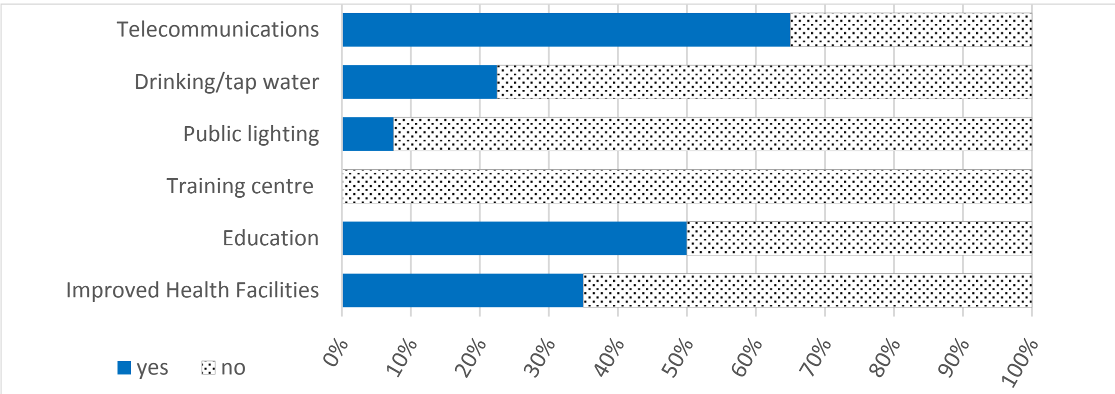

Figure 31: Perceived New or Improved Services in the Community provided by PV system

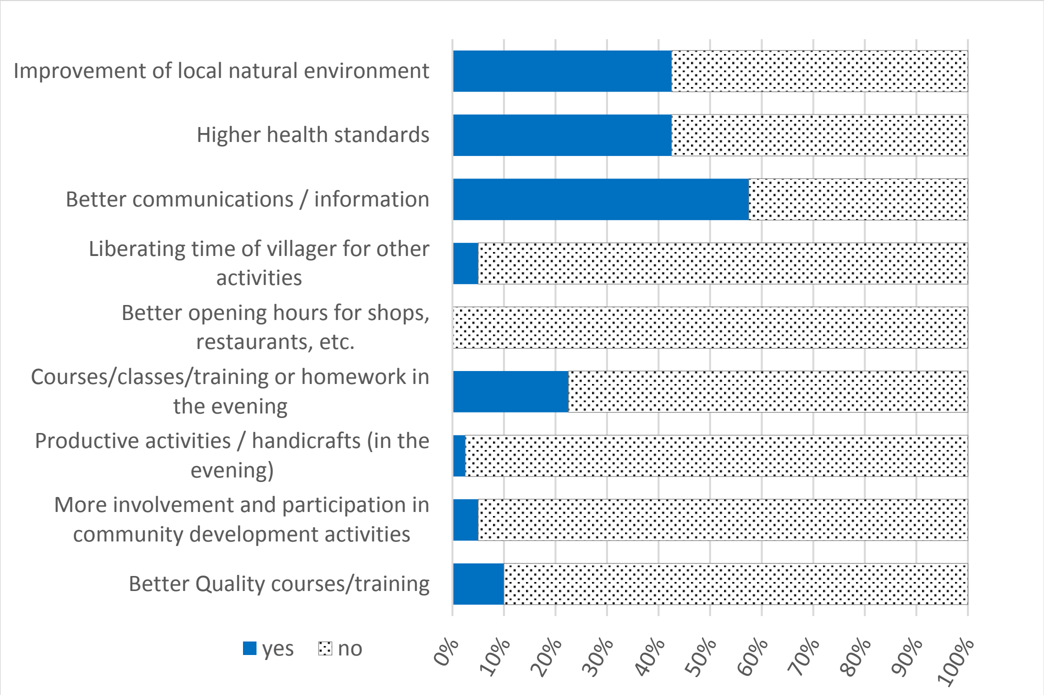

Figure 32: Perception of local lifestyle improvements as a result of PV

9 Sustainability Ranking

In order to consider the overall sustainability of a system or project with respect to others, a ranking process has been applied to the surveyed systems. For each of the sustainability pillars a set of the indicators described in Sections 3-6 above are used for ranking.

Each indicator has been normalised to a range between 0 and 1 and then combined with equal weighting to form a total score for each pillar. All pillars are also then combined with equal weighting to form an aggregate sustainability score between 0 and 1.

9.1 Ranking metrics

Technical sustainability:
Actual usage versus expected usage has been chosen as the critical indicator of technical sustainability as this best represents the current technical performance of each system. Battery Health, Panel Design and Battery Design have also all been used where available. If usage meets or exceeds expectation, the score is 1, otherwise the score is the percentage of actual vs expected usage (0-1). The same rule has been applied to the design metrics. For the binary indicators (good/bad, yes/no) the score is either 0 or 1.

Economic sustainability:
The net income of each project has been arranged from highest to lowest and each project given a score between 0 to 1 based on its position in the list. Bank account existence has also been used as a binary yes/no indicator scoring 1 or 0 respectively.

Social sustainability:
The social sustainability ranking includes yes/no scores (1 or 0 respectively) for existence of a needs assessment, existence of community contributions, whether the district governance is involved in the project, whether there are any stakeholders or not (1 or 0 respectively) and indecent of Theft (scoring 0 if it has occurred and 1 if not). Management Meetings were simplified to score 1 if they were reported to occur at all, and 0 if not.

Organisational sustainability:
The indicators relating to the presence of Technical, Financial, Management skills and training, plus the presence of a maintenance arrangement have been used as binary scores for this pillar.

9.2 Ranking Results

Results are summarised in Figure 34. The aggregate ranking is shown for each system along with the ranking for each pillar. In addition, the observed status of the system is also provided. System rankings are colour coded based on their score of 0-1. Red=0, green=1. System rankings are colour coded as follows: Green=working, amber=partial failure, red=total failure, grey=unknown.

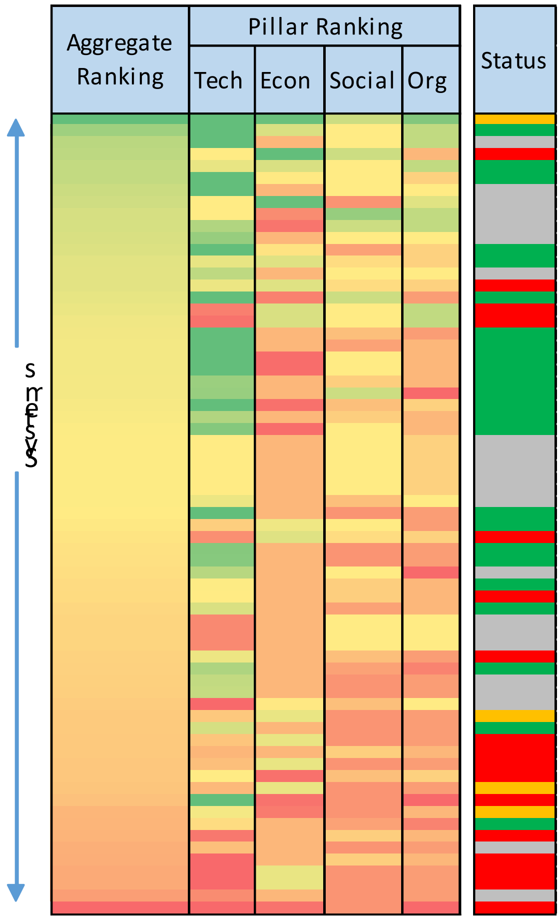

Figure 34: System Sustainability sorted based on Aggregate Ranking

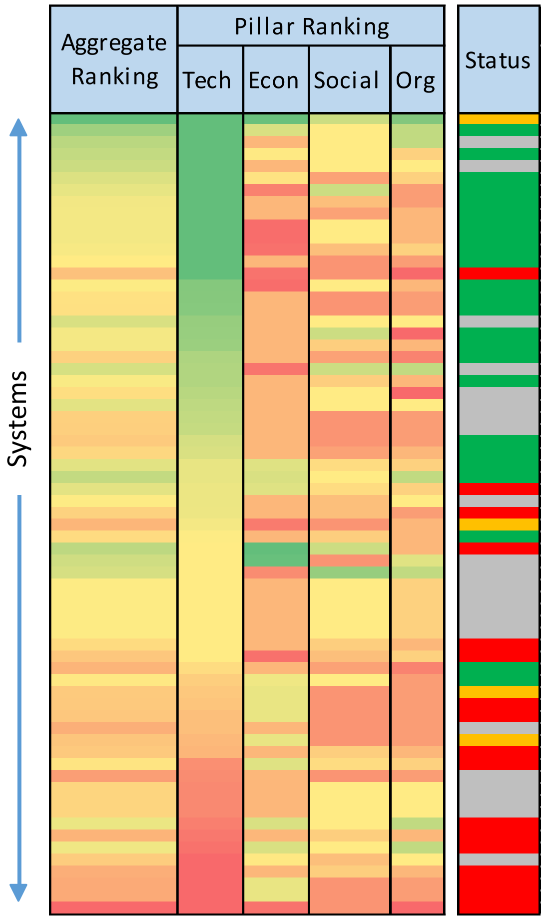

Figure 33: System Sustainability sorted based on Technical Ranking

In Figure 34, the systems are ordered based on the aggregate ranking. Each sub-indicator within the pillar is equally ranked and then the pillars themselves are equally ranked. We would expect a higher aggregate score to correspond, at least, to whether on inspection the technical components are functioning normal. However when comparing the "aggregate rank" to the "status" it is clearly possible for a system to have a very poor ranking in one pillar, yet achieve a reasonably good aggregate ranking. Nonetheless, using the current observed system status as a point of comparison it can be seen that those systems ranked least sustainable are generally experiencing failure and those ranked most sustainable are mostly observed to be working well.

In some cases, a weakness in a particular sustainability pillar could imply no actual weakness in sustainability. For example, based on the way the ranking design, lack of district involvement confers a lower social sustainability score. However, according to the actual operational model, district involvement may be not required which would make the sub-indicator actually irrelevant for scoring. Another example is with respect to existence of a bank account, which again is part of the economics scoring. The existence of a bank account is meant to indicate seriousness of the economic model, imply improved organization and financial oversight. However, it is conceivable that a project is serious, organized, and has oversight even without an account at a bank to store funds. Thus when viewing each project through the ranking lens, it could be argued that the ranking approach itself prescribes a particular model, meanwhile devaluing other models. However, we argue, based on experience taken from the case studies and literature sources, that on the whole they are relevant to these types of project: off-grid community energy systems. Since the pillars and sub-indicators do not get scored on any one metric, than any individual quirks of the operational model should not be entirely irrelevant for each indicator. Following the previous examples, in the social pillar existence of stakeholders to own the project is relevant even without significant district involvement; in the economics pillar existence of an income to backstop the project is relevant even without a bank account.

There are some anomalies with several systems ranked highly for sustainability also currently in a state of failure and vice versa. If the systems are re-ordered based on technical sustainability ranking (Figure 33) a closer relationship between ranked sustainability and status is observed. This is due to the fact that Technical Sustainability ranking is partly influenced by the current technical performance and hence the metrics are linked. Re-ordering in a similar way with any of the other symptoms does not have a similar effect. We examine some case studies within the next section to interpret these results.

10 Discussion

10.1 Technical Sustainability

There are significant indications of poor design and installation practice that indicate poor technical sustainability.

- PV panel orientation and mounting is not always correct
- Battery bank enclosures are often not secure and well ventilated
- Although quality brands dominate the main PV system components utilized, there are still high numbers of what could be deemed to be 'inferior' components being installed in large numbers.
- Uncontrolled inverter load is common (inverter connected directly to batteries). Given the low end spec of inverters used, this method of operation risks regular battery deep discharge, i.e. damage and reduced lifespan
- Typical design assumptions of room lighting usage as 3hrs/7days are valid but should be treated as a minimum – 5hrs/7days is closer to a 90th percentile design standard
- System design practices appear to be erring on the side of optimistic/minimum (budget) assumptions rather than preferring technically robust specifications, and chronic under-specification of battery banks appears to be a particular issue

10.1.1 Linkage between system design and technical sustainability

The sustainability metrics of lost service, battery health and performance against expectation have been assessed for all systems against design 'fitness for purpose' parameters. The results are shown in Figure 35.

For systems that are judged to have an undersized PV array, 15% have completely lost service, and 60% are not meeting lighting expectations. For systems judged to have an oversized array only 4% have lost service, however 62% are not meeting lighting expectations.

For systems judged to have an undersized battery bank array, 17% have completely lost service, 31% have a bad battery health indicator and 67% are not meeting lighting expectations. For oversized battery arrays, lost service and bad battery indicator are 4%, however 40% are not meeting lighting expectations.

There appears to be a reasonably strong link between system under-sizing and the symptoms of lost service and bad battery health, especially for battery bank under-sizing. There is less of an association between system sizing and meeting of lighting expectations.

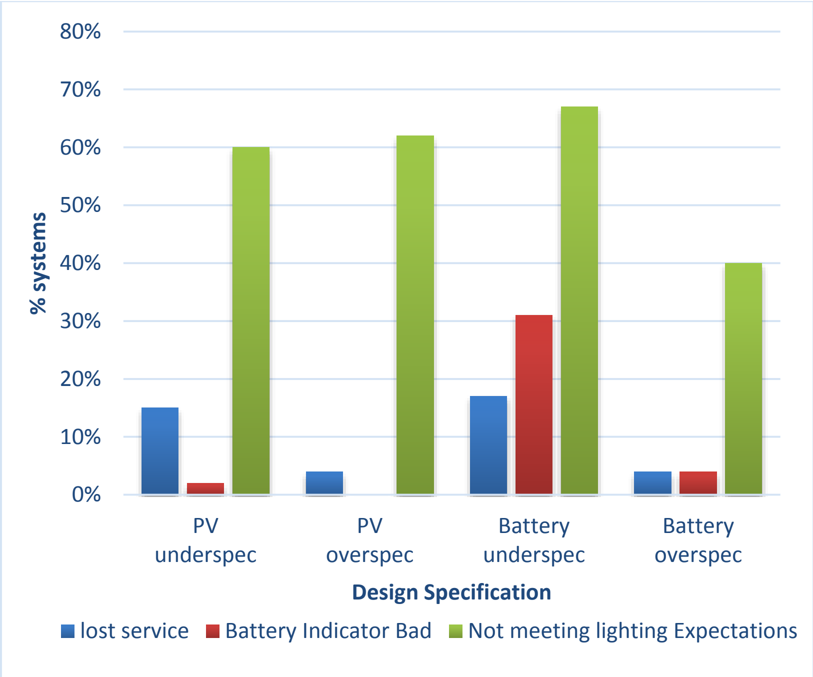

Figure 35: Linkage between sustainability issues and system design

10.2 Economic Sustainability

From the available financial data from the projects, economic sustainability is very poor in the majority of projects. Only 11 projects (28%) have any kind of income at all. Of these only 6 (15% of all projects) also have a bank account. Within the small group of projects that are managing to generate income and had a bank account, there are some case studies available that indicate a community managed financial model could achieve a degree of economic sustainability in terms of meeting running costs if the systems were technically robust and did not experience an unduly high degree of fault. Even in the best performing system in the data set, in terms of finances, it is impossible to expect that it could save enough to replace the likely capital expenses as the system ages. As has been documented in many other sources, it is the lead acid batteries which tend to fail and require replacement.

Given the role of the public institutions themselves it is perhaps not unusual that there is not significant emphasis on revenue generation. Obviously, their primary purpose is not rural electrification, but provision of education and health for the local communities. In this case, electrification is a mean for these other ends. We found little evidence of external sources of ongoing funds supporting the PV infrastructure such as NGOs or district education or health offices. In our sample only 22% of projects cited any sort of district involvement and 7% citing NGO involvement, it is unlikely that these source provide much financial support after inception.

During our study, no projects were able to identify savings targets that would be required to support the maintenance or replacement of system assets or current progress against these targets. Only a token few projects could produce log books or accounting for sales of any goods/services associated with their energy projects. This is a particularly worrying result and raises a host of issues from system design to ongoing implementation of community energy projects. Ideally, capacity building efforts as well as business model design should reinforce the long-term asset management model and develop effective approaches to ensuring funds are available when they are needed to replace failing equipment. Once operational, a structure should be in place to transparently manage funds and ensure discipline when saving.

Without external financial support or sufficient local revenue generation, it is unlikely that many of these projects will endure to reach the full lifecycle of the equipment. In the right environmental and operational conditions, PV projects can last for 10+ years with periodic replacement of the battery array and even cope with the costs of replacing of an inverter or charge controller.

10.3 Social Sustainability

The data gathered from the projects paint a picture of relatively limited involvement by social actors in many cases. While this does not mean necessarily that a project cannot survive without involvement from local or district community, it is also difficult to imagine models for off-grid energy for institutionally sized PV systems in Malawi without a support network.

The most startling figure is the lack of ownership over projects. On one question, nearly half of projects identified no stakeholders involved in the project. Another similar question identified that 18% of projects had no 'decision maker'. Without ownership, one has to assume that a sufficient restoration following a breakdown is unlikely. The difference between these two responses can be interpreted to mean that there in some cases 'custodians' of projects step in to make decisions without fully owning the projects.

The public institutions from our sample show that types of project stakeholders can vary quite considerably from project to project. If one assumes that current ownership structure is by design, then it can be noted that there was no conclusive evidence that any particular ownership model was more successful than others. The complete lack of private ownership or involvement is noticeable; though the result is not surprising given that infrastructure public institutions are by default considered the domain of a public department or the community to provide.

Community consultation at project inception is around 60% and equally for whether a needs assessment was completed. This is an unsatisfactory figure since securing community consent (and indeed engagement) and the existence of an identified need prior to inception is good development practice. As a gauge of community ownership or buy-in at inception, almost no projects have any sort of community contribution that was provided (and no monetary contributions at all). This suggests that even when the community is consulted, the community has only token involvement. Furthermore, community engagement is not sustained after inception; only 18% of the projects stakeholders meet on a regular basis (at least monthly). Any oversight or management by district governance (such has Health or Education offices) occurred in only 22% of projects. When it occurs, district involvement is inconsistent; it does not guarantee that systems are fully functional.

Finally though theft was present it can be considered low, occurring in 28% of projects. However, of the projects which experienced theft only 18% were considered resolved adequately. An open question is the adequacy of rule of law to protect the solar PV project. Introduction of the relatively expensive equipment provides an incentive for theft. It is apparent that alternative means of security such as cages and existence of a security guard are required. Future areas of research could investigate whether higher levels of community engagement and ownership can provide an alternative or complementary measure of security where rule of law is ineffective.

10.4 Organizational Sustainability

Due to the size of the investment, relative complexity of equipment and requirement to embed the PV equipment into a business model (even for public institutions), it is unrealistic to expect that projects can be installed without first assessing the capacity of the prospective owners and operators. Solar PV at rural institutions is currently not 'plug and play'. The skill levels and human resources currently available for project management is extremely low across the set of projects, particular in the area of financial management. The other key capacities of technical skills and managerial skills are similarly not adequately addressed.

For projects that are meant to be self-sufficient, lack of skills will undermine overall project performance as managers are unprepared to make informed decisions on their projects. This suggests that the development process for similar energy projects place higher priority on training of project owners and operators or better identification of qualified personnel. Given the lack of technical skills (and systems to provide skills) in this context, substantial training is the more likely immediate solution.

Project design needs to be more aware of the skills retention problem that this study has documented for community energy PV projects. We found that half of all projects have no ongoing maintenance arrangements in place and more than half have no process of handover training should a management team member leave. It is also well known that health facility personnel and teachers are quite mobile, so ongoing training arrangements either internal or through an external provider are realistically necessary to ensure that personnel on-site are capable of managing the projects. If an internal arrangement is desired, then projects need to consider hand-over training and how to encourage a permanent local knowledge base.

10.5 Sustainability Case Studies

The survey results and analysis indicate significant sustainability issues across the projects. Many of the systems are in a state of complete failure and those that are not have weaknesses across the sustainability pillars. The overall performance of the systems in terms of maintaining the designed for, or expected quality of service is poor. Although the quantitative nature of these results provide many insights into the current state of off-grid solar PV systems in Malawi, further analysis of the relationship between sustainability indicators and the current and future performance of the system will provide a more complete picture of sustainability. For instance, from the ranking analysis it appears that the single most important factor for the system to be maintaining working order is the technical robustness of the system. In the main, systems with poor economic, social and organizational sustainability rankings show good current working status as long as the technical sustainability ranking is high. Conversely, systems may have a high ranking in one or more of the other categories but still be in a state of system failure. Why this is so, what causes the exceptions and whether the working systems can be expected to remain so are questions arising from the results so far.

In order to explore these issues, case studies drawn from the ranking results are set out below

10.5.1 Top ranked project

This project is a small health clinic in Chikhwawa that supports a refrigerator and three rooms with lighting. The system was installed in 2009. The project scores highly on all sustainability metrics (Figure 36). The Social score is lesser due to the absence of district involvement or the presence of any other stakeholders. However, there is an active management committee with a good range of skills and training. There is a project bank account and a positive cash flow from income generation through mobile phone charging and selling cold drinks. The system is reported to be fully meeting performance expectations. However, partial failure is reported in that lighting will sometimes cut out after a few hours at night. This indicates that the batteries are not holding sufficient charge, although a major fault is not apparent as yet. It is also noted that the refrigerator is directly connected to the batteries so is free to drain battery charge with no control. Although a small positive cash flow is observed (MK 3,000 per month) the surveyor reports that the bank balance is not available and also notes that last year MK 35,000 was spent on cement and bricks to repair the building infrastructure. In this case, not only does the project lack support from local government for the PV system, the PV system is subsidising basic maintenance costs that should be met by the district health office. Although this project has many positive sustainability aspects, the current bank balance is critical. With potential battery failure on the horizon and hence loss of service and lack of further income generation opportunity, the sustainability is under threat in the near term.

SYSTEM	PROJECT	TECH SCORE	ECON SCORE	SOCIAL SCORE	ORG SCORE	TOTAL	STATUS
86	25	1.00	0.98	0.67	0.90	0.89	Partial Failure

Figure 36: Sustainability Metrics for Top Ranked Project

10.5.2 Bottom Ranked Project

This project is a primary school in the Northern Region that comprises of a classroom lighting system (sys 76) installed in 2012 and a teacher's house system (sys 77) installed in 2014. The newer system is currently working and meeting all expectations. The classroom is in a state of failure and has the lowest overall ranking of all systems. The project as a whole ranks very poorly across Economic, Social and Organizational Sustainability. Despite no apparent income generation, the project has spent significant sums in the last year replacing light bulbs and paying a security guard. This appears to be sourced from the school committee. There is no recorded external involvement, community engagement, management structures or evidence of training. The battery container is noted to be unventilated. Based on these results it would be expected that the new installation at the teacher's house will operate successfully for a short time, however there is no capacity to repair or maintain the system.

SYSTEM	PROJECT	TECH SCORE	ECON SCORE	SOCIAL SCORE	ORG SCORE	TOTAL	STATUS
77	21	1.00	0.04	0.17	0.00	0.30	Working
76	21	0.00	0.04	0.17	0.00	0.05	Total Failure

Figure 37: Sustainability Metrics for Bottom Ranked Project

10.5.3 Project with multiple systems and range of rankings

This project is located at a health clinic with multiple staff houses and was installed in 2007. The overview of the project sustainability is shown below. It can be seen that the projects all have relatively low scores for Economic, Social and Organisational Sustainability. Technical sustainability ranges from good to bad with 3 systems currently in a working state and 4 in a state of total failure.

SYSTEM	PROJECT	TECH SCORE	ECON SCORE	SOCIAL SCORE	ORG SCORE	TOTAL	STATUS
6	1	0.82	0.30	0.56	0.30	0.50	Working
5	1	0.75	0.30	0.56	0.30	0.48	Working
4	1	0.51	0.30	0.56	0.30	0.42	Working
3	1	0.50	0.30	0.56	0.30	0.41	Total Failure
1	1	0.30	0.30	0.56	0.30	0.36	Total Failure

7	1	0.06	0.30	0.56	0.30	0.30	Total Failure
2	1	0.00	0.30	0.56	0.30	0.29	Total Failure

Figure 38: Sustainability Metrics for Project with multiple systems and range of rankings

The systems that are currently working have their technical score boosted by the current level of performance. All systems have a poor design rating that brings the tech score down. However, as system 6 is currently managing to fully meet expectations, it maintains a high technical score.

On reviewing the project questionnaire in further detail, along with the surveyor's notes, it is apparent that the District Health Office continue to support this large health clinic. This is the main factor that drives up the social sustainability score, which would otherwise be very low. The DHO is noted to occasionally respond to maintenance requests. The system is however completely reliant on this sporadic external support.

Based on this analysis it would be expected that the systems will regularly fail and will only be restored if district support is forthcoming.

10.5.4 Highly Ranked System in State of Failure

The project that places 4th in the overall sustainability ranking is a Youth Club building providing lighting, phone charging and TV shows in Mulanje District. It is however in a state of total failure. Due to the technical design and other factors ranking highly, it maintains an overall high score. A positive cash flow of MK 10,000 ranks highly against other projects and the social structures also rate well. However, there has been little in the way of organizational training. It appears that a recent incidence of panel theft is the cause of the system failure. The bank account balance is unknown and it appears that the youth group do not have the resources or external support to repair the system. There is a suggestion in the surveyor's notes that the available funds have been spent on a variety of activities. Even with a significant available bank balance, the panels are the most costly system component and would not normally be expected to be a maintenance cost. This project's sustainability has suffered due to its vulnerability to theft.

SYSTEM	PROJECT	TECH SCORE	ECON SCORE	SOCIAL SCORE	ORG SCORE	TOTAL	STATUS
105	36	0.50	1.00	0.67	0.30	0.62	Total Failure

Figure 39: Sustainability Metrics for Highly Ranked System in State of Failure

10.5.5 Low Ranked System in Good Working Order

This project is a large health clinic with 8 systems serving treatment rooms and staff houses. The systems were installed in 2010. Only two systems had sufficient data to be ranked. Overall the project performs poorly in the rankings. System 26 places 78th in the ranking table, however the system is observed to be still working. There are no indications of any resource or capacity in place to maintain and operate the systems. Inspecting the surveyor's additional notes the following observation is made "Maintenance costs were once handled by the DHO but they stopped when at a point in time realised that the maintenance that was needed was too big for them to manage". From this it seems reasonable to assume that systems have been regularly falling into a state of failure due to the poor sustainability. The presence of external support and finance allowed the systems to be returned to working status, however this support has been withdrawn and the sustainability outlook is now quite negative.

SYSTEM	PROJECT	TECH SCORE	ECON SCORE	SOCIAL SCORE	ORG SCORE	TOTAL	STATUS
25	4	0.76	0.30	0.22	0.10	0.35	Working
26	4	0.44	0.30	0.22	0.10	0.27	Working

Figure 40: Sustainability Metrics for Low Ranked System in Good Working Order

11 Conclusions

The sustainability picture is bleak across the surveyed set of projects. Elements such as detailed needs assessment, community engagement, establishment and training of management structures, good technical design, quality components, maintenance and operation structures, financial management and a business plan are lacking in many of the projects. Even those systems that rank relatively highly in a sustainability assessment and are currently in good working order have an uncertain outlook.

Specific conclusions with respect to the study questions are outlined below.

To what degree are systems performing as expected?

As noted above, the systems technical performance is poor. There are numerous systems in a state of complete failure. An interesting aspect of the data is that the expected performance of the lighting systems are mainly described as either completely not meeting expectations or fully meeting expectations. It is difficult to say if this is a wholly accurate representation of the system or an indication of difficulty in the questioning process to articulate and capture degrees of satisfaction. Nevertheless, large numbers of systems can be said to be not meeting expectations.

Summary of system performance issues:

- 38% of the systems have completely lost all service
- 58% of room lighting is not fully meeting expectations
- 43% of batteries are showing 'bad' battery health indicator
- 31% of the mainly CFL installed bulbs are not working

What components are used in system design?

The standard components that comprise PV systems (PV panels, Batteries, Charge Controller and Inverter) are found to be prevalent in system design as expected. However, there are significant numbers of obscure brands and hence doubts over component quality. The poor practice of inverter direct connection to batteries is common. Light bulbs are primarily CFL and experience high failure rates.

Sizing and quality of PV system components is critical to appropriate design. Standards in this respect appear to be lacking. The analysis strongly infers that although the Malawian renewable energy sector is regulated and there is an accreditation process of installers and suppliers, there are still serious issues with the supply chain and design process. Design and installation is often below standard and the overall technical sustainability is poor. Specific suppliers and installers are not identified in the survey therefore this issue cannot be linked to the use of non-accredited suppliers.

The ultimate responsibility for ensuring appropriate technical standards for PV installations lies with MERA, however with numerous local and international organisations working with communities across Malawi there is significant chance of proper process being bypassed. In many cases this may be simply a case of the consumer being unaware of how to ensure they are purchasing an appropriate solution. Whilst it is not feasible for all consumers and communities to be fully conversant in PV system design methods and be able to verify their system has been designed properly, the MREAP community energy toolkit emphasises the importance of using MERA accredited suppliers and this should be sufficient in principle. It should therefore be the aim of the sector to ensure that all MERA accredited suppliers are using suitably robust design standards and components. Likewise efforts to better inform consumers (in this case purchasing agents for institutional level PV systems) on minimum quality requirements would allow for better choices during procurement.

What factors are linked to high system performance?

High system performance is assessed as the working state of the system and its ability to meet expectations. Performance overall has been identified as poor. There are no exemplar projects that allow a comparative analysis of factors linked to high performance. For the many systems in a state of failure, the multi-faceted nature of sustainability and the limited scope of this retrospective study makes identifying specific underlying reasons for that failure difficult in most cases. However, it is clear from technical analysis that system design, battery bank sizing in particular, is a critical factor and can be linked to more robust and higher performing systems. Nevertheless, there is also evidence of systems that are technically weak that are maintaining a high level of performance through regular repair financed externally that quickly returns systems to working order after failure.

Which systems can be described as "most" sustainable and why?

We define the most sustainable projects as those scoring highest within the sustainability rankings. In essence, the ranking defines a project as highly sustainable if it meets usage expectations, has relatively strong financial performance, is embedded and accepted within the community, and has the skills available to manage the project. It is essential that the systems are sufficiently technically reliable to maintain a level of performance that available financial resources can support. i.e. project finance can fund the necessary life-cycle costs, and most critically, 3-5 year battery replacement. The encompassing sustainability issues of community engagement, social and organisational structures are also of importance, however in the surveyed systems, insufficient to guarantee sustainability on their own. Although there are a number of surveyed systems that rank highly in all respects, their long term outlook is limited due to the lack of sufficient revenue and forthcoming requirement for battery replacement. Based on the survey responses, even a highly trained, organised and motivated community will be unlikely to maintain their system in the long term without a high standard of technical installation and a degree of external financial support for life-cycle costs. Therefore, it is not clear that an equal weighting across the pillars is appropriate. Furthermore, there may be an absolute minimum requirement for each pillar depending on the particular operational model, a nuance we have only brushed the surface of.

12 Recommendations

Ensuring the use of technically robust design standards and component choice is required for improved technical sustainability. Mechanisms to achieve this should be a priority for the sector and the role of all stakeholders in this should be considered (GoM, MERA, funders, suppliers, communities, etc).

For Community Energy Practitioners

- (Timeframe: immediately) Project design should be based on a sustainability pillars approach. Best practice for all sustainability metrics should be referenced and used to justify a fully sustainable project design prior to implementation. To improve learning, a common set of sustainability indicators should be included within project monitoring and evaluation.
- (Timeframe: immediately) Project designers to consider the role of district authorities in the sustainability of PV systems for schools and health clinics. The study suggests that even projects with apparently good sustainability assessments begin to struggle without external support of some sort. District support has been helpful, but sporadic. It could be made more effective by formalizing respective roles between community and district. Furthermore, linking up and demonstrating the impact of interventions to district objectives could provide the district with more leverage to invest and support such initiatives more widely.
- (Timeframe: immediately) Projects must include long term maintenance costs in project design and explicitly include a facility for this. Even the most successful community led income generation schemes surveyed have not been able to generate and save sufficient revenue for 3-5 year battery replacement.

For Academic Institutions

- (Timeframe: next 3 years) The study shows that previous community solar PV deployment appears to be highly dependent on limited-time donor-based funding that has not been shown to be particularly sustainable. Promising variations on the 'community energy' model need to be robustly tested and conclusions drawn proving long-term sustainability performance of these models.
- (Timeframe: next 3 years) An interface of regular knowledge exchange and policy briefings should be led by academic institutions to ensure government is utilising best practice and can plan for systematic issues such as district management of rural infrastructure.

For Government of Malawi

- (Timeframe: next 3 years) MERA to consider approved component list and to publish on-line design standards that accredited suppliers must comply with.
- (Timeframe: next 3 years) Investigate models where district authorities can partner and support community energy projects for education and health infrastructure, taking into account the cost structure and technical support requirements of deployed PV systems.
- (Timeframe: next 3 years) Support and promote the supply chain for LED light bulbs for renewable energy systems.

For Scottish Government

- (Timeframe: next 3 years) Require a lifecycle costing approach and model in place for any community energy systems funded

- (Timeframe: next 3 years) Require a sustainability pillars approach to project design with appropriate M&E that enables analysis of sustainability performance for any community energy systems funded
- (Timeframe: immediate) Disseminate results from MREAP and encourage similar approaches

Further Work

Despite the limitations of this retrospective survey, many insights as to the sustainability of off-grid PV systems in Malawi have been obtained. It is clear that a more systematic approach to monitoring technical and economic performance of off-grid projects in addition to social and organisational sustainability indicators from project inception, rather than retrospective one-off surveys, would allow more robust research into causes of poor sustainability and potential solutions. Given recent initiatives in Malawi to establish M&E systems for community energy projects and remote-monitoring for off-grid PV systems, the opportunity exists to establish, maintain and grow a valuable data set to serve as the foundation for the ongoing refinement of understanding on best practice for sustainable off-grid PV systems in Malawi.

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14 List of Annexes

1. Solar PV Survey (Annex 1)
2. Survey Guidance (Annex 2)
3. Excel based Data Entry form (Annex 3)
4. Field coordinator Report (Annex 4)

15 APPENDIX - Conceptualizing Sustainability

Due to its ubiquitous use, it is useful to adopt a working definition of "sustainability" here as: "the perceived potential for a system or project to endure, build a self-perpetuating capacity within a community, and ultimately reach the end of its predefined life span or evolve into another beneficial form" following [9].

From the documented sources in Section 1, a stylized story can be constructed that highlights the challenge of sustainability of off-grid community energy projects. Sustainability is complex and multifaceted. Technical issues such as inferior components, bad design, and insufficient maintenance can lead to the project quickly dying out as a key component is broken and goes unrepaired. Many projects have insufficient financial performance to expect long-term sustainability which results in lower performance versus expectation, and then outright failure. As projects are often run with a community or organization that takes on the role of management, its capacity, coherence, and adaptability are also important. Socially, when a (relatively) large project is installed in a remote community and intended to address local needs, it is critical that community has buy-in, support, and oversight to avoid outcomes like elite capture and/or theft. In order to capture the breadth of scenarios and factors that are at play the concept of sustainability must also include corresponding details for it to be operational.

We frame the concept of sustainability using two main sources: indicators framework for evaluating sustainability and (off-grid solar PV) project design guides and toolkits. Though many other potential sources do exist, such as individual case studies or field reports, there is also a high degree of fragmentation of knowledge and experience which makes it difficult to simply adopt a framework that must be both applicable to projects but also provide a systematic basis for comparison. Therefore, our approach is to start from a few well known sources and refine so it is relevant at the project-level, comprehensive in coverage of sustainability factors, and provides a measure of comparability.

15.1 Indicator Frameworks

Firstly, indicator frameworks have been developed for framing sustainable development efforts and are considered at a national level [13, 14, 15]. Efforts to re-envision them at the programme level [16] make them more relevant to projects, but nonetheless retain some of the national indicator framework and sustainable development legacy[11]. Nonetheless, the main pillars identified throughout are a reference point for evaluating project-level sustainability. They include the main themes: technical, economic, social, organizational, and environmental.

In [17] an assessment was carried out using indicators from [16] that assessed sustainability by ranking performance of seven organisations against the indicator set. The study included organisations in three countries: Tanzania, Kenya, and Zambia. The resulting analysis showed how the approach could be used to evaluate peer projects and demonstrated the potential for further use. The authors of [18] used these indicators in separate projects in Nepal, Peru, and Kenya with some modifications to the scoring method as well as introducing additional/revised indicators in areas of gaps. Both studies acknowledge methodological challenges associated interpreting the scores, but nonetheless achieve convincing results.

[11] For example through the use of indicators with a normative disposition: "Share of health centres and schools with electricity", "Share of economically active children", "Share of women in staff and management" and those which include global *sustainable development* indicators: "Share of renewable energy in production" and : Emissions of carbon dioxide".

Another source for comparison, [10] is aimed at uncovering causes of failure and success of stand-alone systems in Guatemala. Corsair uses[12] the term success similarly to sustainability as used in this study, provides a myriad of examples of fragmentation of concept of sustainability, and concludes that the term is poorly defined. As a nuanced definition is built up, it bears similarity to the main themes of other sources including: “success”, “Economics and Utility”, “Institutions & Relationships”, to name a few key areas. As it becomes operationalized within the survey element comparable indicators are employed such as: “energy costs”, “income”, “functionality” for example. This research is another approach which deploys indicators in order to evaluate sustainability, though perhaps more nuanced and qualitative when compared to [16].

The several sources presented in this section show that research into evaluation frameworks for sustainability are active though perhaps not decisive in a definitive approach. There is comparable use of the concept of sustainability and similarity between themes and even some indicators. Finally, an approach to “operationalize” the indicators through the implemented study methods has resulted in convincing analysis of the sustainability of the included projects.

15.2 Sustainability ‘Toolkits’

Another resource for conceptualizing sustainability are ‘toolkits’ which can come under the name of guides, manuals, or other equivalent labels. Toolkits are typically framed from the perspective of designer, implementer, practitioner or manager rather than the evaluator. This distinction is helpful since knowledge to be used before implementation is necessarily normative and meant to be tailored to one’s particular situation.

A highly prominent toolkit from the World Bank [11] is a 21 page operational guidance note summarizing the World Bank experience in off-grid systems. Sustainability in this toolkit can be defined as the ongoing “operation of an off-grid electrification project over the long term”, a definition consistent with our own. The toolkit has useful guidance towards the development process, technology choice, financing options, and selection of business models. Its overall framework (see Figure 41 below) identifies necessary aspects for sustainability: practical technology choice, provision of training, community involvement, maximizing productive uses, etc. The elements that are included in [11] imply the project design address sustainability factors (i.e. technical, social, economic, organizational, and environmental) without necessarily prescribing the ‘right’ solution.

When compared to the indicator frameworks from section 2a, the toolkit has a relatively broader view of sustainability. By addressing aspects of project design, project implementation, institutional environment, regulatory environment, international support, the toolkit links together the whole lifecycle of an off-grid project.

[12] See [9], sections 2.2.1, 2.2.2 for this discussion.

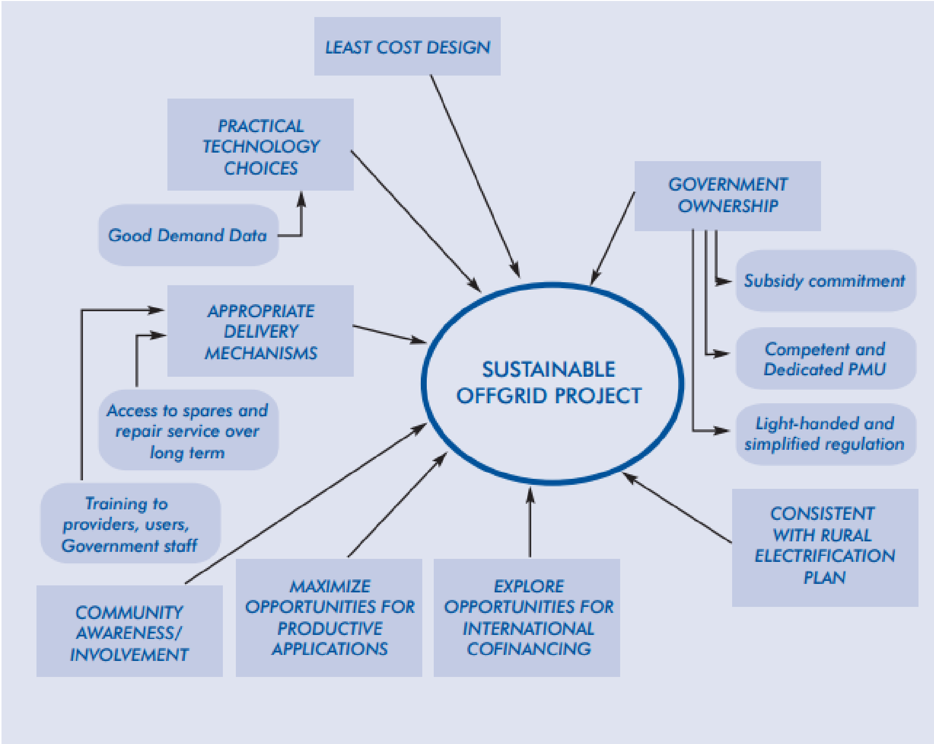

Figure 41: Elements of a Sustainable Off-grid Electrification Project (reproduced from World Bank 2008)

While the World Bank guidance document is prominent, it is by no means the only source of guidance for sustainability of off-grid projects.

Another resource designed specifically for sustainability guidance in the establishment of community PV was produced by ESMAP [12]. The guidance points out that "[t]he key aim should be sustainability, which at the minimum is the reliable, cost-effective operation of a system over its design lifetime" (p5). It describes a phased approach which includes rapid pre-assessment, implementation planning, install, and long-term ongoing operation. The guidance provides very detailed suggestions throughout this process based on the author's experience and is an excellent reference source. Nonetheless, its recommendations do not organize or explicitly address sustainability nor are there any specific indicators which could be used to evaluate sustainability over time.

15.3 Sustainability from Case Studies and other Field Experiences

Other sources come in many forms such as case studies, project reports, presented materials, or specific guides. They are too numerous to list comprehensively, but each has contribution to the understanding of what makes a project sustainable. For example, the case studies from the MREAP community energy evaluation in 2012 [7] identified many areas of concern for sustainability:

- The Solar Villages[13] project was identified as not having a clearly established and effective ownership, operation, and maintenance arrangement. Furthermore, roughly a third of the batteries systems were non-operational, a key indicator of technical system failure. Additionally the ability of the project to secure an income to support its long term maintenance and operation was far insufficient.

[13] For reference see case study 6 within the annex of the evaluation

- The CRED project[14] similarly identified insufficient financial resources in the initial study. Later field reports confirmed this but also identified additional issues such as with the functioning of the community energy committee, the defacto owners of the project, breaking down or in one case, acting on the behalf of a single individual.
- The Senga Bay project[15] identified a lack of a financial model to support the system.
- The Milonde Youth Club Business Centre project[16] identified a lack of transparency and accountability in the record keeping and only limited generation of revenues. Limited system availability was cited as a problem indicating inadequate system sizing during design. Finally, the technical support arrangement was not clear.

While many aspects of sustainability are addressed through these sources, there are challenges in their use as more generally. Rarely (if ever) do they comprehensively address all the potential scenarios and issues a project could face.

There is also a distinct issue of generality during re-use; any recommendations have to be re-interpreted to the particular circumstances of the new context. Monitoring and evaluation (M&E) is uncommon, especially with any standard indicators. This would allow a more robust comparison. Finally, many experiences go undocumented due to cost implications and obviously those which 'fail' are (understandably) not highly publicized.

15.4 Sustainability and PV Study Design

Figure 42 outlines a general framework for consideration of sustainability and connects up the relative role of the project design and implementation phases. This represents the conception of sustainability used in this study. Because the project is strictly constrained by the project design phase, sustainability itself will be linked the decisions made on the design earlier on. Finally, the whole project sits within a set of institutions (i.e. legal, governance, economics, etc.) that enable, detract, or constrain the project as the case may be.

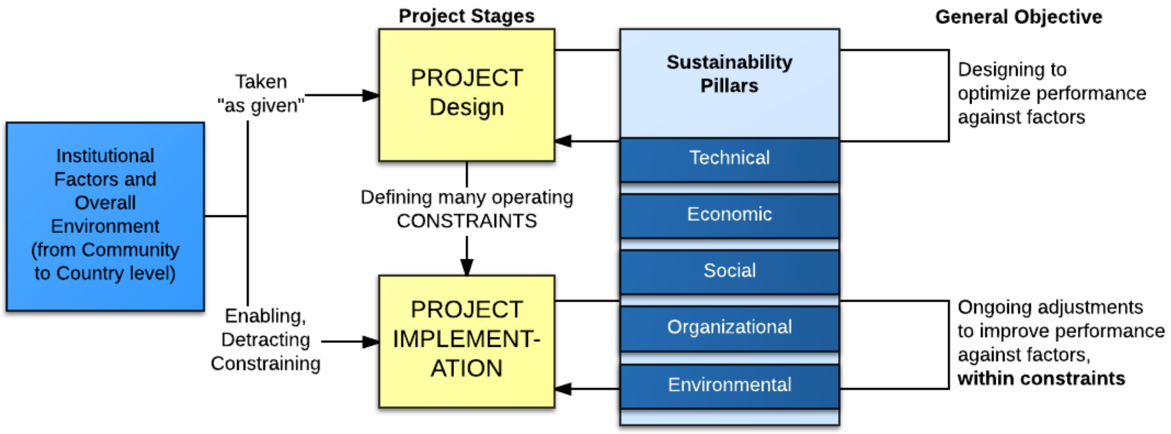

Figure 42: Sustainability Pillars and Project Design

Within the Solar PV Sustainability Study it is used as the framework for analysis and evaluation of sustainability factors in retrospect, that is, after the project has been installed and is operational. The approach to survey design was to capture a set of indicators from included projects that were related

[14] See case study 1
[15] See case study 8
[16] See case study 11

to the various sustainability pillars that ultimately allows for comparison and further analysis. Each sustainability pillar (technical, economic, social, organizational, and environmental) has a distinct section in the survey with relevant questions. It was logistically impossible to capture and include indicators covering the "Institutional Factors and Overall Environment" within this survey.

Since there were no meaningful results from the environmental section of the survey, this has been omitted from the remainder of the report. In short, no significant environmental issues were reported by the projects. This is unsurprising given the fact that all projects utilized Solar PV which (installed) has minimal environmental concerns. Although issues around battery recycling and disposal are clearly relevant to environmental sustainability, the perspective of the respondents and the questionnaire approach was such that this issue was never broached.

In analyzing the results we review responses for each indicator individually and then undertake a ranking process, scoring projects against each of the indicators.

We take a similar approach as in [17] for ranking, but have used an alternative set of indicators which were more readily available and justified a similar ranking approach. It is important to note that this approach effectively establishes a scoring mechanism which is relative to other projects which are included. Some projects are not included due to lack of sufficient data. Thus, a project which is ranked relatively high among this data set may still be absolutely unsustainable; interpretation of the results is necessary.

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Annex 1:Solar PV Survey

Malawi Renewable Energy Acceleration Programme

SUSTAINABILITY OF SOLAR PV SYSTEMS AT RURAL SCHOOLS AND HEALTH CENTRES IN MALAWI

Main Survey

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Document Revision

8/24/2014
V4.0 Final

Ethics Statement

The surveyor (and full research team) is responsible for adhering to the Ethical guidelines listed below.

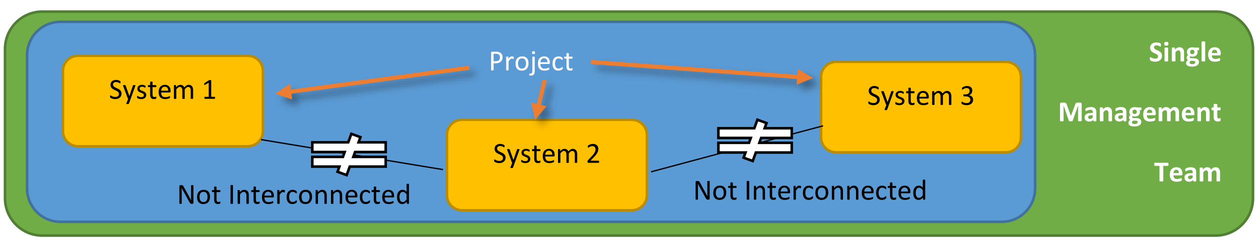
1. Right to knowledge of use and intention of research is shared with respondents and community
2. Respondents are under no obligation to give data or information. In providing the data, it is assumed that respondents are freely doing so, under no coercive force of any kind. If the respondent feels uncomfortable with any question, it is their right to refuse answering.
3. It is understood that the respondents are speaking behalf of themselves only.
4. The research team is expected to act professionally at all times when representing MREAP
5. Any personal data will be made anonymous and will not be shared with anyone outside of the research team
6. It is the desire of the research team to receive honest and unbiased responses.
7. The research team makes no personal judgment onto the responses or respondent
8. The research team will Adhere to MREAP social inclusion policy (https://sites.google.com/site/mreapreef/social-inclusion-policy)
9. The research team will adhere to local customs as appropriate.

Definitions

A common understanding of the terms "project", and "system" amongst the research team is required to ensure survey is implemented correctly. The extent of the project will need to be determined quite quickly at each location. The following definitions are used:

A *Project* is a set of energy assets in which distinct management team is responsible. A project may consist of one or more systems.

A *System* is an individual set of energy assets that are interconnected with each other.



For example, at a typical primary school there is a single solar PV project. This project may provide lighting for 4 rooms for students and at the headman's office, as well as for two households of teachers at the school. The project also has a revenue generating activity that charges money for recharging mobile phones. However this project has 6 separate systems (which are not interconnected with each other):

1. 1 set of panels, batteries, wires, and lights at the headman's office
2. 1 set of panels, batteries, wires, and lights that provides power for level 8 and level 7 classrooms
3. 1 set of panels, batteries, wires, and lights that provides power for level 6 and level 5 classrooms
4. 1 set of panels, batteries, wires, and lights for a teacher's household
5. 1 set of panels, batteries, wires, and lights for another teacher's household
6. 1 set of panels, batteries, wires, and lights for the revenue generating activity

These systems are all under one project since the management team looking after the project is responsible for ensuring the operation and maintenance.

What is outside of this project? In the previous example, if another teacher self-funded their own solar home system and is responsible for it, then it is a separate project.

Surveyor Skills

- Ability to communicate in local language, translate, and transcribe answers into English
- Technical background with an awareness of Solar PV system design
- Awareness of local customs
- Strong verbal communication skills with an ability to ask probing questions

Permission to use survey

During the survey period, restrict access to survey to your team members. After completion of the final report, the survey will be published along with all documentation on the MREAP website.

Preparation to have access to necessary documents

Before you travel to the survey site and again before the survey starts at site, make sure that all necessary documents (data sources, log books, financial records etc) are readily available and accessible by the respondents!

Read-Out Loud (English Version)

The main purpose of the survey conducted today is to learn about the sustainability of solar PV systems in Malawi at rural health centres and schools. This work is part of the Scottish Government MREAP grant, which seeks to accelerate renewable energy in Malawi. I am from [organization] and my role is [role]. Our full team consists of The University of Strathclyde in Scotland, Renew'N'Able Malawi, the Polytechnic, Mzuzu University, and Concern Universal.

Currently, solar PV systems often fail or do not live up to the expectations. Ultimately, we would like to help implementers to improve sustainability of systems, like yours, so they can deliver the benefits they promise and make an impact on the community.

Over the country we are learning from over 45 community solar PV projects, which we will analyze to determine what is working and what's not. Your project will influence what we learn. Our goal is to influence policy makers, implementers, educators, and communities.

We will ask many questions about how the project is operating from a technical perspective, economics and finances, ownership and decision making, and impact. This will likely take around 4 hours in all to complete. I, as the surveyor, will be guiding the process, asking the questions and helping you to answer properly. I have been trained to implement this survey and can answer any questions you may have about it at any time.

Before we get started I want to express my gratitude to you for your willingness to tell us about your project, and for the time you have committed. Thank you very much!

Read-Out Loud (Chichewa Version)

Tikuchita kafukufuku ameneyu kuti tidziwe ngati magetsi oyendera mphamvu ya dzuwa (kapena kuti magetsi a sola) angathe kufika pokhala magetsi odalirika m'zipatala ndiponso m'masukulu a m'midzi ya ku Malawi kuno.

Dziko la Scotland ndi limene lachititsa kafukufukuyu monga mbali ya ntchito zotukula njira zamakono zogwiritsa ntchito zipangizo zosawononga chilengedwe. Ine ndachokera ku **[tchulani bungwe]** ndipo udindo wanga ndi **[tchulani].**

Kafukufukuyu tikuchitira limodzi ndi anzathu a ku University of Strathclyde ku Scotland, a ku Renew'N'Able Malawi, ku Polytechnic, ku Mzuzu University ndi ku Concern Universal.

Anthu ambiri amene anayesapo kugwiritsa ntchito magetsi oyendera mphamvu ya dzuwa masiku ano, amaona kuti ndi osadalirika.

N'chifukwa chake tikufuna kuthandiza mabungwe amene amabweretsa magetsiwa, kuti azitha kubweretsa magetsi odalirika kuti madera a kumidzi atukuke.

M'Malawi muno, pali madera oposa 45 a kumidzi amene tikuchitamo ntchito younika bwinobwino kuti tione ngati magetsi oyendera mphamvu ya dzuwa kumeneko akupindulitsa anthu kapena ayi, n'kuona mbali zofunika kuzikonza.

Moti ntchito imene ikuchitika kwanu kuno itithandiza kudziwa zambiri pankhani imeneyi.

Cholinga chathu n'choti nzeru zimene tizipeze pa kuunikaku tizigawane ndi aboma, mabungwe, masukulu ndiponso mafumu.

Tikufunsani mafunso ambiri okhudza mmene ntchito imeneyi ikuyendera kwanu kuno pankhani ya zipangizo, ndalama, bizinesi, ndiponso mmene mumayendetsera nkhani zosiyanasiyana zokhudza ntchitoyi.

Tikufunsaninso za mmene ntchitoyi ikukhudzira miyoyo ya anthu kunoko.

Tikufunika maola 4 kuti timalize zonse.

Mafunsowo ndizifunsa ndi ineyo, inuyo muzingoyankha zimene ndafunsazo basi, ndipo ngati penapake simunamvetsetse, nenani kuti ndifotokoze bwinobwino.

Ineyo ndauzidwa zonse zokhudza kafukufukuyu moti ngati muli ndi funso lililonse pankhaniyi khalani omasuka kundifunsa nthawi ina iliyonse.

Tisanayambe chilichonse, ndikufuna kukuthokozani chifukwa chovomera kuti tikufunseni mafunso okhudza ntchito imene mukuchita kwanu kuno, komanso polola kusiya kaye zimene mumachita kuti muyankhule nafe.

Zikomo kwambiri.

Section 0 - Record of Survey (fill as much as possible before starting the interview)

0.01	**Name of Surveyor**	
0.02	**Organization of Surveyor**	
0.03	**Date Survey Conducted**	
0.04	**Name of School or Health Centre/Post**	
0.05	**Region (N,C,S)**	
0.06	**District**	
0.07	**City/Village**	
0.08	**Traditional Authority**	
0.09	**Density**	Rural ◯ Peri-Urban ◯ Urban ◯
0.10	**Surveyor Relationship to project**	Selected by Field Partner ◯ Selected by Survey Coordinator ◯
0.11	**Definition of Site**	Junior Primary School ◯ Full Primary School ◯ Secondary School ◯ Gov. Health Centre ◯ Private Health Centre ◯ Other (mention)
0.12	**Respondent 1 Info: (obligatory)**	Name: Age: Role/Position: Gender: Primary Profession:
0.13	**Respondent 2 Info: (if applicable)**	Name: Age: Role/Position: Gender: Primary Profession:
0.14	**Respondent 3 Info: (if applicable)**	Name: Age: Role/Position: Gender: Primary Profession:

Project:

Section 1 – Basic Project Profile Information (mainly sourced on project administration/ management level)

1.01	**Number and ID# of Systems in Project** *(example: #1 Store Rooms & Vaccine Fridge, #2 Teacher Battery Charging, #3 Phone Charging & Lighting Classroom 1+2) – if more systems than rows, add on the backside in same way; clearly indicate question number.*	1.02	**When did the solar system(s) start operations?** (Month, year; if different dates, mention per system
#		#	
#		#	
#		#	

1.03	**Initial Project Capital funding:** Input amount for each funding source and estimated % of total funding. Additional details for loans are also requested. Indicate currency in the last column. (Note: In-kind contributions are NOT asked at this point.)	Community (Cash)		Est. Amount (%)		(Curr.)
		Grant		Est. Amount (%)		
		Loan		Est. Amount (%)		
		Interest Rate (%)		Payment prd. (years)	(months)	
		Down Payment (%)				
		Gifts		Est. Amount (%)		
		Other:		Est. Amount (%)		
		Unknown ○	If unknown, name and contact of a person who might know more?			

1.04	**Name of Sponsoring Organizations that gave funding?**		○ Local	○ Foreign
			○ Local	○ Foreign
			○ Local	○ Foreign

1.05	**Were there any other organizations that were involved with procurement, training, installation?**	Name		○ Local	○ Foreign
		Role(/s):	☐ install	☐ procurement	☐ training
		Name		○ Local	○ Foreign
		Role(/s):	☐ install	☐ procurement	☐ training
		Name		○ Local	○ Foreign
		Role(/s):	☐ install	☐ procurement	☐ training

1.06	**Name & Location of contractor**			☐ Unknown
1.07	**When installed, was the contractor MERA certified?**	☐ Yes	☐ No	☐ Unknown

1.08	**Who owns the project?**	A. Entirely Community Owned	○	
		B. Utility Owned	○	
		C. Entirely Privately Owned	○	Who:
		D. Externally Owned	○	Who:
		○unknown ○ Other	How:	

1.09	**Does this project participate in a Carbon Credit Scheme?**	☐ Yes	☐ No	☐ Unknown
1.10	**Does this project have an income generation activity?**	☐ Yes	☐ No	☐ Unknown

Section 2 – Data Capture Routines (1 page/data source)

[Note to Surveyor: Print multiple versions for this page. Each page should filled out for each data source].

2.01	**Name of Data Source**	**Kind of Data Source #***	**Data Metrics Captured (i.e. voltage, current, income, expense, operational status, etc.)**		
	*Kind of Data Source #: 1 Logbook, 2 Set of Forms, 3 Receipts, 4 Digital Logbook, 5 Other: describe				
2.02	**Who was trained to capture data? (Designation/Role, not name)**				
2.03	**When was the last training on data capturing (Month/Year)**				
2.04	**Frequency of data captured. In the last month how frequently was the data captured?**	More than once per day ◯	Once per week ◯		
		Once per day ◯	Once per month ◯		
		Between 1 and 7 times per week ◯	Less than once per month ◯		
2.05	**Consistency of data captured. Were there any gaps in the data in the past month?**	No Gaps ◯			
		Some gaps present ◯			
		No Data was recorded over the past month ◯			
2.06	**Why do you record this data? How is this data used?** (list all uses)				
2.07	**Any other important information on this data source?**				

Section 3-7 Sustainability Pillars

Section 3- Technical Sustainability

Table 1: General Health Check – one form/system

3.01	**System ID**	
3.02	**Panel Orientation- Is the panel North Facing?**	Yes ◯ No ◯
3.03	**Panel Installation:** **Specific mounting or roof-attached?**	Mounting ◯ Roof Attached ◯ Other ◯
3.04	**Vegetation**	No apparent vegetation issues ◯ Vegetation are overhanging or in close proximity to panels ◯
3.05	**Do the batteries have a solid enclosure?**	Yes ◯ No ◯ If yes, is it well ventilated (when closed)? Yes ◯ No ◯
3.06	**Does the system have a Control Board?**	Yes ◯ No ◯
3.07	**Are all end-use devices connected via charge controller?**	Yes ◯ No ◯
3.08	**The inverter is…**	connected through charge controller ◯ directly connected to battery ◯ No inverter ◯
3.09a	**Are fuses or circuit breakers present?**	Yes ◯ No ◯
3.09b	**[Q to surveyor] is there any evidence of tampering with original system design?** (Answer Yes if <u>any</u> component shows <u>any</u> sign of tampering)	Yes – sign of tampering ◯ No sign of tampering ◯ Unclear / Unable to determine ◯ If yes, describe briefly

Project:

Table 2: System Components Spec and Health – One form/System

	Component	Number of units	Total Rating (Watts, Ah, Amps)	Brand	Model number	Health Check Status
3.10	PV Panels	Design: Observed:	(total **Watts Peak**)			No apparent issues ☐ Panels Dirty ☐ Visible Damage ☐ Wiring Fault ☐ No. Mis. Missing ☐
3.11	Batteries	Design: Observed:	(total **Ah**)			No apparent issues ☐ Corrosion seen ☐ Visible Damage ☐ Wiring Fault ☐ Missing ☐ No access ☐ Health Indicator (if available): Good ☐ OK ☐ Bad ☐
3.12	Charge Controller		(**Amps**)			No apparent issues ☐ Non operational ☐ Fuses Blown ☐ Visible Damage ☐ Wiring Fault ☐ Missing ☐ No access Charge Controller health indicator (if available): Good ☐ OK ☐ Bad ☐
3.13	Inverter		(**Watts or Amps as available**)			No apparent issues ☐ Non operational ☐ Visible Damage ☐ Wiring Fault ☐ Missing ☐ No access
3.14	Fuses/Circuit Breakers		(**Amps**)			No apparent issues ☐ Visible Damage ☐ Wiring Fault ☐ Fuses Blown ☐ Missing ☐
3.15	Cabling/ wires	(see cable table below)				No apparent issues ☐ Poor Insulation condition ☐ Hanging or improperly fixed ☐ Missing ☐

Cable/Wire Segment	Gauge (mm)	Sign of Tampering	Unable to inspect
Panels to Charge Controller		☐	☐
Charge Controller to Battery		☐	☐
Load Curcuits		☐	☐

Project:

Table 3: Lighting Load: Usage and Expectations – 1 row / room (1 sheet per 6 rooms)

Sys #	Rm #	Room Type	AC/DC	Total # of light sockets/ fittings	Number of working lights	Bulb Type	Rating per light bulb (W)	Usage				Main Source of Constraint (actual usage vs. expected), if any
								Actual		Expected		
								Days per week	Hours per day	Days per week	Hours per day	
		Classroom/ Maternity W. ○ Office ○ Staff House ○ Other ○	AC ○ DC ○			CFL ○ LED ○ Incandescent ○ Other ○						User ○ System ○ Unclear ○
		Classroom/ Maternity W. ○ Office ○ Staff House ○ Other ○	AC ○ DC ○			CFL ○ LED ○ Incandescent ○ Other ○						User ○ System ○ Unclear ○
		Classroom/ Maternity W. ○ Office ○ Staff House ○ Other ○	AC ○ DC ○			CFL ○ LED ○ Incandescent ○ Other ○						User ○ System ○ Unclear ○
		Classroom/ Maternity W. ○ Office ○ Staff House ○ Other ○	AC ○ DC ○			CFL ○ LED ○ Incandescent ○ Other ○						User ○ System ○ Unclear ○
		Classroom/ Maternity W. ○ Office ○ Staff House ○ Other ○	AC ○ DC ○			CFL ○ LED ○ Incandescent ○ Other ○						User ○ System ○ Unclear ○
		Classroom/ Maternity W. ○ Office ○ Staff House ○ Other ○	AC ○ DC ○			CFL ○ LED ○ Incandescent ○ Other ○						User ○ System ○ Unclear ○

Table 4: Other System Loads, REGULAR Loads – 1 form/system

	System:				Usage				Main Source of Constraint, if any
					Actual		Expected		
	Load Type	Number	Rating (per item, W)	AC / DC	Days per week	Hours per day	Days per week	Hours per day	
3.20	Mobile phones			AC ◯ DC ◯					User ◯ Unclear ◯ System ◯
3.21	Radios			AC ◯ DC ◯					User ◯ Unclear ◯ System ◯
3.22	Computers			AC ◯ DC ◯					User ◯ Unclear ◯ System ◯
3.23	TV			AC ◯ DC ◯					User ◯ Unclear ◯ System ◯
3.24	Refrigerator			AC ◯ DC ◯					User ◯ Unclear ◯ System ◯
3.25	Stereo			AC ◯ DC ◯					User ◯ Unclear ◯ System ◯
3.26	Other:			AC ◯ DC ◯					User ◯ Unclear ◯ System ◯

3.27	Table 5: Other System Loads, Occasional Loads – 1 form/system			
	Load Type	Number	Rating (per item, W)	AC / DC
				AC ◯ DC ◯
				AC ◯ DC ◯
				AC ◯ DC ◯

Project:

Table 6: Technical Problems/Symptoms: 1 table/system

System: #					
Symptom					
Have all services been lost (both lights and power)?		Yes	◯	No	◯
Lighting problems	All lights failed all of the time	Yes	◯	No	◯
	Lights only on during day	Yes	◯	No	◯
	Lights on at night for short time but cut out	Yes	◯	No	◯
Power problems (all other regular services)	All power services lost all of the time	Yes	◯	No	◯
	Power only during day	Yes	◯	No	◯
	Power at night for short time but cuts out	Yes	◯	No	◯

System: #					
Symptom					
Have all services been lost (both lights and power)?		Yes	◯	No	◯
Lighting problems	All lights failed all of the time	Yes	◯	No	◯
	Lights only on during day	Yes	◯	No	◯
	Lights on at night for short time but cut out	Yes	◯	No	◯
Power problems (all other regular services)	All power services lost all of the time	Yes	◯	No	◯
	Power only during day	Yes	◯	No	◯
	Power at night for short time but cuts out	Yes	◯	No	◯

System: #					
Symptom					
Have all services been lost (both lights and power)?		Yes	◯	No	◯
Lighting problems	All lights failed all of the time	Yes	◯	No	◯
	Lights only on during day	Yes	◯	No	◯
	Lights on at night for short time but cut out	Yes	◯	No	◯
Power problems (all other regular services)	All power services lost all of the time	Yes	◯	No	◯
	Power only during day	Yes	◯	No	◯
	Power at night for short time but cuts out	Yes	◯	No	◯

System: #					
Symptom					
Have all services been lost (both lights and power)?		Yes	◯	No	◯
Lighting problems	All lights failed all of the time	Yes	◯	No	◯
	Lights only on during day	Yes	◯	No	◯
	Lights on at night for short time but cut out	Yes	◯	No	◯
Power problems (all other regular services)	All power services lost all of the time	Yes	◯	No	◯
	Power only during day	Yes	◯	No	◯
	Power at night for short time but cuts out	Yes	◯	No	◯

Section 4 – Economic Sustainability

4.01	**What was the initial capital cost of the project**		MWK ◯ / USD $ ◯ / Other

INCOME

4.02 **Type and gross income of Revenue Generation Activities**

Record ALL income into the project.

Types	Check if yes	Typical Income per month (MWK)	Last Month income (MWK)	Last Year income (MWK)	# customers last month
Mobile phone charging	☐				
Barber shop	☐				
12V (car battery) charging	☐				
TV/Stereo/Radio shows	☐				
Night room rental	☐				
Fee for other electric service	☐				
Other: _______________	☐				

4.03 **Are there any occasional gifts that benefit the project?**

Yes	◯	**If Yes**, describe below incl source, frequency, type, estimated amount.
No	◯	

COSTS

4.04 **Operational Costs**

Record ALL costs for the project (note System maintenance costs handled in next question)

Types	Check if yes	Typical Monthly Costs (MWK)	Last Month Cost(MWK)	Last Year Cost(MWK)
Fuel, Type: ____________	☐			
Land Leasing Costs	☐			
Payments to Security	☐			
Revenue Gen. Labour (eg Customer Care)	☐			
Payments to dedicated Operator(s)/Technician(s)	☐			
Payments to Committee	☐			
Other: _______________	☐			

MAINTENANCE COSTS

4.05 **System Maintenance Costs**

Types	Check if yes	Typical Monthly Costs (MWK)	Last Month Cost(MWK)	Last Year Cost(MWK)
Maintenance Labour	☐			
Maintenance Transport	☐			
Repair/replacement of light bulbs	☐			
Repair/replacement of batteries	☐			
Repair/replacement of inverter	☐			
Repair/replacement of wiring/sockets/switches	☐			
Repair/replacement of charge controller	☐			
Repair/replacement of Solar Panels	☐			
Other: ___________________ ________________________	☐			

REV GEN EXPENSES

4.06 **What costs have been incurred to support revenue generating activities not covered above?**

Describe expenses	Typical Monthly Costs (MWK)	Last Month Cost(MWK)	Last Year Cost(MWK)

OTHER USES OF INCOME / NON-SYSTEM COSTS

4.07 **What non-system related costs have been incurred? This includes spend for community/school items (i.e. uniforms, meals, class materials)**

Describe expenses	Typical Monthly Costs (MWK)	Last Month Cost(MWK)	Last Year Cost(MWK)

	Shared services / goods				
4.08	**Are any services supplied to anyone for free?**	Describe service	Frequency	Who?	Value if charged (MWK per month)

	Routines			
4.09	**Is there someone appointed as a treasurer?**	Yes ◯ No ◯	**Is financial data available to stakeholders?**	Yes ◯ No ◯
4.10	**Is there a bank account established for the <u>project</u>?**	Yes ◯ No ◯		
4.11	**What is the current balance of the Maintenance & Operation budget? Is it on track?**	No M&O budget ◯ Balance: ________ Yes ◯ No ◯	**What targets were set for balances for M&O budget?**	Target: ________ Date: __________
4.12	**Do you have insurance available for the project?**	Yes – we have insurance ◯ No – too expensive/other reasons ◯	None available ◯ Don't know / unsure ◯	
4.13	**Was a market survey completed prior to implementing the project?**	Yes ◯ No ◯ No Idea ◯	**If YES, did the survey determine the potential customer willingness to pay for energy services?**	Yes ◯ No ◯
4.14	**Has the system been significantly expanded since inception?**	Yes ◯ No ◯	4.15 **Are there currently (concrete) plans to significantly expand the system?**	Yes ◯ No ◯

	Competition	
4.16 a	**What competition to revenue generating activities currently exist in close proximity to the project (less than 5 km)? If so, how can it be quantified?**	
4.16 b	**Are you aware of any future plans that could introduce competition? Please describe**	

Section 5- Social Sustainability

	Inception			
5.01	**Was the community consulted prior to project inception?**	Yes ◯ / No ◯ / Unknown ◯	**Was a social needs assessment completed prior to project inception?**	Yes ◯ / No ◯ / Unknown ◯
5.02			**Did the needs assessment identify a significant energy need?**	Yes ◯ / No ◯ / Unknown ◯
5.03	**What level of community contribution was provided to the project?** ◯ Unknown			

Type		Amount/Unit
Money	◯	
Time/Labour	◯	
Materials	◯	
Other	◯	

Stakeholders

5.04	**How often does a stakeholder group meet and discuss this project?**	Weekly or more ◯	Once/ 2 weeks ◯	Once / month ◯			
		Once / 2 months ◯	Less than once / mo ◯	Never ◯			

Which Stakeholders are represented in the project, and at what authority?

	Stakeholder	Attends meetings?	What decisions are they involved in?		
5.05	◯ **Community Based Organization**	Yes ◯ / No ◯	Daily Operations ◯ / Conflict resolution ◯	Transparency ◯ / Financial mgmt. ◯	Long-term plans ◯ / Other:__________ ◯
5.06	◯ **NGO: ____________**	Yes ◯ / No ◯	Daily Operations ◯ / Conflict resolution ◯	Transparency ◯ / Financial mgmt. ◯	Long-term plans ◯ / Other:__________ ◯
5.07	◯ **Gov't Body: ____________**	Yes ◯ / No ◯	Daily Operations ◯ / Conflict resolution ◯	Transparency ◯ / Financial mgmt. ◯	Long-term plans ◯ / Other:__________ ◯
5.08	◯ **Traditional Authority**	Yes ◯ / No ◯	Daily Operations ◯ / Conflict resolution ◯	Transparency ◯ / Financial mgmt. ◯	Long-term plans ◯ / Other:__________ ◯
5.09	◯ **School Representative**	Yes ◯ / No ◯	Daily Operations ◯ / Conflict resolution ◯	Transparency ◯ / Financial mgmt. ◯	Long-term plans ◯ / Other:__________ ◯
5.10	◯ **Student Representative**	Yes ◯ / No ◯	Daily Operations ◯ / Conflict resolution ◯	Transparency ◯ / Financial mgmt. ◯	Long-term plans ◯ / Other:__________ ◯
5.11	◯ **Other: ______________**	Yes ◯ / No ◯	Daily Operations ◯ / Conflict resolution ◯	Transparency ◯ / Financial mgmt. ◯	Long-term plans ◯ / Other:__________ ◯
	◯ **Other: ______________**	Yes ◯ / No ◯	Daily Operations ◯ / Conflict resolution ◯	Transparency ◯ / Financial mgmt. ◯	Long-term plans ◯ / Other:__________ ◯

Decision Making Process				
5.12	If there is a fault on the system, **for example, it stops working entirely**, who is responsible for making the decision on how to handle it? What would the decision process look like?		**Has this occurred ever?**	Yes ◯ / No ◯ / unknown ◯
			If so, in your opinion, was this resolved adequately?	Yes ◯ / No ◯ / unknown ◯
5.13	If there is there is a decision on how to use the money generated from the system, **for example, on either the replacement of the inverter, or to buy school improvements,** who is responsible for making the decision on how to handle it? What would the decision process look like?		**Has this occurred ever?**	Yes ◯ / No ◯ / unknown ◯
			If so, in your opinion, was this resolved adequately?	Yes ◯ / No ◯ / unknown ◯
5.14	**In general, who is it that makes decisions for this project?**	An Individual ☐ / Committee ☐ / Community Gathering ☐ / External Organization ☐		
5.15	**Is there District level involvement in the project?**	Yes ◯ / No ◯	If yes, was involvement only at inception? (check if so) ◯ / What District Authority(/ies)?	
Theft				
5.16	**Has this project experienced any issues with theft?**	Yes ◯ No ◯		
5.16	**If yes, what was stolen?**	Money ◯ Equipment ◯ Other ◯		
5.17	**If so, was the person brought to justice?**	Yes ◯ No ◯		
5.18	**Are there security measures in place to prevent/mitigate?**	Yes ◯ No ◯		
5.19	**If yes, which measures do you feel are useful for prevention/mitigation of such theft?**			

Project:

Section 6 - Organizational Sustainability

Training

6.01 What type of training was provided prior to or during installation?

Type	Check if Yes	Delivered To: General/ Community	Delivered To: Committee / Project Managers	Delivered by (Fill in organization name)
Technical	☐	☐	☐	
Approx. No. of Days			Approx. No of People	
Financial/ Accounting	☐	☐	☐	
Approx. No. of Days			Approx. No of People	
Management	☐	☐	☐	
Approx. No. of Days			Approx. No of People	

6.02 What type of training is currently provided on an ongoing basis to anyone involved in the project?

Type	Check if Yes	Frequency: < 1/year	Frequency: 1/year	Frequency: > 1/yr	Delivered by (Fill in organization name)
Technical	☐	○	○	○	
Financial/ Accounting	☐	○	○	○	
Management	☐	○	○	○	

6.03 Current Team, Roles and Education levels. Do you currently have someone on staff filling the roles of management of the project (could be part of managing committee)?

Type	Check if Yes	Yrs. Of exp. In role (round up)	Education Level (highest level of completion): Primary	Secondary	Further	Does this person have education relevant to role?
Technical	☐		○	○	○	Yes ○ No ○ unknown ○
Financial/ Accounting	☐		○	○	○	Yes ○ No ○ unknown ○
Manageme nt	☐		○	○	○	Yes ○ No ○ unknown ○

6.04 When a person on the current team leaves, what training does the new person get?

Training organization above trains new person	☐	Informal on-the-job training	☐
Successor trained by person currently doing the job	☐	No training	☐
		No process in place	☐

6.05 Do you currently have an arrangement with a technician or organization to support maintenance and/or replacement of equipment? Yes ○ No ○

6.06	**Use / Condition of Tools**	Type	Access?		Main form:	In good shape?				
		Technical maintenance tools	Yes	◯		Yes	◯			
			No	◯		No	◯			
		IT systems (incl. Computers)	Yes	◯		Yes	◯			
			No	◯		No	◯			
6.07	**What is the availability of the following spare parts?**	Type	No. of Spares currently on hand?	Availability?						
		Light Bulbs		Within 5km	◯	5km – 20km	◯			
				> 20km	◯	unknown	◯			
		Station Batteries		Within 5km	◯	5km – 20km	◯			
				> 20km	◯	unknown	◯			
		Charge Controllers		Within 5km	◯	5km – 20km	◯			
				> 20km	◯	unknown	◯			
		Inverters		Within 5km	◯	5km – 20km	◯			
				> 20km	◯	unknown	◯			
		Solar Panels		Within 5km	◯	5km – 20km	◯			
				> 20km	◯	unknown	◯			

Section 7 - Environmental Sustainability

7.01	**Have any local potential environmental impacts been identified? List all below**	
7.02	**Through disposal of waste products**	Positive Impact ◯ Negative Impact ◯ Both ◯ None ◯ N/A ◯
7.03	**Through release of pollutants**	Positive Impact ◯ Negative Impact ◯ Both ◯ None ◯ N/A ◯
7.04	**Other:** Positive Impact ◯ Negative Impact ◯ Both ◯ None ◯ N/A ◯	
7.05	**Other:** Positive Impact ◯ Negative Impact ◯ Both ◯ None ◯ N/A ◯	
7.06	**Other:** Positive Impact ◯ Negative Impact ◯ Both ◯ None ◯ N/A ◯	
7.07	**Other:** Positive Impact ◯ Negative Impact ◯ Both ◯ None ◯ N/A ◯	
7.08	**Is there a (concrete) plan to mitigate the potential impacts? If yes, please describe briefly below**	Yes ◯ No ◯
7.09	**Is the plan both active and well supported?**	Yes ◯ No ◯

Section 8: Impact Records

SECTION 8 A – Social Services and Community Development: 1 form/project

8.01	*Social Services and Community Development.* **In your opinion, what kind of social or community services/infrastructure have been offered or improved thanks to the introduction of PV-electricity?** Check box(es), (more than one possible) or fill in last row choice if service not listed	**Improved Health Facilities**	☐
8.02		**Education**	☐
8.03		**Training centre (professional, farmer)**	☐
8.04		**Public lighting**	☐
8.05		**Drinking/tap water**	☐
8.06		**Telecommunications**	☐
8.07		**Other, namely: ______________________________**	☐

8.08	**In your opinion, in what way has local lifestyle improved because of the introduction of Solar PV-electricity?** Check box(es), (more than one possible) or fill in last row choice if impact is not listed	**Better Quality courses/training**	☐
8.09		**More involvement and participation in community development activities**	☐
8.10		**Productive activities / handicrafts (in the evening)**	☐
8.11		**Courses/classes/training or homework in the evening**	☐
8.12		**Better opening hours for shops, restaurants, etc.**	☐
8.13		**Liberating time of villager for other activities**	☐
8.14		**Better communications / information**	☐
8.15		**Higher health standards**	☐
8.16		**Improvement of local natural environment**	☐
8.17		**Other, namely: ______________________________**	☐
8.18	**In your opinion, how has the introduction of PV-electricity at this site impacted the surrounding local economy?**	Overall positive ◯ Overall negative ◯ Both equally ◯ None ◯ N/A ◯ **How:**	
8.19	**In your opinion, were there any other positive and negative impacts that have not been mentioned or that need further explanation?**		

Project:

SECTION 8 B – Complete for **Primary Schools Only – Attendance & Entrance Rates (2 Forms/Project)**

8.20	**Year of Data**		**PV system installed?**	Yes ◯ No ◯		**Avg. Teachers**		**Total Students**	**Male:**		**Female:**	
Secondary School Entrance Rates												
8.21	**Total who sat for tests**		**Number going to national secondary school**		**Number going to district secondary school**		**Number going to conventional secondary school**		**Number going to community day secondary school**		**Number failed**	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**

8.20	**Year of Data**		**PV system installed?**	Yes ◯ No ◯		**Avg. Teachers**		**Total Students**	**Male:**		**Female:**	
Secondary School Entrance Rates												
8.21	**Total who sat for tests**		**Number going to national secondary school**		**Number going to district secondary school**		**Number going to conventional secondary school**		**Number going to community day secondary school**		**Number failed**	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**

8.20	**Year of Data**		**PV system installed?**	Yes ◯ No ◯		**Avg. Teachers**		**Total Students**	**Male:**		**Female:**	
Secondary School Entrance Rates												
8.21	**Total who sat for tests**		**Number going to national secondary school**		**Number going to district secondary school**		**Number going to conventional secondary school**		**Number going to community day secondary school**		**Number failed**	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**

8.20	**Year of Data**		**PV system installed?**	Yes ◯ No ◯		**Avg. Teachers**		**Total Students**	**Male:**		**Female:**	
Secondary School Entrance Rates												
8.21	**Total who sat for tests**		**Number going to national secondary school**		**Number going to district secondary school**		**Number going to conventional secondary school**		**Number going to community day secondary school**		**Number failed**	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**

Project:

SECTION 8 C – Complete for Secondary Schools Only (2 forms/project)

8.22	**Year of Data**		**PV system installed?**	Yes ◯ No ◯	**Avg. No. of Teachers**		**Total Student Population**	**Male**	**Female**

Secondary School Student Impact Information

8.23	**Number of students selected this year to go to public university**		**Students achieving (this year) … grade pt. 1 (highest)**		**Grade pt. 2**		**Grade pt. 3**		**Grade pt. 4**	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
8.24	**Grade Pt 5**		**Grade pt. 6**		**Grade pt. 7**		**Grade pt. 8**		**Grade pt. 9 (fail)**	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**

8.22	**Year of Data**		**PV system installed?**	Yes ◯ No ◯	**Avg. No. of Teachers**		**Total Student Population**	**Male**	**Female**

Secondary School Student Impact Information

8.23	**Number of students selected this year to go to public university**		**Students achieving (this year) … grade pt. 1 (highest)**		**Grade pt. 2**		**Grade pt. 3**		**Grade pt. 4**	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
8.24	**Grade Pt 5**		**Grade pt. 6**		**Grade pt. 7**		**Grade pt. 8**		**Grade pt. 9 (fail)**	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**

8.22	**Year of Data**		**PV system installed?**	Yes ◯ No ◯	**Avg. No. of Teachers**		**Total Student Population**	**Male**	**Female**

Secondary School Student Impact Information

8.23	**Number of students selected this year to go to public university**		**Students achieving (this year) … grade pt. 1 (highest)**		**Grade pt. 2**		**Grade pt. 3**		**Grade pt. 4**	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
8.24	**Grade Pt 5**		**Grade pt. 6**		**Grade pt. 7**		**Grade pt. 8**		**Grade pt. 9 (fail)**	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**

SECTION 8 D – Complete for Health Centres Only (2 forms/ project)

8.25	**Year of Data**		**PV system installed?**	Yes ◯ / No ◯	**8.26**	**Total no. of births in clinic**	
						How many during night hours (6pm – 6am) ?	

8.27	**Mother mortality rates due to complications at birth**	No. Mothers going into labor	Mother deaths	**Child mortality due to complications at birth**	No. children to be born	Baby Deaths
	General statistics			**General statistics**		
	Of these, in night hours (6pm – 6am) - if available			**Of these, in night hours (6pm – 6am)**		

8.25	**Year of Data**		**PV system installed?**	Yes ◯ / No ◯	**8.26**	**Total no. of births in clinic**	
						How many during night hours (6pm – 6am)?	

8.27	**Mother mortality rates due to complications at birth**	No. Mothers going into labor	Mother deaths	**Child mortality due to complications at birth**	No. children to be born	Baby Deaths
	General statistics			**General statistics**		
	Of these, in night hours (6pm – 6am) - if available			**Of these, in night hours (6pm – 6am)**		

8.25	**Year of Data**		**PV system installed?**	Yes ◯ / No ◯	**8.26**	**Total no. of births in clinic**	
						How many during night hours (6pm – 6am)?	

8.27	**Mother mortality rates due to complications at birth**	No. Mothers going into labor	Mother deaths	**Child mortality due to complications at birth**	No. children to be born	Baby Deaths
	General statistics			**General statistics**		
	Of these, in night hours (6pm – 6am) - if available			**Of these, in night hours (6pm – 6am)**		

8.25	**Year of Data**		**PV system installed?**	Yes ◯ / No ◯	**8.26**	**Total no. of births in clinic**	
						How many during night hours (6pm – 6am)?	

8.27	**Mother mortality rates due to complications at birth**	No. Mothers going into labor	Mother deaths	**Child mortality due to complications at birth**	No. children to be born	Baby Deaths
	General statistics			**General statistics**		
	Of these, in night hours (6pm – 6am) - if available			**Of these, in night hours (6pm – 6am)**		

Annex 2: Survey Guidance

MREAP SOLAR PV SUSTAINABILITY SURVEY GUIDANCE

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Document Revision

8/24/2014
v4.0 Final

Ethics Statement

The surveyor (and full research team) is responsible for adhering to the Ethical guidelines listed below.

1. Right to knowledge of use and intention of research is shared with respondents and community
2. Respondents are under no obligation to give data or information. In providing the data, it is assumed that respondents are freely doing so, under no coercive force of any kind. If the respondent feels uncomfortable with any question, it is their right to refuse answering.
3. It is understood that the respondents are speaking behalf of themselves only.
4. The research team is expected to act professionally at all times when representing MREAP
5. Any personal data will be made anonymous and will not be shared with anyone outside of the research team
6. It is the desire of the research team to receive honest and unbiased responses.
7. The research team makes no personal judgment onto the responses or respondent
8. The research team will Adhere to MREAP social inclusion policy (https://sites.google.com/site/mreapreef/social-inclusion-policy)

Adherence to Local Customs

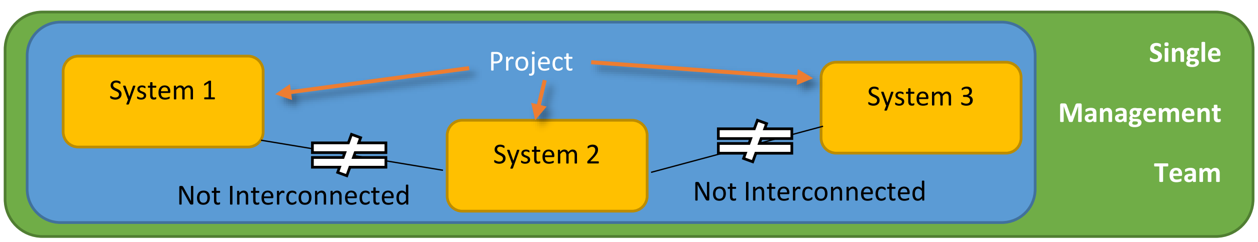
The research team will adhere to local customs as appropriate. Where possible

Definitions

A common understanding of the terms “project”, and “system” amongst the research team is required to ensure survey is implemented correctly. The extent of the project will need to be determined quite quickly at each location. The following definitions are used:

A *Project* is a set of energy assets in which distinct management team is responsible. A project may consist of one or more systems.

A *System* is an individual set of energy assets that are interconnected with each other.



For example, at a typical primary school there is a single solar PV project. This project may provide lighting for 4 rooms for students and at the headman’s office, as well as for two households of teachers at the school. The project also has a revenue generating activity that charges money for recharging mobile phones. However this project has 6 separate systems (which are not interconnected with each other):

1. 1 set of panels, batteries, wires, and lights at the headman’s office
2. 1 set of panels, batteries, wires, and lights that provides power for level 8 and level 7 classrooms
3. 1 set of panels, batteries, wires, and lights that provides power for level 6 and level 5 classrooms
4. 1 set of panels, batteries, wires, and lights for a teacher’s household

5. 1 set of panels, batteries, wires, and lights for another teacher's household
6. 1 set of panels, batteries, wires, and lights for the revenue generating activity

These systems are all under one project since the management team looking after the project is responsible for ensuring the operation and maintenance.

What is outside of this project? In the previous example, if another teacher self-funded their own solar home system and is responsible for it, then it is a separate project.

Not Available and Not Applicable parts of the survey

Throughout the survey, there will be questions that are both **not applicable**; the question does not make sense for the particular project, and **not available**; the respondent is unaware/unsure or surveyor cannot determine the answer reliably.

Rather than leaving the answer field blank, which is ambiguous, surveyors are requested to use the following conventions:

1. **N/A for Not Applicable**
2. **N/V for Not Available**

Section 0 - Record of Survey

This section is to record where, when and who implemented the survey. It must be complete for each location being surveyed.

In addition to filling out the information in the dedicated boxes, label each project with a unique identification (top left of each page).

Detailed guidance below:

0.01 Enter name of main person conducting the survey

0.02 Enter surveyor's organization

0.03 Indicate Date survey was actually undertaken

0.04 Full name of school or health centre

0.05 Enter region within Malawi: North, Central or South

0.06 Indicate district where school is located

0.07 Indicate City or village where school is located

0.08 Indicate the Traditional Authority at the location of the school

0.09 Estimate population density level

0.10 Mark whether this project was chosen by the field partner or by the survey coordinator (RENAMA)

0.11 Indicate the school's status as a primary, full primary, secondary etc. or the status of the Health Centre/Post as private or governmental

0.12 Input information from the respondent. Note that this is to be kept confidential within the research team. For Role/Position – this is in reference to the project at question (might not be the actual position of today).

Section 1 - Basic Project Profile Information

This short section captures key information on the project. In addition to assisting the surveyor get started with the project, the section focuses on **project inception** information.

This section must be completed once per project.

Detailed guidance below:

1.01 Refer to the guidance on breakdown of systems vs. project. For this question, enter the ID of each system that exist for the project and give it a unique and clear name so as to differentiate the different systems, e.g. #1 Store Rooms & Vaccine Fridge, #2 Teacher Battery Charging, #3 Phone Charging & Lighting Classroom 1+2. If there are more systems than rows, add the additional ones on the backside of the Section 1 page in same way; please clearly indicate question number (1.01)!

1.02 Self – explanatory

1.03 This captures the breakdown and total capital cost of the system at the start of the project. Capital cost is all costs of equipment and labour required for installation. Several categories are specified.

The right hand side column *est. amount* % refers to the percentage of funding this category comprises of the total funding.

Community Cash: refers to money raised directly by the community. For *loans*, additional info on the terms of the loans is helpful including the interest rate (yearly rate), down payment amount – this is the amount upfront, and the payment period in years and/or months.

Note: In-kind contributions are NOT asked at this point.

Insert the *currency* used next to each

1.04 Sponsoring organizations which have provided gifts, loans, grants, or other forms of financial support are listed here. Indicate whether they are local or foreign. This is meant to be the ultimate funding source (for example funding ultimately came from the Scottish Government International Development Fund)

Note – The same organization can be included in both 1.04 and 1.05 if they both provided financial funding and other types of support.

1.05 The main organizations (max 3) involved in project procurement, training, and installation are recorded here. If one organization was involved in several aspects, ticking several options per row is ok.

1.06 The contractor (e.g. installing company) that was used, if any, is recorded here along with their primary business location.

1.07 Check if the contractor was MERA certified AT THE TIME OF INSTALLATION (you can see the license from the contractor or check with MERA).

1.08 Capturing project ownership is critical. Several common options are given. *Utility owned* refers to ESCOM ownership. *Privately owned* refers to ownership by a person, group, enterprise, NGO or business that is neither a community organization, nor a utility. An *externally owned* arrangement refers to foreign owned projects such as a non-Malawian NGO, university or private organization. If the ownership is different from these categories or is unknown, please mark the appropriate box and explain as necessary.

1.09 Is the project registered with one of the existing carbon trading programmes, so that in return for the saving of CO_2 emissions from reduced use of paraffin etc., the project is credited a certain amount of money per year to support itself?

1.10 Self-explanatory

Section 2 – Data Capture Routines

The purpose of this section is twofold: first, to determine the actual data sources that are available and related to sustainability and second, to determine routinely recorded data and to learn how they are used.

This section is important because as much as possible we want answers in the rest of the survey to be based on a recorded data source rather than based on respondent recall, which can be inaccurate. In addition, determining the routines in itself is important to learn about how much is recorded and why. An aim of this research study is to learn about how communities are recording data and using it.

The responding institutions may have more data sources then we would be interested in – indeed this section is not meant for surveyors to *exhaustively capture* every source of data at the school, only the ones that are related to the energy project and the specific impact indicators we have identified. As a rule of thumb, we are interested in data containing project finances, power system performance, project management meeting records, school attendance and entrance rates, Revenue Generating Activity – Log Books, health centre delivery information.

This form/section must be completed PER data source. Print out extra forms in case there are more data sources than you anticipated. It is likely that some projects will have more or fewer data sources, or none at all.

If you determine a data source, ask to see it and then use it throughout the rest of the survey. They can be very useful to tease out inconsistencies or ensure the respondent has a fresh memory of what is going on.

Stage 1: Data Source Identification. As a strategy for determining all of the data sources, you can first ask if the respondent has any data related to any sustainability pillars (for example: “do you keep any technical data on the project?”, “Do you keep finances for the project?”) and impacts (for example: “do you track the impact of the project in any way?”). You are looking for **routinely captured** data - this is data that is done on a regular basis for some identifiable reason. Data captured informally is not covered in this form.

Log each routine data source using one form per source.

Stage 2: Data Source Entry.

2.01 Name the Data using a unique name. It is important that we distinguish different sources and do not get them confused. Examples: “Paid Phone Charging Log”, “Medical Staff Battery Charging Log”, “System Status Log”, “Customer Register”, “Inventory” etc. You can follow what the records says on its title unless this is not logical or can easily be mixed up, or ask them how they call it, otherwise use a logic name.

For type of data, you can enter one or more of the below mentioned figures from #1-5. Describe briefly in the “other” box if it does not conform to any of the data types.

Examples of individual metrics include voltage, current, indicator light color, income, expense, balance, dates, fee, etc. For a standard log-book, this is typically the column titles.

2.02 Here we are looking for the person(s) that were trained on capturing and recording this data source - their designation at the institution or position in the project, NOT their name(s), e.g. Board Treasurer, Head Teacher, All Committee Members…

2.03 Self-explanatory

2.04 Determine the frequency of data capture. Use/Look at the data source to confirm frequency, also look at the last month of data to determine this.

2.05 Determine the consistency of the data capture. Use the last month of data to determine this.

2.06 Briefly list the primary uses for the data mentioned by the respondents themselves (do NOT prompt answers).

2.07 Any other relevant information about the data source can be recorded here.

Repeat this for each data source on a new form.

Section 3 – Sustainability Pillars

Technical – how has the technical system performed vs. design?

Technical sustainability is the ability of the system to operate as designed, from a technical perspective, and provide the expected level of energy service for the planned system lifespan.

Technical problems at the selected sites may be obvious in many cases, however a structured approach is necessary to classify the problems and explore the reasons behind the problems.

This section is designed to not only capture the **system specification** and its **basic health**, but also explore the **usage** of the system and look for indicators pointing to the cause of any existing issues and also the potential for future issues.

The technical section is split up into 6 tables as follows:

TABLE #	TITLE	REQUIREMENT
1	General Health Check	per system
2	System Components Spec and Health	per system
3	LIGHTING Load: Usage and Expectations	per room
4	Other System Loads, REGULAR Loads	per system
5	Other System Loads, Occasional Loads	per system
6	Technical Problems/Symptoms	per system

This section will require that you visit each system, determine its components and health, and then determine system and room loads.

Tables 1, 2, 4, 5, 6 in the survey are to be completed per system. For table 3, a row will need to be completed for each room within a system.

IMPORTANT: You will likely need to print out multiple versions of these tables as 1 is needed per system in most cases; for table 3, 1 row is needed per room. ***Carry enough extra copies*** just in case there are more systems/rooms than you expected.

Stage 1: System Spec and Health Check

Walk around with the respondent/users to establish the system spec and general health. This is to be conducted per system at the site – i.e. one site being visited could have multiple systems for buildings and staff house. (Refer to the definition of project and system at the beginning of this document if in question.)

Stage 2: System Loads and Usage

Following the system walk around, user interview to capture the types of load connected to the system and the approximate usage patterns.

Tables 3, 4, 5 are to be completed per system. Table 3 is to be completed per room with lighting. Table 4 is for the loads regularly used on the system. Table 5 is to capture any occasional loads that are ever connected to the system.

Finally table 6 is to be completed per system. This is to capture some key symptoms of technical problems.

Table 1

Table 1 is to be completed through inspection of the system with user present. Surveyor must make the ultimate decision for the correct response in this section.

3.01 System ID: Enter the specific system ID code for the system you are examining in this sheet, according to your definition of system IDs in Section 1.

3.02 Panel Orientation- Is the panel North Facing? Approximate this by visual inspection and use a compass.

3.03 Mounting is 'roof mounted' if Solar Panels are in some way attached to the roof of a building. If Panels/system are attached to a free standing structure – select 'bepsoke mounting'

3.04 Vegetation refers to tree cover affecting performance of the panels etc.

3.05 Self-explanatory

3.06 Control Board: Yes indicates that all electronics and protection properly mounted and wired on a bespoke (tailor-made) mounting board.

3.07 All loads connected via charge controller: Check that no fridges etc are connected directly to battery bank.

This question refers to end-consumer devices/loads only, not to the inverter as an in-between load.

3.08 Self-explanatory

3.09a Self-explanatory

3.09b This question is directed towards the surveyor who must determine whether the system appears to have any tampering. Note, in the next table you will be able to identify which components have been tampered with. As this is a judgment from the surveyor, if it is unclear or you are unable to determine tampering, select the appropriate option. Tampering can be defined as deviation from the original system design, for example by user or unqualified person. Simple examples include re-wiring, bypassing charge controller, connecting devices directly to battery, destroyed component housing, etc.

Table 2

Enter "N/V" into any of the fields in which information is not available.

Note on ownership of system components: In some cases (i.e. for lighting in teacher's households that are part of the project), there are some components (i.e. most commonly batteries?) that are in fact owned and taken care of by someone else besides the project (and project management). In this case, please included all of the equipment listed in table 2, <u>whether or not it is actually owned by the project</u>, make a note at the bottom of the page (in the space) as two which equipment is owned by the project and which equipment is owned by someone outside the project.

3.10 PV Panels: "Total rating" is in Watts-peak for all of the panels connected to the system. "Missing" refers to some or all of the panels missing. If some are missing, enter an estimate of the number that are missing.

3.11 Batteries: "Total rating" is in amp-hours for all batteries connected to the system.

Batteries: For sealed/maintenance-free batteries: …

For batteries that require acid refill or similar: …

Batteries typically will include a simple colour indicator (green = good, yellow/orange = warning, red = bad) that can be checked to determine health of batteries. If you are unclear as to the battery health, leave blank.

3.12 Charge Controller: "total rating" refers to the amp limit

Charge Controller: "charge controller health indicator" – typically the charge controller will have an LED indicator that is supposed to indicate state of the system with green=good, yellow=warning, red/orange=not OK. The colour scheme may differ depending on the model.

3.13 Inverter: “total rating” refers to the amp or watt limit.

3.14 Fuses/Circuit breakers: “total rating” refers to the amp limit

3.15 For wiring, not all information is relevant. Indeed, only health check status is used. In place of the other column headers is “wire/cable gauge estimate” and “sign of tampering” for three key segments of the system: Solar Panel to charge controller, charge controller to battery, and the load circuits.

Table 3

This table **is ONLY for lighting**. All other loads will be handled elsewhere.

- Each room should be captured in a row of this form.
- Select AC or DC depending on whether the load is supplied via the inverter or not.
- Select AC or DC depending on whether the light is connected via the inverter or not.
- Rooms should be mapped to system. A simple labelling approach can be used (system 1, room 1,2,3, etc…).
- Total # of light sockets/fittings refers to the number of light sockets that have been installed in the system, no matter if they are currently operational or if there is currently a working light bulb attached. In other words, this is equal to the total number of lights that COULD be attached.
- Number of working lights refers to the number that demonstrably work. This means there must also be a working bulb in them.
- For security lights outside the actual room: if they are connected to the same system, include all security lights within 1 ‘room’ for simplicity if they have same usage profile. If they have different usage patterns, put each one on in a different ‘room’.

For questioning respondent about *Usage*, some care must be taken to ensure accurate answers.

First, ask about current usage: How many days per week, approximately, do you use lighting in this room? How many hours per day do you use it? This part is relatively straightforward.

The *Expected Usage* tries to capture whether the use meets expectation and why. Because this section is at risk of being unclear, ***a specific line of questioning is shown below that all surveyors must follow.***

[1] Ask about expected usage as follows: “*When the system was first installed did you expect to have the current amount of light, more, or less?”* It is important to establish the expectation for the <u>user at the time of installation</u> to see if there is a difference between actual and expected usage.
[2] If respondent answers **more**, then ask “how many days a week did you expect to be able to use it?”, then “how many hours per day?”
[3] If the respondent answers **current amount** or **less**, follow-up and ask “so you did not expect to use it more than you are using it now?”
[4] Enter the respondent’s final answer.
[5] If there is a difference between Actual and Expected, then we would like to know if there is a particular reason why they don’t use it more. Ask: “why don’t you use it more?”
[6] By checking **user** this corresponds to a user imposed behavior – they <u>could</u> use it more, they just choose not to for whatever reason. This could be that someone (designer, management, technician, etc.) has told them that there is a limit to the use and that they can only use it for a system amount. Or that the user behavior itself restricts the usage of the system (e.g. the pupils break the bulbs repeatedly).
[7] By checking **system** this corresponds to a system imposed limitation – they <u>would</u> use it more if the system allowed them to.

[8] If it is unclear why they are not using it as much as they expect, then check: **UNCLEAR**.
[9] If current usage equals expected usage, leave *Main Source of Constraint* blank.

Table 4

Unlike lighting load (table 3), only one form of table 4 and 5 is needed per system, which captures all other loads.

Table 4 is for all regular system loads, **except for lighting**. "Regular" refers to loads that are on the system on a weekly basis or more often.

Select AC or DC depending on whether the load is supplied via the inverter or not.

Common loads are listed. For those not listed, use the space provided in 3.26.

Similar to Table 3, determine the actual and expected usage. Use the structured line of questioning as described in the guidance for table three to determine expected usage and the main sources of constraints.

Table 5

Table 5 is used to capture all non-regular (i.e. occasional) loads on the system. Non-regular is defined as less than once per week.

Stage 3: Categorise any system problems by symptom.

The previous sections should have established any obvious system health problems. This section is designed to capture the symptoms the user is experiencing.

Table 6

is to be completed in conjunction with the user. Fill out one table per system by checking the presence of a particular symptom. Be sure to properly label the system that is being diagnosed according to your systems definition in Section 1.

Economic Sustainability

Economic sustainability is concerned with the continued financial well-being of the project throughout the planned system lifespan.

To capture the economic sustainability of the project, an accurate accounting of the financial situation is needed. This section therefore captures the project assets, cash inflow, expenditure outflow as well as some other key information like gifts to the project, services offered by the project free of charge, and competition that is faced by the project.

Note: In this section, it may be useful to approach the questions that address the income and expenses by starting with the column 'Last Month' which appears in most sub-sections. Use the data source if available. Then move to last year, again using the data source. Finally, 'typical' monthly amount is a question to the respondent – if the data shown is not representative of the typical monthly amount (according to the respondent), we want to know what a typical amount is. For example the RGA may have brought in MK 20,000 last month according to the log book, but the respondent indicates, that most of the time this is higher MK 30,000 per month.

Detailed section guidance below:

4.01 Capital refers to the Initial cost of the project including: equipment, materials tools, training, full labour installation costs, etc. (This corresponds with Section 1).

4.02 The income section captures all income sources for the project. Several common/likely categories are provided, and any other major source of income not provided should be entered into the appropriate row. All revenue is to be reported in MWK. *Typical Monthly income* can be estimated by the respondent. *Last month income* and *Last year income* should use data sources (recall section 2) to verify. If possible capture the number of customers for each service over the last full month. In this section you should try to systematically determine all project income sources.

Fee for other electric service refers to payments made to the project for electric service not provided under the other services. If customers have a monthly fee to the project, or a pay-per-charge model, for connected service (i.e. lighting and an outlet), or a portable lighting system (i.e. BBOXX, etc.) This can be included within this section. Some arrangements may have a community facility (i.e. school, or teacher's training facility) that is responsible for paying the project directly for service. Note that not all projects actually charge users for the services! Community payments to the project (i.e. through pupil/HH contribution) would be included here.

All other services are self-explanatory.

4.03 Gifts to the project can be both non-formal and formal. This is important to track as the economic sustainability of a system may be dependent on a gifting arrangement. These sources of income are sometime not tracked within most accounting systems so the respondent may have to depend on recall. Ask them to refer to the last year to get an estimate.

4.04 Operational costs are the ongoing costs to run the project and full capability. Several common types are given. If there are other operational costs not listed, use the space provided. For *typical monthly costs*, this can be determined by respondent recall. For *last month cost* and *last year cost*, use data sources (recall section 2). Note that depending on the arrangement, some or all of these costs are never incurred or are not accounted for by the project. In this section you should try to systematically determine all operating costs for the project. Review the other 'costs' sections in the survey prior to beginning the investigation for this section: 'maintenance costs', 'Revenue Generating Expenses', 'other uses of income / non-system costs'.

Fuel refers to any fuel costs incurred by the project. The survey targets Solar PV projects, however, some projects may also have a mix of generation (i.e. diesel gen set). Fuel might also be relevant where regular vehicle transport is needed to deliver systems for rental or similar as part of the IGAs.

Land Leasing Costs includes both land and facility leasing costs.

Payments to Security refers to the costs for security services specifically for the project – careful not to enter here the normal security guards whom the school or health centre would have employed even without the solar installation and which are not paid out of the project budget/income!

Payments to Revenue Generating Labour refers to the cost of employment for all revenue generation activities.

Payments to Operator/Technician refers to the costs for employing an operator for the system, or a technician that typically runs the technical operation of the project. Note that "maintenance" is covered elsewhere, so this section should only include the regular system operators, if applicable.

Payment to Committee refers to any fees or regular allowances paid to a management/energy committee separate to those costs already covered.

4.05 Maintenance costs are those incurred to repair the system, replace common components, and to keep it functioning at full capacity. Several common types of maintenance costs are included. Use the space provided for any other major maintenance costs not included. *Typical Monthly Cost* can be estimated by the respondent. For *last month cost* and *last year cost*, use data sources (recall section 2).

4.06 An open space is provided for revenue generation expenses to be recorded. Include all major expenses that are incurred to support revenue generation activities but not captured previously. Since revenue generation activities may be quite varied, the costs for provision may also be varied. This section can include purchase/repair of mobile phone charging equipment, purchase of seeds for community cash crop to support project, etc.

4.07 Other uses of income / non-system costs refer to all other costs that are incurred but which are not directly related to maintaining the projects assets or operating the systems involved. Costs included in this section can be quite varied, but for schools has typically included paying for school uniforms, food for pupils, classroom materials, etc.

4.08 Captures any free services that are provided by the project. If possible, estimate the monthly value of the service if a charge were applied for its use.

The Routines sub-section captures some of the key behaviors of the project related to its economic sustainability.

4.09 Self-explanatory

4.10 This is asking for a specific bank account dedicated to the project/installation/maintenance itself, not just the general school or health post account.

4.11 M&O refers to 'maintenance and operation'. Every project should have a target for its M&O budget to repair and replace equipment that fails. If the Project does not have a specific M&O budget or target, check 'no M&O budget' and skip the rest of the question.

4.12 Self-explanatory

4.13 This question asks whether a market survey of some sort was conducted prior to installation of the project and a follow up of whether the survey specifically included a section which captured potential customers' willingness to pay for energy services.

4.14 Self-explanatory

4.15 Self-explanatory

4.16 *Competition* to the project's income generation is captured here and can be varied depending on the type of services provided by the project. As a strategy for checking competition, ask about each energy service provided by the project and whether in the opinion of the respondent they feel like there are other people/businesses offering those services in close proximity to the project. If there is competition, describe, then ask if the impact of this competition can be quantified (i.e. less mobile phone charging due to grid connection, from 100/week to 10/week).

4.16a,b List potential future competition, as perceived by the respondent. These could be from any source. You should specifically ask if they are aware of any future grid extension that is supposed to come to nearby their area.

An approach for determining competition is to ask the respondent as to whether each service that the project provides is also provided nearby by some other source.

To determine how to quantify current competition, ask the respondent to estimate the market share of the competitors.

Social Sustainability

Social sustainability is related to engagement and representation, and acceptance of a project within a social structure, i.e. a community.

This section is perhaps the most challenging to implement due to potential complexity of the decision making approach, ownership arrangements, and finally the potential for subjective answers. Although a weakness for the entire survey, the social section is particularly at risk of the respondent providing biased answers. Ideally this section would be answered by a representative within each stakeholder group. However, since it is likely that we will be limited (due to time and resource constraints) to only one respondent who will speak about the social sustainability of the project we can only highlight this risk whilst crafting the questions to be objective as possible.

Detailed Guidance below:

5.01, 5.02 "Consulted" typically means that the village leaders or other sufficient representatives of the community have been engaged in identifying the need and location for the project. A needs assessment can be carried out in a number of different ways, but ultimately captures the needs for the community and provides some sort of prioritization.

5.03 Projects that are granted or gifted to a community often involve some sort of community contribution. This is captured in this question with several main categories, and an 'other' field for unlisted types. In the amount area, enter the unit type as appropriate (MWK, man-days, etc.).

5.04 Stakeholders are groups of people that are affected by the project. This survey tries to uncover the level of decision making that each stakeholder has for the project.

5.05-5.11 Several common stakeholder groups are listed along with an 'other' box for those not listed. The surveyor should try to systematically determine all of the stakeholders and the type of decisions that they are involved in. As projects are organized differently, not all stakeholders listed here may be present. In the section *What decisions are they involved in* several common categories are used to simplify the survey, try to use these as much as possible. Multiple boxes can be ticked per stakeholder according to their major involvement in several aspects.

In the *Decision Making Process* section (5.12-5.15), two hypothetical situations are posed to the respondent to try to determine who would (or has if this has actually occurred) make the decision on how to handle it. Although this question somewhat overlaps 5.05-5.11, asking it in this format may reveal who actually is making the decisions as well as what the priorities for the project are.

5.12 This is a common problem for a project that may require external assistance if the management team lacks capacity to troubleshoot and repair the system.

5.13 This situation puts to different preferences at odds with each other.

5.14 Check all that apply

5.15-5.19 Self-explanatory

Organizational Sustainability

Organizational sustainability considers how the human and business assets must be maintained over project inception and growth. Business assets are those not directly related to the electricity service, for example, IT systems, business management structures and standard operating procedures.

Projects are sometimes unsustainable because the organization running it does not have sufficient capacity. This section seeks to capture the human and organizational capital of the project and the routines in place to sustain it.

Detailed Guidance Below

6.01 Several common types of training are listed, check all that were delivered prior to or during installation of equipment. Several additional details can also be included, length of training, number of people trained, training organization, and to whom it was delivered.

The surveyor should use their best judgment as to which category or categories the training is most closely described. A few follow-up questions on what the training entailed should be sufficient to determine the category. A general definition for each skill area is defined below:

- *Technical* – related to the equipment, operating procedures, troubleshooting, monitoring of power delivery, system limitations, etc.
- *Financial* – related specifically to financial management, handing of money and book-keeping (note that financial skills can be seen as a sub-skill to management; for this survey treat these two skill areas as exclusive)
- *Management* – related to project leadership, strategic decision making for the project, day to day operation

6.02 This question captures <u>ongoing</u> training that the project has access to with the same categories in 6.01.

6.03 Captures the skills of the current team. Mark all roles that are present and filled.

6.04 Captures how re-training occurs, if at all. Refer to past experience if unclear for the respondent.

6.05 If there is no technical person onsite (or even if there is) sometimes a project will come to an arrangement with a technician or company to troubleshoot and maintain the technical aspects of the project.

6.06 In addition to the human capital, tools are also tracked. Check whether the project uses two categories of common tools, what form exactly they take, and if they are in good shape.

6.07 Availability of spare parts is handled here. Count the current stock of spares on hand and whether replacements parts are available nearby.

Environmental Sustainability

Environmental sustainability is related to the environmental impact, positive and negative, that a project's introduction into a community brings.

This survey takes a narrow view to environmental sustainability; looking only into the local impacts that a project has. It specifically does not consider the role this project has on global environmental challenges.

The objective of the surveyor is to systematically determine if any environmental impacts have been identified by the project, and if so, if there are plans in place to mitigate this impact. The surveyor should go through the several defined categories of environmental impact (7.01 – 7.03) and then ask if there are any other (7.04) impacts that are not already covered. These can be asked as follows: "Does the project team consider ***[insert impact – i.e. Disposal of waste products]*** as a potential environmental impact?" Then ask "If not, is that because it is not identified as an impact, or because it doesn't apply to this project?"

By answering "positive", this means the project has identified a potential beneficial impact. **By answering "negative",** this means that the project has identified a bad impact through this aspect. **By entering "both",** the impact has positive AND negative sides which do not have a clear bias to one side. **"None"** means that the project considers this aspect not to have any environmental implications. **"N/A**" means that the aspect itself (eg release of pollutants) is considered not-applicable to the project.

Detailed Guidance Below:

7.02 This includes disposal of batteries, light bulbs, solar panels and other project equipment

7.03 This includes all manner of pollutants (note: most renewable energy projects will have no pollutants but there could be some from battery acids, toxins from solar panel breakage, toxic gases from energy saver bulbs).

7.04 If you are unsure as to whether the impact, as perceived by the respondent, is 'environmental' or not, just include it within the space provided.

7.08 Self-explanatory, complete if any impact was identified. Note, be sure that respondent understands we are asking about concrete plans to mitigate potential impacts, not just aspirational plans.

7.09 Active and well supported is defined to mean the respondent, in their opinion, feels that the plan (in 7.08) has adequate community support, sufficient means or financial support to implement it, and is achieving objectives according to their expectations.

Part 4 – Impact Records

This section in the survey captures some specific impact records for the schools and health centres.

Depending on the type of institution, different sections should be completed.

- All projects will complete Section 8A.
- If the site is a primary school, complete Section 8B.
- If the site is a secondary school, complete Section 8C.
- If the site is a Health facility, complete Section 8D.

Section 8A

This section is answered from the perspective of the respondent – i.e. the respondent's opinion. The answers are only asking about *positive improvements* in the areas listed. At the end of each sub-section is an "other" box that can be completed if the respondent feels that a key services should be added.

Question 8.18 is slightly different from the other questions in this section in that it asks whether there has been a positive, neutral or negative impact on the local economy.

Section 8B – Primary Schools Only

For primary schools, we are interested in school attendance and entrance rates into secondary schools. Most schools keep fairly accurate monthly/yearly records of attendance and entrance rates.

First, 8.20 and 8.21 are specified for a given year. The form is then repeated for each subsequent year of data that is available.

Capture school attendance and entrance rates, if possible, for up to four years before project inception. Use the remaining forms to capture data for ALL the years after project inception. The forms allow for 4 years of data to be captured so you will typically need about 2, maximum 3 pages per site.

As an example to fill this form out, take the case of a hypothetical project that was installed in 2010. The surveyor should try to get data starting in the 2006 school year until the current date. At the end of the 2014 school year this would include 9 years of data. This would require a total of 3 forms be printed out to include the additional years.

Year of Data – enter the relevant year for data (for school years, the year in which the school year ends and exams are written)

PV System installed? – check yes if there is a functioning PV system at the school.

Total student Population – include total population and breakdown of male and female

Total sat for tests – refers to all students that sat for secondary school tests and breakdown of male v. female.

Entrance rates – note the number that were accepted into the different categories of secondary school and those that failed.

Section 8C – Secondary Schools Only

For Secondary schools, we are interested in school attendance, entrance rates into public university, and student grades. Most schools keep fairly accurate monthly/yearly records of attendance, entrance rates, and student grades.

First, 8.22, 8.23 and 8.24 are specified for a given year. The form is then repeated for each subsequent year of data that is available.

8.23 Enter number of students in the given year that were selected into public university, disaggregate by sex

8.24 Each potential grade point is listed from grade point 1, which is a highest possible grade (distinction), to grade point 9 which is a fail. For the entire student population, enter number of students achieving the respective grades for each complete year.

Like the school impact form, annual data is captured both before and after installation of the solar PV system. Space is provided for 3 years of data. Ideally data is captured starting 3 years <u>before</u> the solar PV system is installed, and 3 years afterwards.

Section 8D – Health Centres Only

For health centres, we are interested in general birth and maternity attendance rates, as well as more specifically births and mortality of mothers and newborn/unborn babies during the dark hours. Dark hours are defined as roughly 18:00 – 6:00. If there is no specific data available for the night hours, only take the health centre's general statistics (many recent electrification programmes focussing on maternity lighting are asking the health centre to capture specific data on this, though).

Like the school impact form, annual data is captured both before and after installation of the solar PV system. Space is provided for 4 years of data. Ideally data is captured starting 4 years <u>before</u> the solar PV system is installed, and 4 years afterwards.

Survey Closure

When you have completed the survey thank the respondent for their time and offer to answer any questions that they may have for you.

If the respondent(s) want(s) to leave an email address with you, we will be able to send him a copy of the end report beginning next year. We would also appreciate if they would share their phone number with us in order for us to be able to do clarification calls and do later follow-ups to keep the project database updated, if they don't mind.

Annex 4: Field coordinator Report

Surveyor Report & Analysis

Report Submitted by (Full Name)	
Report Reviewed by (Full Name)	
Further contributors to this report (list all)	
Date Submitted	
Organization	
MREAP Work Stream	

Submit completed reports to:

- Martina Kunert (chair@renewnablemalawi.org)
- Peter Dauenhauer (peter.dauenhauer@strath.ac.uk)

Instructions

This report is to be completed by the Surveyor team and must be completed only after all data has been inputted to the specified digital format and submitted to the field coordinator and project lead (emails above). There is a two-step process for completion of this report. In the first instance the report is submitted according to the guidelines provided (see below). Second, the initial submission will be reviewed and any questions, or requirements to re-write sections will be provided. Assuming these are adequately addressed, the report will be considered complete. If not, further iterations will be necessary.

Guidelines for completion

- All sections must be completed and written professionally in English.
- Word targets are provided for each section.
- You must answer all questions within the guidance text. If you have any questions, do not hesitate to make contact.
- Use your data sources to answer questions. Answers that are provided that are not supported by data will be rejected and you will need to re-write the section.

Process

Surveyors	
Who conducted the survey? Was it just one person, or a team? Were multiple people working together at one site or did you work separately at different sites? How did you split the tasks – who did what? **Target – 250 words**	
Provide a brief professional background for each person involved in the team and their general responsibility. **Target – 100 words each**	

Availability of Respondents	
In general (not project-specific), what kind of respondents (level, roles in the project) did you have access to? Did you have access to people who had been involved in the project from the beginning or through decisive phases and/or challenges of the project? **Target – 150 words**	
Where the respondents at site/on community level knowledgeable about all enquired aspects of the project or did you have to reach out to additional respondents (e.g. from project implementing office or contractor/installer or District staff) to get the necessary add-on information?	

Target – 150 words	

Availability of Data Sources	
To what degree were written or digital data sources typically available at site? **Target – 150 words**	
How did this impact the information that you were provided? **Target – 150 words**	

Accuracy of Responses	
Accuracy of SURVEYOR's answers	
Particular sections of the survey required you, <u>the surveyor</u>, to judge or determine the answer to the question (notably the technical sustainability section). In these sections, were there any issues you had in answering the questions accurately? What areas, exactly, were problematic? **Target – 150 words**	
As a result, how confident are you in the results? **Target – 100 words**	
Accuracy of RESPONDENT's answers	
Many sections of the survey required a respondent to answer the questions.	

Did you find the respondents had problems remembering/recalling information? **Target – 150 words**	
In general, did you feel the respondent was truthful in their answers? **Target – 150 words**	
Do you think there were any situations where respondents were just trying to satisfy you (or the questionnaire) with their answer in some way? If so, please discuss these circumstances. **Target – 150 words**	
Why do you think these situations occurred and what impact do you think it has on the results? **Target – 150 words**	

Confusing Questions	
Were there any questions that were often unclear or confusing to the respondents? Please describe these questions and how you handled it. **Target – 150 words**	

Length of Questionnaire / Fatigue	
How long, on average, would you say the questionnaires take you to complete? Did you take any breaks? **Target – 100 words**	

Did you find that the respondents or your team were fatigued at any point during the survey? If so, what impact do you think it had on the survey results? **Target – 100 words**	

Completion of Questionnaires	
Were all the surveys completed fully, or were particular sections skipped for some reason? If questionnaires could not be completed fully, please describe the reasons and in particular, which sections were skipped. If this happened only in some cases, please mention site number and site name according to site selection list, as applicable. **Target – 150 words**	

Survey Analysis

This section is to be completed by the surveyor team using the data captured in the questionnaires. In answering, try to reflect on all of the projects you visited and identify any notable trends or learning that you have accumulated. What stood out and why? When answering – explain your reasoning while using the evidence that you have gathered.

Provide your analysis using short conclusive summaries.

Description of Projects *Please refer to the site IDs (# and names as given in the final site selection table sent to you before the survey) when describing individual projects.)*	
Selection	
How was each project selected? Was it selected by your organization or by another? What method was used? For the sites selected by your organization? Why was it chosen? Was there any particular reason? **Target – 250 words**	
Provide a list of all the projects and dates that you conducted a survey on.	
Location	
Where was each project located? Indicate with coordinates or a map where each project was located. Make note of any clustering of projects (i.e. within a single district or even more localized) **Target – 150 words**	

Intervention level	
What kind of scale and applications were common in the projects that you visited (e.g. primary schools, secondary schools, households of staff, health centres, other)? **Target – 150 words**	
Age	
How old were the projects? For example, make note of how many were: ➢ Less than 1 year old ➢ Between 1 and 3 years old ➢ Between 4 – 5 ➢ Between 5-10 ➢ Older than 10 years **Target – 100 words**	
Phase/Adjustments	
In the sense of extension or change of purpose, was the project still in its original state as intended when it was set up, or has it undergone alterations by other projects that were not just planned maintenance? (E.g. a change from electricity supply to back-up after ESCOM installation or use for computers instead of lights; replacement of core parts to restore lost functionality; etc.) **Target – 150 words**	
Data Sources	
What data sources were available?	

What data sources were typically not available, that would have been very helpful? In general, how, if at all, were the data sources being used BY the project? (E.g. who was using the data in the project on a regular basis and why?) **Target – 150 words**	

Sustainability *Complete the following section with short summaries/analysis of results or individual case studies adhering to the word targets listed.*	
Technical	
What were the systems being used for? Please make note of typical applications (using the technical sections) such as lighting, etc. **Target – 100 words**	
Were projects functioning as expected? Please make note if any projects were operating at less than full capacity or not working at all or potentially some aspects not working. Note if there were missing components or poorly maintained components, for example. Did the users appear to be using the system as intended? **Target – 150 words**	

What types of loads (lighting, and other) were NOT being provided reliably? **Target – 100 words**	
How healthy were the systems? Were there any components that were not maintained or in poor health? **Target – 150 words**	
Did the systems appear to be sized properly? Why or why not? **Target – 100 words**	
What other trends were apparent based on the captured technical data? **Target – 250 words**	

Economic	
How much did the projects initially cost (capital costs) and what level of community buy-in was achieved? **Target – 150 words**	
What were the primary income sources? How significant were they? **Target – 250 words**	
What type of operating expenses were common? How significant were they? **Target – 150 words**	

What type of system maintenance were common? How significant were they? **Target – 150 words**	
Were there significant non-system costs that were paid for by the systems? What were they and how significant were they? **Target – 150 words**	
How sizable were the Maintenance and Operation Budgets for the projects you visited? **Target – 150 words**	
What other trends were apparent based on the captured economic data? **Target – 250 words**	

Social	
Were projects consulted prior to installation and were there needs assessments completed? **Target – 100 words**	
Who were the main decision makers? Did the decision making process appear to be inclusive to the community? Why or why not? **Target – 150 words**	
To what degree was theft apparent? **Target – 100 words**	
What other trends were apparent based on the captured social data?	

Target – 250 words	

Organizational	
How much training was provided both before installation and on an ongoing basis? **Target – 250 words**	
How did projects handle handover of duties (such as technical or managerial)? Were the people managing the projects qualified? **Target – 100 words**	
What other trends were apparent based on the captured organizational data? **Target – 250 words**	

Environmental	
What environmental conditions impacts were typical? **Target – 100 words**	
How did projects handle any identified environmental impacts? **Target – 150 words**	
What other trends were apparent based on the captured environmental data? **Target – 150 words**	

Sustainability Analysis
Given your analysis, what outlook do you think your projects have for sustainability?

'Unsustainable Projects' Were there any projects do you feel, based on captured data, that were unsustainable or would become unsustainable soon (within next 3 months)? (unsustainable is defined as fully non-operable) Why is this the case? What factors are informing your conclusion? **Target – 500 words**	
'Sustainability Pillars' Of the all the sustainability data that was captured, were there any results that seemed particularly critical for the sustainability of the projects you visited? Highlight the key data and related sustainability pillar section and analyze what it means for project sustainability? **Target – 500 words**	
'Successes/what IS working' Were there any projects that were performing particularly well or had aspects that were very positive? Of the all the sustainability data that was captured, were there any results that seemed particularly critical for the success of sustainability of the projects you visited? Highlight the key data and related sustainability pillar section and analyze how it has	

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contributed to the project's high level of sustainability? **Target – 500 words**		
'Recommendations and Learning' Given the data you have captured and subsequent analysis, highlight several key learning points and recommendations for future similar projects. **Target - (100 words each)**	**Learning Point 1**	
	Learning Point 2	
	Learning Point 3	
	Recommendation 1	
	Recommendation 2	
	Recommendation 3	