# DRD Solar Home Systems (SHS) in Myanmar: Status and Recommendations

Report to the World Bank

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# Abbreviations

| | |
|---|---|
| AC | alternating current |
| ADB | Asian Development Bank |
| AGM | absorbed glass matt (lead acid battery) |
| CEI | Columbia Earth Institute |
| DC | direct current |
| DRD | Department of Rural Development (in MoLFRD) |
| ESE | Electricity Supply Enterprise |
| FY | fiscal year |
| GIS | geographic information system |
| IEA | International Energy Agency |
| IEC | International Electrotechnical Commission |
| ICT | information communication technologies |
| IDTR | Decentralized Infrastructure for Rural Transformation (Bolivia) |
| kV | kilovolt |
| kW | kilowatt |
| kWh | kilowatt hour |
| LED | light emitting diode |
| LVD | low voltage disconnect |
| MoEP | Ministry of Electric Power |
| MoLFRD | Ministry of Livestock Fisheries and Rural Development |
| MSC | Medium Term Service Contract |
| MW | megawatt |
| NEP | National Electrification Plan |
| PEA | Provincial Electricity Authority (Thailand) |
| PO | Partner Organization (in IDCOL program) |
| PPA | power-purchase agreement |
| REA | Rural Energy Agency |
| REAM | Renewable Energy Assocation of Myanmar |
| SHS | solar home system |
| SPP | small power producer |
| SPPA | standardized power purchase agreement |
| VRLA | valve regulated lead acid |
| VSPP | very small power producer |
| Wp | watt peak |

# 1 Overview

This study investigates the status of solar home systems (SHS) deployed by the Department of Rural Development (DRD) in the Ministry of Livestock, Fisheries and Rural Development (MoFLRD). It seeks to understand how SHS that have already been installed are functioning in the field and to identify design, installation, and usage issues that contribute to failures in the field. The study discusses the process by which SHS come to be installed in particular households in particular villages, including how selections are made at the household, village, and township level; how companies are chosen, how systems are installed, and how maintenance and warranty service are administered. In addition, the study looks at several areas not directly related to DRD SHS, but relevant to solar electricity's role in rural electrification including DRD solar mini-grids, hire-purchase SHS, solar electric equipment widely available in rural market towns, and -- through discussions with cell phone companies and the companies that provide tower services -- the intersection between Information Communication Technologies (ICT) and solar electricity.

DRD's SHS program has accomplished important successes, including providing solar home systems to tens of thousands of households in hundreds of villages. As long as they remain functional, these SHSs strongly reduce household expenditure for candles, kerosene, and diesel fuel. This study found monthly household non-heating expenditures reduced an average of about 12,000 kyat in the villages surveyed. The existence of DRD staff at the township level provides a good basis for addressing occasional repairs of system components, especially in villages where the township level DRD staff is in frequent contact with the local village leader.

Despite impressive efforts, the DRD solar home system program is stretched thin in many dimensions. At the village level, only a portion of households receive systems in villages selected to participate in the program. With a very low price cap of 200,000 kyat per installed system, the quality of components and installation is strongly compromised, and companies struggle to cover costs, especially those companies that take efforts to build systems with higher than average quality. Warranty and follow-up service are also stretched thin – many villagers are unaware of their options when equipment breaks and companies have considerable logistical problems in addressing warranty claims. Program administration is stretched thin with DRD staff at all levels lacking training in electricity in general and solar home systems specifically and with the DRD occupied by many other pressing rural development tasks. Based on sightings of many non-DRD SHS on homes along the routes traveled in this study, SHS appear very common in rural areas. Solar panels, batteries, Light Emitting Diode (LED) lights and 12-volt TVs, inverters, and charge controllers are readily available in most market towns. Much of the equipment is inexpensive and of low quality imported from China or India, and shops provide little or no guidance in system design or installation.

The study concludes with a number of recommendations. There are many opportunities for the World Bank and other development partners to work with the DRD to improve the situation, bringing substantial benefits at low cost. Options include: changes in the design of the DRD subsidy program, targeted trainings and education materials for SHS users, installers, designers, and DRD; trade finance for SHS companies, revision of DRD specifications, and product quality assurance through component testing.

# 2 Background

## 2.1 Rural electrification and the DRD

At present, about 33 percent of the population in Myanmar has access to electricity from the national grid. The Government is committed to achieve 100 percent electrification by 2030, which will require a roughly tripling the current pace of approximately 190,000 new connections per year.

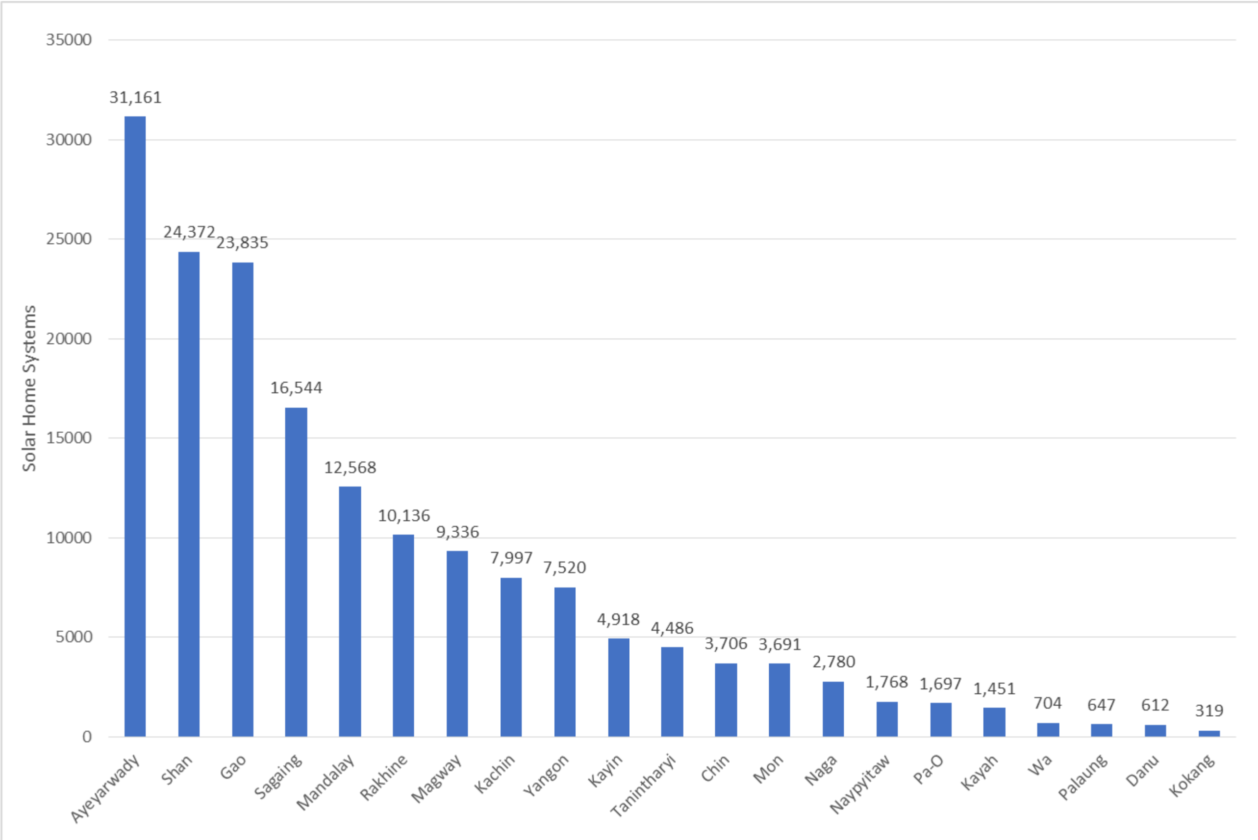
Myanmar's National Electrification Plan (NEP), based on analysis by the Columbia Earth Institute (CEI) projects that ultimately well over 90% of areas will be electrified by the grid. But many areas may not receive electricity for at least 10 years, even if Myanmar is able to achieve its ambitious rural electrification grid extension scale-up targets. This leaves considerable scope for off-grid pre-electrification solutions such as solar home systems and micro-hydropower to provide basic electricity services (lighting, cell phone charging, TV and DVD players) until the grid arrives.

The DRD has been given the responsibility of rural electrification. According to DRD Deputy Chief Engineer U Khant Zaw, off-grid areas are exclusively the responsibility of the DRD, while on-grid areas are electrified in coordination with the Ministry of Electric Power and especially the Electricity Supply Enterprise (ESE). Rural areas, for electrification purposes, are defined as 'village tracts' and are the smallest administrative unit in Myanmar. DRD is responsible for electrification of village tracts, whereas the Ministry of Electric Power (MoEP) is responsible for rural electrification that involves large communities ("Ward" or "Quarter").

## 2.2 DRD's solar home system program

As a key component of its off-grid rural electrification efforts, the DRD is engaged in an ambitious solar home system program. In FY 2013-14 the DRD oversaw a 4 billion kyat government budget to procure solar home systems in approximately 300 villages. According to DRD data, as of April 2014, DRD solar home systems had already been installed in 174 villages. At the same time, 249 villages were newly connected to national grid, or about 0.4% of the remaining unelectrified villages.  In Fiscal Year 2014-15 the DRD is gearing up to install solar home systems in 170,248 new households in 1491 villages, as well as implement 129 micro-hydropower projects and 8 biomass projects (see Figure 1 below). The total budget is expected to exceed 37 billion kyat. DRD solar home systems are granted to recipients with 100% subsidy.

*Figure 1: solar home systems planned by DRD using government budget in Fiscal Year 2014-15. Source: MoLFRD*[1]




The solar home systems are standardized, and include 80 watt solar panel, lead-acid 12-volt battery, charge controller, inverter, and three lights. This size system is sufficient for cell phone charging, radio, and – in sunny periods – a two or more hours of operation of a small TV and DVD player.

This is an ambitious program when one considers that the DRD is a relative newcomer to the field of rural electrification with staff stretched thin that must cover wide rural territory, generally in areas with poor roads and communication infrastructure. In some of these areas, logistics are complicated by security concerns from armed conflict, poppy cultivation, or meth-amphetamine production. DRD is hampered at all levels by a lack of staff, particularly electrical engineers with experience in solar electricity.

In the long run, the success of these government-granted solar home systems, and indeed, rural use of solar electricity in general, will hinge, among other factors, on the quality of the components and their installation, and whether or not an effective mechanism to provide maintenance can be implemented. A similar 100% subsidized program implemented in Thailand

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[1] DRD, “The Implementation of Rural Electrification with Union Budget (DRD) in 2014-2015 Fiscal Year.”

of over 200,000 solar home systems in 2004-5 led to widespread failures because inadequate provision of maintenance.[2]

### 2.3 DRD's solar home system specifications

Companies that participate in DRD SHS tenders are expected to install systems that comply with the specifications shown below in Box 1.

*Box 1: DRD SHS specifications*

**Specification for Solar Household System(2014-2015)**

1☐ LED 3 Watt (2)No☐ 20 Watt Lamp (1) No Household System

| | | | |
|---|---|---|---|
| | | | **Limited Warranty** |
| (1) | 80-90 Watt Solar Pannel | - (1) No☐ | (5-10)Years |
| (2) | Battery 12 Volt (65) Ah | - (1) N0☐ | (1-2)Years |
| (3) | Controller (10)Ah(12V-24V) | - (1) No☐ | (5-5)Years |
| (4) | Inverter 300 Watt | - (1) No☐ | (5-5)Years |
| (5) | Cable (5)Meter | - (3) No | |
| (6) | LED 3 Watt | - (2) No | |
| (7) | 20 Watt Lamp | - (1) No | |
| (When -TV-21"Flat LCD is ON 20Watt Lamp has to be OFF) | | | |
| ( 8) | Phone Charger | - (1) No | |
| ( 9) | Total Cost | - (200000) Kyats | |

The specifications do not include equipment quality or installation quality standards. Appendix D provides a detailed review of these specifications and offers a suggested improved set of specifications, briefly summarized below in Table 6 on page 35.

## 3 Scope and Methodology

Field work for this study included site visits between 29 November and 12 December to 10 villages with DRD SHS systems, two unelectrified communities without DRD systems, and 6 DRD offices in Kayin State, Thanintharyi District, and Shan State, as well as interviews with SHS installation companies and ICT companies in Yangon. Visits to DRD offices and villages were completed with the assistance of professional translator Sai Nay Lin as well as a representative of the DRD Naypyitaw office, Zin Lin Htun.

[2] Andrew Lynch et al., Threatened Sustainability: The Uncertain Future of Thailand's Solar Home Systems., June 2006, http://www.palangthai.org/docs/SHSReport6June06.doc.

DRD offices. The team visited and surveyed DRD offices at the state, district, and township level. In interviews with these officials the team sought to understand how many DRD SHS have been deployed in their area in the past fiscal years, the DRD office's level of experience and interest in training, the procurement process including vendor selection, and how villages are selected. The survey form used for these semi-structured interviews is included in Appendix A.

Village visits. 10 villages to visit were selected by the DRD, comprising two villages in Kayin State, five in Thanintharyi State, and three in Shan State. In each village visit the author was accompanied with two or more DRD local officers, usually one from the state or district level and one from the township level. Villages visited in the course of this study comprised 1288 households and accounted for 597 solar home systems installed in homes, with another 27 installed in schools or other public buildings. The villages, locations, and quantity of households and SHS installed are described below in Table 1.

*Table 1: Villages surveyed in SHS assessment and associated SHS installation data. Coordinates in italics are approximate.*

| **Date visited (2014)** | **Village name** | **District & State** | **Latitude & Longitude** | **Date SHS installed** | **Company** | **Total households in village** | **Total households receiving SHS** | **Schools, etc. receiving SHS** |
|---|---|---|---|---|---|---|---|---|
| 1-Dec | Yay Kyaw Gyee | Hpa An, Kayin | N 16.87110, E 97.65658 | Mar-13 | Industrial Department before program moved to DRD | 370 | 90 | 14 |
| 1-Dec | Pan Gong | Hpa An, Kayin | N 16.73273 E 97.58802 | Jun-13 | Moe Ko San | 110 | 110 | 4 |
| 3-Dec | Pan Taw | Dawei, Thanintaryi | N 14.07641 E 98.19622 | Jan-14 | Aung Myanmar Coop | 102 | 102 | |
| 3-Dec | Thar Byar | Dawei, Thanintaryi | N 14.07260 E 98.26978 | Nov-14 | Earth Renewable Energy Company | 160 | 34 | |
| 3-Dec | Taung Poh | Dawei, Thanintaryi | N 14.06982 E 98.25923 | Nov-14 | Earth Renewable Energy Company | 122 | 26 | |
| 6-Dec | Taung Pa Le | Myeik, Thanintaryi | N 14.14239 N 98.09141 | Apr-12 | SolaRiseSys | 140 | 94 | |
| 6-Dec | Ma Zaw Pyin Gyee | Myeik, Thanintaryi | N12.367769 E98.835273 | Mar-14 | Ant Htoo Gabas | 90 | 32 | |
| 9-Dec | Pan Lian | Loilem Dist, Shan | N21.287891 E98.531367 | Apr-14 | Myanmar Solar Power | 18 | 18 | |
| 9-Dec | Thien Phan (Lahu) | Loilem, Shan | N21.27524 E98.48477 | Apr-14 | Myanmar Solar Power | 56 | 18 | |
| 10-Dec | Khaung Nwe | Loilem, Shan | N20.87991 E97.49532 | Dec-13 | Zabuyit Pale Co. Ltd. | 120 | 55 | 10 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Total** | | | | | **1288** | **597** | **27** |

In each village, the team surveyed two or more households selected at random collecting usage data, socio-economic information, energy expenditure data, and performing a technical assessment of the current status of the system. The 115-question survey form used to guide these semi-structured interviews and equipment inspections is included in Appendix B.

In the technical assessment portion of the SHS inspections, data collected included solar panel short-circuit current and open-circuit voltage, solar insolation, solar panel orientation and tilt, battery voltage while resting and under charge, electricity consumption of lights, inspection of wiring, and dimensions and quality of wiring.

Solar home system companies. The team conducted interviews with manufacturers, system integrators, and installers in Hpa An (1 company) and Yangon (5 companies) to determine products and services offered, pricing, equipment sourcing, staffing levels and experience, solar experience, company practice and policy regarding warranty provision, and major issues in the industry. Of these six companies, three installed SHS that were encountered in the village visits. Survey forms for semi-structured interviews is included in Appendix C.

ICT companies. The team conducted in interviews with one cell phone service provider and two tower companies to explore the intersections between ICT and rural electrification, including incorporating mobile money technology into pre-pay meters, use of cell-phone data carriers to provide real-time monitoring of remote mini-grids, and interest of parties in business models that include provision of electricity to both cell-phone towers while also electrifying a surrounding village.

# 4 Research results

The following sections describe the results of the fieldwork. These start with a discussion of the village selection process and tendering processes used by DRD. This is followed by village findings based on interviews of users and technical assessments of a number of SHS performance parameters. The section ends with a discussion of mini-grids and non-DRD systems encountered in the course of the fieldwork.

## 4.1 Village selection process

With tens of thousands of villages to choose from, the DRD has a significant administrative task in choosing priority villages to receive SHS and to determine how many SHS to allocate to each village. Based on discussions with DRD staff at the state, district and township levels, this process is initiated from the bottom-up, starting with the township level. The process comprises the following steps:

1. At the township level, a group comprising the village leader representatives to the township, the DRD officer for that particular township, and a committee of other

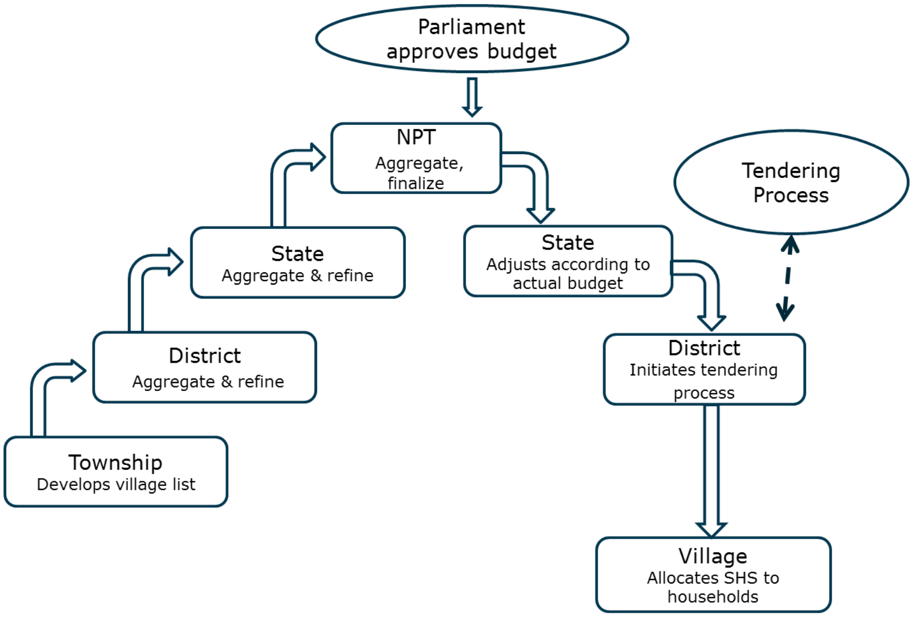
important local figures draws up a list of villages suitable for receiving SHS. The committee also divides the list roughly in thirds, assigning each village to the category 1st, 2nd, or 3rd priority. This determination takes into account:

   a. Distance from the main grid (or, where there is no main grid, distance from the nearest town);
   b. Village income (poorer villages get priority);
   c. Existence of privately-purchased SHS or diesel generators (those without SHS are prioritized); and
   d. Villages' other priority infrastructure needs (e.g. water, road -- if water is a priority, DRD will focus on that instead) and an attempt to balance who gets what (e.g. if one village gets SHS, another might get a road).

2. After the meeting, the DRD township official takes this list to the DRD district office, where modifications are made if the district office sees fit.
3. The list is then presented to the regional DRD which may make modifications as well.
4. The regional office then sends the list to the Naypwitaw office of the DRD which adds it to those from other regions and adjusts the lists if appropriate. Here Naypwitaw DRD Director U Khant Zaw plays a key role, together with the Minister of MoLFRD.
5. The list goes to the MoLFRD where an overall budget is proposed.
6. The budget (or a modified version) is approved by Parliament.
7. Funds are then sent back to the state/regional DRD office, which adjusts the list and SHS per village in accordance with the actual budget allocated.
8. The district office then initiates the tender process (described in 4.2 below), and awards contracts based on price, quality and "guanxi"[3]. If the winning bid price is lower than the 200,000 kyat cap, the DRD office generates a proposed use of the savings (e.g. building a road to a specific village) and informs the head office (NPT) to seek agreement.
9. It is the village's responsibility to determine how SHS are distributed if, as often is the case, there are not enough for one for every household. The process that villages use to allocate SHS is discussed in 4.3.1 below.

*Figure 2: DRD SHS Village selection process*

[3] In Mandarin Chinese, *guanxi* refers to the system of social networks and influential relationships that facilitate business and other dealings.




## 4.2 Tendering process

Once the village selection process is complete, the tendering process may proceed. SHS tendering is done at the same time that other DRD infrastructure (road, bridges, water, house construction, latrines) are tendered out. The tendering process appears to vary somewhat from region to region. In Thanintharyi, tendering is conducted at the regional level. In Shan and Kayin state, a committee that oversees tendering is convened at the state level. In Shan State the state government minister is chair, and the State DRD director is secretary. Five other state level members on the committee include: (1) General Administration Department; (2) Public Works Department; (3) Irrigation Department; (4) State Development Committee; and (5) Planning Department.

The tendering committee places advertising in local newspapers, TV, and radio indicating the day that the tender documents are available. In response, bidders come to the DRD office and collect bid documents, fill them out, and return with a sample SHS to demonstrate. This FY (2014-5) 48 companies applied for the SHS program in Shan State, of which 44 won contracts. Of the 44, four are from Shan State and the rest mostly from Yangon. In Kayin state, five companies won SHS tenders. As part of the decision in awarding tenders, the state committee determines how many systems are allocated to what companies in what villages. The final list is then returned to the DRD. Some companies get 2-3 townships. In other cases -- with bigger townships, one township may serve 2-3 companies. The price they receive is independent of how remote the village is.

Once installation is complete, a township DRD officer visits to ensure the systems were actually installed, and then the township office transfers payment to the company. The township officer has responsibility for regular follow up, but this is difficult because of limited staff. In theory the township officer visits at least two times per year and calls the company if there is a problem with broken equipment.

DRD staff at all levels (union, state, district, township) expressed that that they have little experience and ability to make good judgments about selecting vendors. All they have to go on is the demonstration unit that a vendor sets up in front of the panel. The DRD only has the skills to check the components against the DRD specifications, but have limited ability to judge quality of the design and components.

## 4.3 Findings from village visits

Through interviews with villagers and inspections of SHS in operation in people's homes, the team gathered information on how SHS are allocated within the village; the socio-economic profile of village homes with SHS; the benefits from SHS – particularly in the form of reduced expenditures for kerosene, diesel, and candles; usage patterns, and how villagers address problems that arise when SHS equipment breaks. Inspections of SHS covered a wide range of parameters covering wiring, solar panel, charge controller, battery, inverter, lighting, and the operations manual.

### 4.3.1 Allocation of solar home systems within village

In three of the ten villages, enough solar home systems were provided through the DRD program to install one in every house. In the remaining seven villages, a fraction of the households -- between 21% and 67% -- received SHS. In the villages visited, on average 45% received SHS.

In all villages visited the decision of how to allocate SHS among households was left to the villages to decide. In five of the villages, SHS were allocated on a simple lottery basis. Khaung Nwe village employed a slight variation: the village of 120 households was allocated 65 SHS and the village decided to allocate one each to the clinic, school, and monastery. Another seven SHS were provided to poorer households. The remaining 55 distributed by a lottery system.

Taung Pe Le village has 140 households, but only 94 SHS were available. The village set up a first-come-first-served process in which those who wanted SHS paid 30,000 kyat. The payments were pooled to purchase (smaller) SHS for those that did not receive them from DRD.

### 4.3.2 Customer profile

Of village households with DRD SHS that were interviewed, the strong majority were farmers (94%) mostly growing paddy and vegetables, while a few operated small shops (23%).[4] One respondent was a seasonal laborer and wood cutter. Another ran motorcycle repair business and sold fuel. Two provided transportation, either in the form of a motorcycle taxi, or a larger tractor/wagon for group trips to the nearby town.

Reported monthly income ranged from 0 to 500,000 kyat per month, with an average of 115,000 kyat per month. Household size ranged from 2 to 7 members, with an average family size of 4.2. In 35.3% of households SHS were operated by both men and women, 35.3% by women only,

[4] Sum exceeding 100% indicates multiple occupations.

and 29.4% by men only. Homes were generally wood with tile or metal roofs (58%), while the remaining significant minority (42%) had grass or bamboo roofs and homes with bamboo floors.

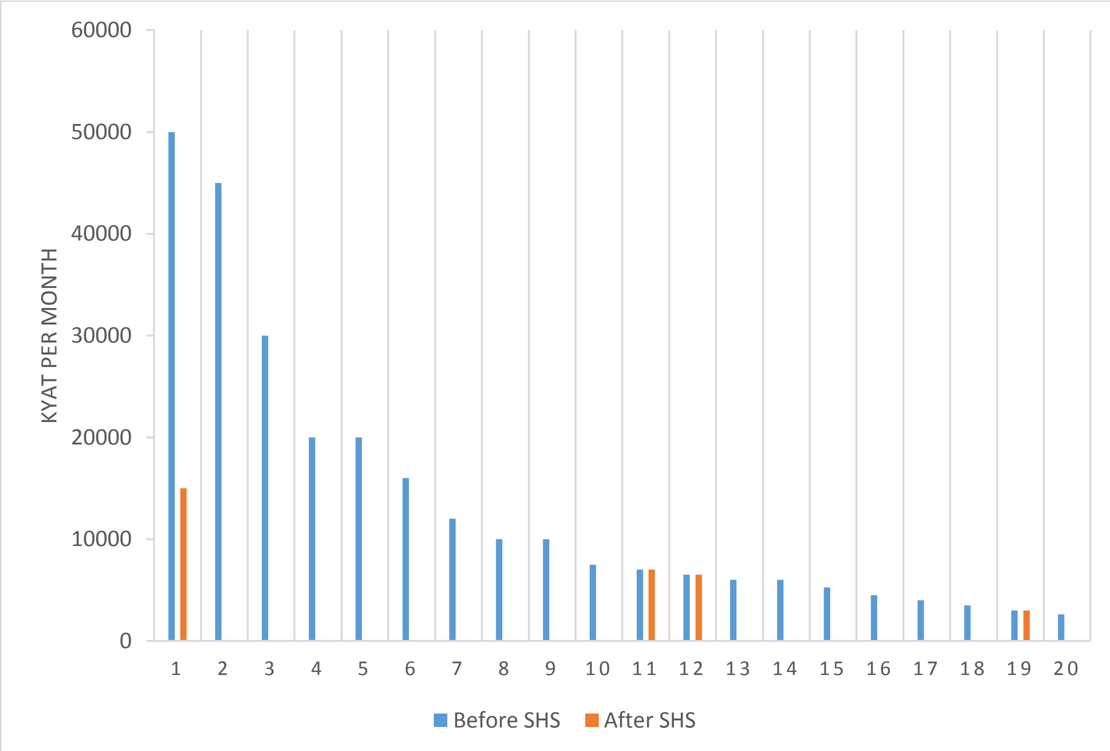
### 4.3.3 Savings enabled by SHS

As long as SHS remain functional, the benefits of SHS to household cash flow are stark. Prior to installation of the SHS, villagers in 20 households queried paid between 2600 and 50,000 kyat per month on non-heat energy, with an average expenditure of 13,400 kyat/month. This money was spent on candles (about 100 kyat per night), kerosene lamp oil (a 0.66 liter bottle costs about 700 kyat and lasts 2-3 days) and, in some cases, diesel fuel for a household generator or shared community diesel generator.

After the installation of the SHS, most households' routine non-fuel energy expenses reduced to zero[5]. When asked about how life has changed with the SHS, most respondents mentioned the reduction expenditures for energy. A distribution of household expenditures before and after the SHS is shown below in Figure 3, sorted from highest to lowest. In the figure, household #1 (which had been paying 50,000 kyat/month, the highest) reduced to 15,000 kyat/month but continued to operate a diesel generator for TV. Households #11 and #19 had broken SHS and now pay the same that was paid prior to the SHS, demonstrating the obvious but important fact that SHS save money only when they are working. Household #12 pays the same as before because it is a customer of a community diesel power mini-grid with a minimum monthly payment of 7000 kyat/month for up to 10 kWh per month. At the end of the month the homeowner uses any remaining quota to iron clothes. The SHS in this particular case was installed only a week prior to the visit, so the household may yet decide to not renew the diesel generator membership.

[5] Six households reported they still bought candles for use in their family altar, paying about 100 kyat per night (3000 kyat/month). This is arguably a religious expense and not an energy expense since solar LED lights could be used (and many households do use) in the altar.

*Figure 3: Distribution of household expenses before and after SHS for non-heat energy in Myanmar Kyat per month. Most households pay zero non-heat energy expenses after installation of the SHS.*




### 4.3.4 Usage patterns

Electricity from solar home systems is predominantly used for three purposes: lighting, TV/DVD, and cell-phone charging. DRD SHS recipients each received three LED lights. Indoor lights are powered between 3 and 10 hours per night, with an average of 4.9 hours per night. Three out of 24 households had installed one of their lights as an outdoor light and typically that light was powered “all night” – about 10 hours per night.

TVs (or “laptop” DVD players) were used in 47% of households surveyed. While these were mostly powered through the inverter, four households use 12-volt DC TVs. TV watching in some cases is seasonal. For example, one house in Myeik, Thanintharyi reported that they could watch two hours of TV per night except during the rainy season. During the rainy season TV was switched off in order to ensure sufficient electricity for lights.

Like TVs, cell phone charging can be done either with DC or AC. Many cell phones charge using a standard USB (5 volt) connector. Even though not required by the DRD specifications, five companies (Earth Renewable Energy Company, Moe Ko San, Ant Htoo, Myanmar Solar Power, and Zabuyit Pale Co.) supplied USB charging ports in addition to 12-volt lighting receptacles and 230 volt outlets. Sixty nine percent of DRD SHS encountered were used to charge cell phones, either using the inverter or a USB port. Charging with an inverter is not recommended because if the inverter is turned on only to power the cell phone the inverter is operated at a point on its power curve where it is less efficient.

### 4.3.5 What happens when something breaks

The DRD specifications indicate warranties for key components (5 years for PV panel, controller and inverter, 1-2 years for battery as indicated in Box 1). In the village, however, knowledge of the warranty, or how to go about making a claim was sparse. No one in the village specifically knew that there is a warranty.

Follow-up varied from excellent to non-existent. On the one hand, a resident of Pan Taw Village (installed by Aung Myanmar Coop) reported that the DRD comes to check about 6 times per year, and the company came three times per year and changed out broken LED light bulbs. Much more common was lack of follow-up and lack of information about whom to contact in the event of a problem. When asked what people do when something breaks, more than 60% replied either “I don’t know” or “we try to fix it ourselves”. Twenty percent of respondents contact the village leader who aggregates reports of broken equipment and contacts the installation company. None of the companies based in Yangon who installed systems in the villages visited maintain permanent staff in the state or district. Considering that all actually do perform installations, it follows that these companies have access to technicians (generally based in Yangon) with the skills to perform equipment replacements.

### 4.3.6 Technical assessment of DRD SHS performance and equipment quality

The following subsections detail the technical performance of DRD SHSs encountered in the field, including wiring, solar panel, charge controller, battery, inverter, lighting, and the presence or absence of a user manual. Overall, 16 out of 23 systems inspected (69.6%) were functioning properly.

#### *4.3.6.1 Wiring*

##### 4.3.6.1.1 Wiring installation

In all houses visited except one, wires (especially wires to lights) were draped on rafters and nails, creating hazards and opportunities for wires to be pulled and broken in the course of day-to-day activities in the house. The one house visited with correctly installed wiring was rewired by the household residents after the installation team left.

*Figure 4: examples of sloppy and hazardous household wiring. In bottom photo notice location of nail immediately next to DC inverter terminals creating a significant fire hazard as these unfused wires are connected directly to the battery terminals.*

#### 4.3.6.1.2 Splices and connections

In at least 90% of the SHS installations visited, wires (especially the wire from solar panel to controller) were improperly spliced. Generally wires were simply stripped, twisted and taped, or using an interior-rated terminal connector. Neither of these splice methods provide protection against corrosion from rain and moisture. Splices of this nature will fail when water intrudes and corrodes contacts.

Battery connections are particularly important because current passes twice (on charge and discharge) through these connections, and because battery terminal connections are particularly prone to corrosion resulting from mismatch of alloys between battery cables and terminals.

*Figure 5: Example of poor splice with wires simply wrapped and taped, also positioned so that it will be soaked in the rainy season.*

##### 4.3.6.1.3 UV resistance of exterior wires

The PV-to-controller circuit in over 90% of installations surveyed used interior-rated wires that lack UV-light resistant insulation. In a few years, UV light will make the insulation brittle, creating possibilities of short circuits and setting conditions for the wire to corrode.

#### *4.3.6.2 Solar Panel*

##### 4.3.6.2.1 Solar panel certification and quality standards

In DRD SHS encountered in the field visits, solar panels without brands were used by 3 out of 10 companies (Industrial Department, SolaRiseSys, Ant Htoo Gabas). 5 out of 9 companies used solar panels with IEC certification (SolaRiseSys and Earth Renewable Energy Company). In addition, one company interviewed in Yangon (but whose systems the team did not see in the field) used certified PV modules (T & T Ltd.). One company used solar panels with solar cells that were visibly chipped and discolored (Myanmar Solar Power).

#### 4.3.6.2.2 Solar panel performance

As an indicator[6] for solar panel performance, temperature-adjusted[7] and insolation-adjusted rated short-circuit current is compared against the solar panel's measured short circuit current.[8]

$$\text{Ratio of measured Isc to adjusted-rated Isc} = \frac{I_{sc-measured}}{(I_{sc-rated})\left(\frac{\text{Insolation}}{1000\frac{W}{m^2}}\right)(1+(T-25))(I_{sctempcoeffient})}$$

Where:

> $I_{sc\text{-}measured}$ is the measured short-circuit current (in Amperes),
> $I_{sc\text{-}rated}$ is the rated short-circuit current (in Amperes),
> Insolation is the measured global solar insolation in the plane of the array (in watts/$m^2$),
> T is the measured ambient temperature at the solar panel in degrees Celsius,
> $I_{sctempcoefficient}$ is the typical temperature coefficient for short-circuit current for crystalline silicon solar cells (0.061 %/deg C).

Only one solar panel produced a short-circuit current within 90% of its adjusted rated short circuit current. Most (9 out of 11 measured) performed below 50%. Three of the solar panels with IEC certification had the highest scores (Figure 6 below).

Caveats should be noted: the insolation measurement and the short circuit current measurements were not taken at the same instant. Variations in cloud cover in the interval between measurements are a source of possible error (though mostly skies were clear). Also, low short-circuit current readings are attributable in part to dust on the module surface reducing the amount of sunlight reaching the cells rather than entirely due to below-spec performance. Low readings are not attributable to shading, as insolation measurements were taken in the plane of the module, and thus subject to any shading that the module was subject to. This method of assessing PV performance is indicative only and does not take into account the solar panel's voltage performance or its fill factor (the ratio of maximum power production divided by the product of $V_{oc}$ and $I_{sc}$) – factors likely to work even further against the chance of the module meeting specification.

The persistently low indicator of performance measurements suggest that many solar panels installed in DRD SHS perform substantially below their rated output.

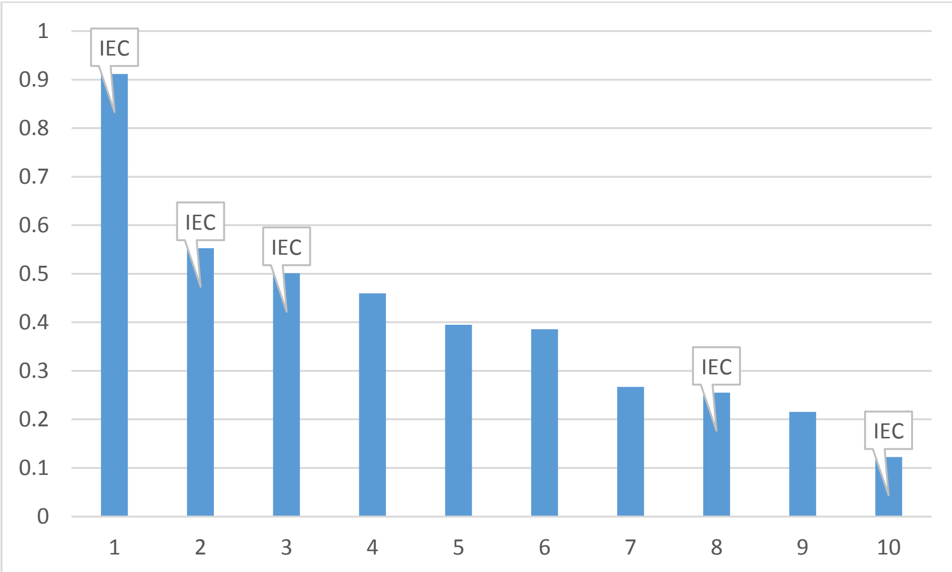
*Figure 6: PV performance indicator defined as the measured short circuit current divided by temperature- and insolation-adjusted rated short circuit current. A value of "1" indicates the PV module is performing consistent with*

[6] Fully testing each module would have required a laboratory with a IV-curve tracer and a calibrated light source.

[7] Typical temperature coefficient for short-circuit current is 0.061 %/deg C. Source: http://forum.solar-electric.com/showthread.php?15312-Temperature-Coefficients.

[8] Short-circuit current and temperature were both measured with a factory Fluke 197 True RMS Multimeter (factory calibrated 11/11/24). Solar insolation was measured with a Dr.Meter SM206 Digital Solar BTU Power Meter.

*rated capacity. Only solar panel #1 (SHS in Khaung Nwe village installed by Zabuyit Pale Co. Ltd.) had a measured performance indicator exceeding 90%. Data label indicates whether the panel had IEC certification.*




#### 4.3.6.2.3 Solar panel orientation

Most SHS systems encountered had the solar panel installed with large (and sometimes very large) deviation from orientation towards true south[9], as shown in the "error" column in Table 2 below.

*Table 2: solar panel orientation and error from true south*

| Orientation (180 = true south) | Error (Degrees from true south) |
|---|---|
| 46 | 134 |
| 222 | 42 |
| 175 | 5 |
| 197 | 17 |
| 182 | 2 |
| 193 | 13 |
| 150 | 30 |
| 93 | 87 |
| 302 | 122 |
| 205 | 25 |
| 267 | 87 |
| 229 | 49 |
| 201 | 21 |

[9] Orientation measurements were made with a Garmin GPS which is not affected by magnetic declination.

#### 4.3.6.2.4 Shading

Many solar panels were significantly shaded at the time the system was inspected or were installed in locations that would clearly be shaded for significant portions of the day. In large part this is a consequence of PV-to-controller wire lengths that were too short. The DRD specifications indicate wires shall have a length of 5 meters, which in many cases is inadequate to reach sunny areas. In other cases, shading is simply the result of not paying sufficient attention to unshaded south-facing options.

#### 4.3.6.2.5 Solar mounting

Companies varied considerably in the quality of the solar mounts that were used. On the high quality end, Earth Renewable Energy Company used substantial wooden poles with engineered steel brackets. On the low-quality side, SolaRiseSys used poles of small diameter (approximately 3 inch) and of soft (rot-prone) wood which appear likely to fail by the end of the next rainy season. These should be replaced soon with more substantial, rot-resistant materials. Many households, especially those that installed their own SHS, simply laid the solar panel on the roof (generally corrugated iron). This presents dual problems of (a) overheating because insufficient air gap is provided between the hot roof and the panel's back surface; and (b) high risk of the solar panel blowing off the roof and falling to the ground in high winds.

*Figure 7: Rot-prone, small diameter poles, flimsy mounting*

### *4.3.6.3 Charge Controller*

All SHS were originally installed with charge controllers, but these vary considerably in quality, functions, and durability. In a number of cases these were bypassed.

##### 4.3.6.3.1 Controller circuitry type

Controller circuitry varied considerably in terms of function and durability. On the worst end of the scale, the SHS systems installed under the Myanmar Industrial Department (prior to the DRD) contained a very simple relay-based controller with no indicator lights of any kind. At least half of these controllers had failed after 21 months of use.

All of the SHS installed under current DRD program were installed with solid-state switching, which is considerably more reliable than relay type controllers. At least one controller type encountered in the field (Earth Renewable Energy Company) uses pulse width modulation (PWM) – a feature that helps prolong battery life by tapering current as the battery approaches full state of charge, rather than simply turning off current when the battery reaches a certain voltage.

##### 4.3.6.3.2 Low Voltage Disconnect (LVD)

In the case of “plug and play” systems it was impossible to determine which had Low Voltage Disconnects (LVDs). Visual inspection of the circuits suggested that LVDs were included.

Systems with discrete components (as opposed to components installed in a single metal box) all had controllers with LVDs except one (Myanmar Industrial Department (installed prior to the DRD SHS program). In all cases, inverters were not wired through the LVD terminals, allowing inverter-based appliances to deplete battery charge down to the level at which the inverter turns off or sounds a low voltage alarm. This is not necessarily an error, as LVDs are generally current limited (typically 10 Amperes) -- effectively reducing the maximum power output from the inverter from 300 watts to 120 watts (12 volts x 10 amperes). However, it does create additional risks that inverter-powered appliances will draw down the battery below a safe voltage.

##### 4.3.6.3.3 Fused vs. electronic-based current limiting vs. no protection

Controllers generally have over-current protection and protection against reverse polarity. Those that use fuses to provide this protection are more likely to fail or be bypassed compared to controllers that use electronic means of overcurrent protection. In the case of controllers with fuse protection, the typical progression of events leading to failure is that a short circuit or reverse polarity incident melts the fuse, rendering the controller inoperable. If a spare fuse is not available the user simply bypasses the controller or “fixes” the fuse by covering it with aluminum foil. The next time a short occurs, the meter’s (now unprotected) circuitry is damaged. Of solar home systems installed by nine companies that the team observed in the field, four companies used fuses to provide overcurrent and reverse polarity protection. Fuses had blown in two of the systems installed by these companies. Of the remaining five companies, it was impossible to determine without either seeing the specification sheets or potentially destructive component testing whether the controllers had electronic current limiting or had no protection.

##### 4.3.6.3.4 Controller bypassed

Out of 24 systems visited in the field, the charge controller was bypassed in two systems, leading in both cases to severe overcharging of the battery and depletion of battery electrolyte to such an extent that the cell plates were exposed to air. Controllers in systems in which components were assembled together in a single “plug and play” box were less likely to be tampered with and bypassed compared to those using discrete components.

#### *4.3.6.4 Battery*

##### 4.3.6.4.1 Battery types

All companies with systems encountered in the field used sealed lead-acid batteries except one company (Aung Myanmar Coop) which used a flooded lead-acid type battery. Sealed “maintenance free” batteries require less maintenance (especially topping up cells with distilled water), but flooded batteries can last longer if properly maintained because they accommodate equalization charges (periodic intentional overcharging to remove sulfation). Flooded batteries require additional installation steps as well: they are generally shipped dry, and electrolyte must be added and an initial forming charge performed before use.

Among sealed lead acid batteries manufactured worldwide, the most common are Absorbed Glass Matt (AGM) batteries – also known as valve regulated lead acid (VRLA) batteries. AGM batteries were also probably the most common sealed battery encountered in the field, but most batteries lacked sufficient marking to make this determination.

##### 4.3.6.4.2 Battery enclosure

Batteries in systems installed by two companies (Zabuyit Pale Co. Ltd. and Myanmar Solar Power) included metal box enclosures – as required by Shan State DRD specifications. Batteries installed by all other companies either had no enclosure. Battery enclosures improve safety by reducing the chance of accidental short circuits by dropping a metal device across the terminals and protecting small children from direct encounters with the battery. Enclosures may also reduce tampering.

The metal enclosure in Shan state is required to prevent, of all things, the use of batteries for shocking fish. When 44 companies submitted example systems in the Shan State tendering process, some had all the components in a single metal cabinet box, others had separate components. After seeing the systems in a single box, the tendering committee reflected on their experience that if the system has separate components, many villages will take the battery down to the local fishing hole and use it to shock fish. Out of concern for the battery (and perhaps the fish) the committee felt that it was important to put the battery in a metal box with everything else since they felt this would help deter villagers from this misuse of the battery. The committee informed the bidders that their winning bids would only be accepted if they put all the components in a metal box. At least one company complained, saying, "the box alone costs me 20,000 kyat" but none of the companies pulled out.

##### 4.3.6.4.3 Battery failures

Out of 26 SHS investigated, batteries had clearly failed in three installations and a fourth was very weak (with voltage dropping immediately from 12.9 volts to 11.3 volts when PV was removed). Others may have been close to failure, but because visits to villages were during the daytime, higher voltages from recent solar charging almost certainly masked some battery problems. [10]

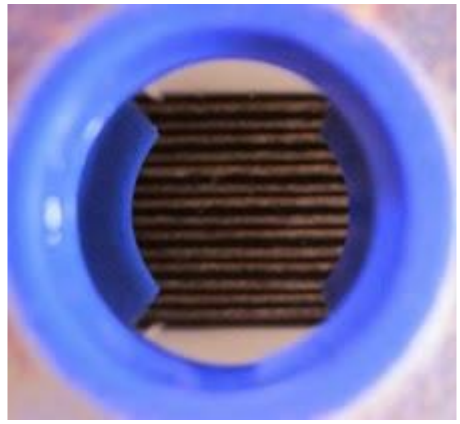
*Table 3: Battery failures observed in DRD SHS*

| Company | Battery type | Battery age when visited | Comments |
| --- | --- | --- | --- |
| Myanmar Industrial Department | Sealed | less than 20 months | Probably caused by controller failure. 20" LED TV and DVD players were loads. |
| SolaRiseSys | Flooded (replacement for earlier battery) | 7 | Probably caused by controller failure |
| Zabuyit Pale Co. Ltd. Taunggyi | Sealed | 13 | Battery apparently damaged – acid reportedly leaked out at time of installation but the recipient did not bring the issue to the attention of the installer. |

The range of battery ages encountered was zero to 24 months, with an average of just over 12 months. Under the conditions and considering the common lifetime of batteries, DRD should expect high failure rates in coming months.

*Figure 8: (Left) Voltage of this (dead) battery is 8 volts starting the evening. (Right) closeup of overcharged battery cell with lead plates exposed (non-DRD system with no charge controller).*

[10] An observable characteristic of a failing battery is that its voltage rises quickly under charge and falls relatively quickly when discharging (e.g. 1 hour at a C/10 discharge rate depleted to a low voltage cutoff of 11.5 volts instead of 10 hours with a healthy battery). Stated simply, its capacity appears diminished. During the daytime – when the battery is charging, and with access typical loads in a village household, , this depletion still takes too long to observe in the course of a typical household visit. A charged but battery failing battery will still appear to hold charge when measured in the short run running relatively small loads. As a lesson learned, future SHS inspections would benefit from the use of a dedicated battery analyzer tool rather than a voltmeter and village loads.

#### 4.3.6.4.4 Battery recycling

Questions about battery recycling and disposal of used batteries were not included in the village survey instrument, and therefore were not part of the average village household interview. However, in the course of interviews the team did ask several village households what they do with old batteries. The answer was consistent: people save old lead acid batteries because every several months a truck arrives traveling from village to village purchasing old batteries by the kilogram. More research is necessary to determine if the price of lead seems is sufficiently high (about $1 per pound internationally) that the private sector addresses dead battery collection effectively, and whether private sector recycling can expand sufficiently fast to match the growth in SHS under an expanding DRD program.

### *4.3.6.5 Inverter*

#### 4.3.6.5.1 Inverter failures

Overall, inverter failures were noted in 4 out of 23 households surveyed. In Taung Pa Le village, Myeik, Thanintharyi State (installation by SolaRiseSys in April 2012), about 60 households used the inverter in their SHS to power a TV. Of these 60 households, the village leader estimated that 90% (about 54) of the inverters had failed. In Ma Saw Pyin Gyee village in Myeik, Thanintharyi State (installation of 32 SHS by Anto Htoo Gabas in March 2014), the village leader estimated that 50% of inverters in the village had failed.

#### 4.3.6.5.2 Inverters and lighting

Fortunately, inverters were used to power lights in systems installed by only three out of twelve companies: Earth Renewable Energy Company and the “pre-DRD” Ministry of Industry (all three lights), Mo Ko San (tube light only) and Aung Myanmar Coop (tube light only). Powering lights with inverters lowers resiliency and reliability because if the inverter fails the light cannot be used.

##### 4.3.6.5.3 Inverter non-use

In Thien Phan village, Loilem District, Shan State no inverters were broken because none were used. They inverters were still in their original bubblewrap. Villagers reported they could do everything they needed (lights, cell phone, TV) with DC.

#### *4.3.6.6 Lighting*

All companies provide at least three LED lights. One company (Earth Renewable Energy Company) provided four. The LED lights came in sizes of 3, 5, 9 and 10 watts. Most systems provided a mix of two smaller (3 to 5 watt LEDs) and one large (9 or 10 watt LED light). One company (Zabuyit Pale Co.) provided three 9 watt LED lights. Most LEDs were DC, but (as discussed in the section 4.3.6.5.2 above) several companies provided AC lights powered through the inverter.

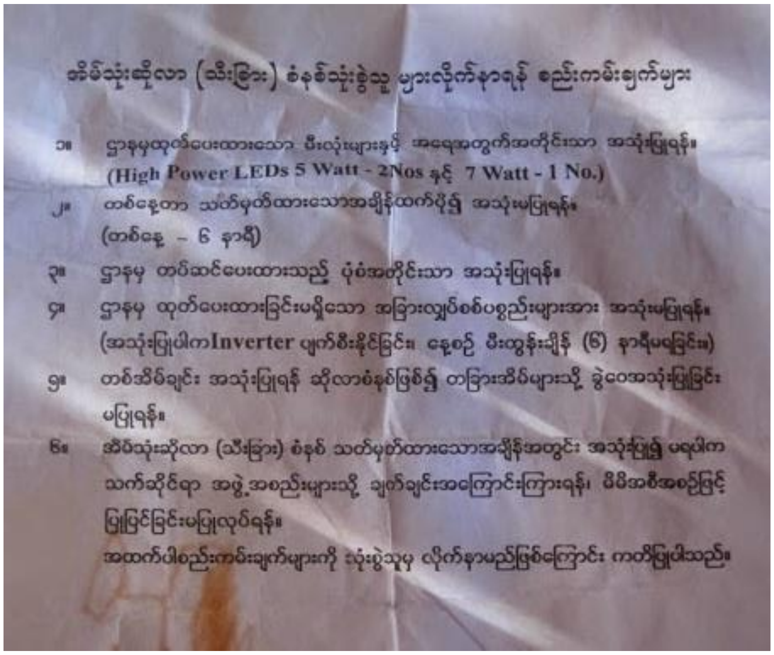
Lighting installed outdoors was, in every case, an indoor rated fixture installed outdoors with generally inadequate shielding from rain. Of 24 households in 11 villages, LED light failures occurred in four households. Three of these were in systems installed in April 2012 (older than most) by SolaRiseSys.

*Figure 9: Interior lamp fixtures used in outdoor applications with insufficient rain protection. This*

*4.3.6.7 Operation manual*

DRD specifications do not require an owners' manual, but one is clearly needed. About 45% of respondents said they had received a 'manual' but in all cases this was actually just a single sheet of paper listing 5-10 rules such as "don't use a rice cooker" and "don't make modifications to the system". While better than nothing, this does not provide users with the necessary understanding of their SHS to use and maintain it properly.

*Figure 10: "Operations manual" in Yay Kyaw Gyee village, Kayin State consists of a single piece of paper listing prohibited actions.*



အိမ်သုံးဆိုလာ (သီးခြား) စံနစ်သုံးစွဲသူ များလိုက်နာရန် စည်းကမ်းချက်များ

၁။ ဌာနမှထုတ်ပေးထားသော မီးလုံးများနှင့် အရေအတွက်အတိုင်းသာ အသုံးပြုရန်။
(High Power LEDs 5 Watt - 2Nos နှင့် 7 Watt - 1 No.)

၂။ တစ်နေ့တာ သတ်မှတ်ထားသောအချိန်ထက်ပို၍ အသုံးမပြုရန်။
(တစ်နေ့ – ၆ နာရီ)

၃။ ဌာနမှ တပ်ဆင်ပေးထားသည့် ပုံစံအတိုင်းသာ အသုံးပြုရန်။

၄။ ဌာနမှ ထုတ်ပေးထားခြင်းမရှိသော အခြားလျှပ်စစ်ပစ္စည်းများအား အသုံးမပြုရန်။
(အသုံးပြုပါကInverter ပျက်စီးနိုင်ခြင်း၊ နေ့စဉ် မီးထွန်းချိန် (၆) နာရီမရခြင်း။)

၅။ တစ်အိမ်ချင်း အသုံးပြုရန် ဆိုလာစံနစ်ဖြစ်၍ တခြားအိမ်များသို့ ခွဲဝေအသုံးပြုခြင်း မပြုရန်။

၆။ အိမ်သုံးဆိုလာ (သီးခြား) စံနစ် သတ်မှတ်ထားသောအချိန်အတွင်း အသုံးပြု၍ မရပါက သက်ဆိုင်ရာ အဖွဲ့အစည်းများသို့ ချက်ချင်းအကြောင်းကြားရန်၊ မိမိအစီအစဉ်ဖြင့် ပြုပြင်ခြင်းမပြုလုပ်ရန်။

အထက်ပါစည်းကမ်းချက်များကို သုံးစွဲသူမှ လိုက်နာမည်ဖြစ်ကြောင်း ကတိပြုပါသည်။

### 4.3.7 DRD centralized systems

While the SHS are the most common form of solar electrification, DRD appears to have considerable flexibility to accommodate both solar mini-grids and central battery charging stations where conditions are appropriate.

In Thit Sar Aye Myaing village (N 17.18369; E 97.67213) in Kayin State are nine PV mini-grids installed under the DRD program in Dec 2013 by Moe Ko San, a social enterprise PV company in Hpa An. The village was chosen for a mini-grid because it is a fairly dense settlement with households in a grid pattern. Each of the nine identical systems has the following key components, all manufactured in Korea:

- 3 @ 250 watt, 72-cell solar panels, IEC 61215 certified,
- two 12-volt 250 Ah batteries (in series) lead calcium sealed
- 1000 watt, 24-volt inverter
- Controller (20 A)

In each of the 278 houses in the village power is provided two AC LED lights (3W) plus 201 LED street lights (5 W). In addition, a central station provides cell-phone charging. No outlets are provided in households and TVs, irons, rice cooking, torch charging are prohibited. The system is only turned on from 4-6 am and from 6-9 pm.

*Figure 11: One of nine AC mini-grids installed at Thit Sar Yeik Myaing village in Kayin State.*

The system was well-installed but there are some significant problems technical problems and user problems.

User problem: some users have tried to run TVs by disconnecting the wires to the light and routing it to a TV. Short circuits created by sloppy handling of this process trips breakers in the house and sometimes fries transistors in the inverters.

Technical problem: two batteries exploded. Others are starting to fail. Battery voltage under charge for batteries comprising two separate 24-volt series string were radically different voltage. In one case, 11.6 and 13.93; another case 11.62 and 14.10. This was under conditions of about 20 charging amps. Clearly the batteries at 11.6 volts are in trouble. In another case, a pair of batteries was at 16.52 volts and 15.82 volts respectively. This is far too high for a sealed 12-volt led-acid battery.

The battery problems including exploded batteries almost certainly the result of charge controllers set with a high voltage disconnect that was far too high. Sealed lead-acid battery are subject to thermal runaway and voltage must be carefully regulated to prevent overcharge. In the village many controllers were set to 33.6 volts. Default factory setting is 27.4 and elsewhere a recommended setting for a 24-volt VLRA battery is 28.2 to 29.4 volts.[11]

[11] http://www.homepower.com/articles/solar-electricity/equipment-products/ask-experts-battery-queries

### 4.3.8 DRD battery charging station

In Thein Phan Village, Loilem District, Shan State, the company Knowledge Nugget provided portable battery packs that include a 2.8 Ah 12-volt battery, two 3-watt LED lights and two USB charging plugs. Twenty charge from a single 140 watt module. The woman we interviewed liked it because it is portable. These are not exactly under the DRD budget; we were told they were donated, but the DRD looks after them and has provided repairs, especially for cables that were failing. At least two other companies active in the DRD SHS program – T&T Solar and Asia Solar -- are producing similar very small portable battery pack charging systems.

### 4.3.9 Hire purchase SHS

In addition to DRD SHS which are given to villagers for free, at least one “hire purchase” program operated by a (separate) branch the Myanmar government is in existence.

One system observed that was installed under the program was similar to DRD SHS in Shan State, but with smaller solar panel and battery.

- Components in a powder coated metal cabinet.
- Battery 12 V 40 Ah valve-regulated lead acid
- 40 watt solar panel (mounted on roof). At the time (about 2pm) it was producing:
    - $I_{sc}$ = 2.6 amps
    - $V_{oc}$ = 20.14 volts
- Inverter rating: 500 watts. No brand. Transformerless type, gold color, with one outlet which had been removed and AC wires connected to two outlets on the metal chassis.
- Charge controller with LVD. Brand: Sinoware. Like the inverter, it had also been "hacked" with its LED indicators rewired to light up tiny LEDs on the chassis.
- Five 12-volt receptacles
- Three LED lights each 3 watts.

The program is operated by the Mandalay State Project Planning Department, working together with a private company, Heatec, which manufacturers the hardware. The government department purchases the equipment from the company, provides marketing, distributes the equipment, and collects payments. Reportedly, “thousands” of systems have been installed under the program. The author encountered a family with one of these systems in Mai Pon town, an unelectrified area outside of the municipal area of Pwin Oo Lwin, Mandalay. The system was installed in December 2013.[12]

The price of the system to users is 450,000 kyat (about $450) paid in a 1-year installment plan with 9.75% interest. Considering the smaller equipment, and the similar quality of the equipment and installation, this seems quite expensive compared to the 200,000 Kyat cost of a system with larger battery and larger PV module under the DRD programs. At the time of the interview, the family still had three months of remaining payments to make. The bearings of the inverter’s fan

[12] Contact of person at government office: U Sanye Win (09493177), State Department Manager.

were failing, making a loud screeching noise whenever it was turned on. The family reported that it was "difficult to reach the company for repairs."

### 4.3.10 Privately purchased SHS

In the course of conducting field visits on DRD SHS, the team inspected eight solar home systems purchased by users themselves and saw hundreds more from afar. Several observations are worthy of note: (1) user-purchased SHSs are common; (2) equipment is widely available, inexpensive, but of questionable quality and shops do not provide detailed guidance on installation; and (3) typical user-purchased SHS have severe technical shortcomings. These findings are discussed in more detail below.

#### *4.3.10.1 User-purchased SHS are common*

In all four states visited in the course of this study, solar panels were frequently seen on houses as the team drove to villages chosen to receive DRD SHS. It is difficult to estimate with precision what portion of homes have user-purchased systems, but the author's estimate is that in villages along main roads in the areas visited at least 25% have SHS if they do not already have electricity from power lines.  In some areas (road side towns in Kayin state, for example) it would not be surprising if the percentage exceeded 50%. In addition to fixed homes, solar panels were frequently seen at temporary tent housing occupied by road construction workers. Driving in southern Thanintharyi along the national highway, homes with solar panels basked in the glow of LED lamps, while little yellow candles shine dimly from those without. Again, it seemed at least 25% had solar.

One of the criteria for choosing which villages receive DRD SHS is that they household do not have electricity already. Yet even in these "electricity poor" villages, among the households visited 6 out of 24 (25%) were also using privately purchased solar home systems.

#### *4.3.10.2 SHS shops*

In all cities and market towns that the team passed through there were hardware shops selling solar panels, wire, LED lights, and 12-volt batteries. These shops also sold hardware of all kinds: shovels, buckets, pipes, twine, rat traps, clothes hangers, and carpentry tools.

In a small town northwest of Hpa An, Kayin State (coordinates: N17.18180, E97.66895) the team stopped at one of at least six shops in the selling PV equipment. A sampling of products and listed prices is shown below in Table 4. Note – these prices are as marked. In stores like this bargaining is the norm so actual prices are likely to be somewhat lower. Even before bargaining, prices of solar panels are below $0.70/watt peak.

*Table 4: Some solar equipment and pricing at a hardware store in a small town northwest of Hpa An.*

| Item | Brand | Country | Size | Price (Kyat) |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| PV panel | Tata | India | 20 watt | 18000 |
| PV panel | Tata | India | 38 watt | 30000 |
| PV panel | Tata | India | 80 watt | 60000 |
| PV panel | Tata | India | 100 watt | 70000 |
| LED TV/DVD/MP3/USB | Sanook | Thailand | 11.6" screen rated 1.5 Amperes at 12 volts (18 watt) | 43,000 |
| Inverter | No brand | China | 350 watt | 18000 |
| Inverter | No brand | China | 400 watt | 20000 |
| Inverter | No brand | Myanmar | 500 watt | 50,000 |
| Battery electrolyte | | | 1.5 liter $H_2SO_4$ 34% | 1800 |
| Battery distilled water | | | 2 liter | 600 |
| Battery | 3K | Thailand | Combined 2, 4, 6, 8, 12 volt. Light-weight | 33000 |

The hardware store selling these products did not provide guidance on how to correctly install the system, and it appears that those who purchase systems are on their own to figure out how to install them.

*Figure 12: Solar PV products on display at a hardware shop in Kayin State*

Solar panels and deep-cycle marine batteries were also sold in an automotive battery store visited in Dawei. More expensive and higher quality solar equipment imported from Japan, Taiwan, Europe and the USA were seen in specialty solar company storefronts in Hpa An and Yangon.

#### *4.3.10.3 Typical user-purchased SHS have severe technical shortcomings*

##### 4.3.10.3.1 No charge controllers

Of the privately purchased solar home systems inspected in the course of this research, only one out of eight (12.5%) had a charge controller. It was not surprising, then, that chronically overcharged and dry batteries were also encountered in these user-purchased solar home systems.

##### 4.3.10.3.2 Mismatch between solar panel and system voltage

A different interesting and pervasive problem encountered in user-purchased SHS is a severe mismatch between solar panel voltage and battery voltage. Judging from the size of solar panels seen on homes, many – if not most – appear to be large panels in the 200 to 250 watt range. Industry-wide, solar panels larger than 140 watts are typically designed to be part of an array on a grid-connected rooftop system or a solar farm.[13] They are not designed to power 12-volt solar home systems. The crucial difference is in the number of cells per panel. Solar panels designed to charge 12-volt panels have 36 cells in series. Because of limitations in the size of solar cells that can be produced, large solar panels typically have 60 or 72 cells in series.

A 60-cell solar panel will charge a 12-volt battery, but it does so very inefficiently because the solar panel is forced by the battery voltage to operate far from its power point. In one system the team measured, the battery voltage was resting at 11.6, while the open-circuit voltage of the solar panel was 38.3 volts. A 240-watt 60-cell solar panel charging a 12-volt battery produces roughly the same current a 136 watt 36-cell panel.

In order to properly use a 240 watt solar panel with a 12 volt battery, a maximum power point tracking (MPPT) controller (or similar impedance matching device) is necessary. These are available in Myanmar (sold by Earth Renewable Energy Company in Yangon) but are expensive (over $200) and were never encountered in this field visit.

##### 4.3.10.3.3 Wiring inadequate

SHS purchased privately in use in villages had wiring problems nearly identical to those detailed in the DRD SHS descriptions in sections above including poor splices, lack of proper UV resistant insulation, insecure wires, and undersized wires. In many cases, simple corrosion-prone “alligator clip” connectors were used at battery terminals.

[13] http://www.solar-electric.com/solar-panels-mounts-kits-accessories/solarpanels/hiposopa.html

#### 4.3.10.3.4 Panel orientation, dust

Solar panels in private SHS were often installed at incorrect orientation and tilt angle. Especially where SHS were installed along major roads, solar panels were often coated in thick dust.

*Figure 13: Dusty solar panel on roof*

## 4.4 DRD SHS supply chain

The research included meetings with six Myanmar companies that install (and in some cases manufacture) solar home system equipment under the DRD program. Of these six companies, five were in Yangon and one was in Hpa An (Moe Ko San). Table 5 below summarizes key features of these companies.

*Table 5: Statistics of Myanmar companies installing Solar Home Systems*

| Name of Company | Type of product/ service offered | Number of staff | solar sector experience | SHS built to date | Sourcing of components for DRD SHS | Revenues (Thousand US$/year) | Expected increase FY2014-5 |
|---|---|---|---|---|---|---|---|
| Moe Ko San Solar | SHS and mini-grids | 33 | 2 years | 780 | Korea, China | 160 | 200% |
| T & t Co. Ltd | SHS and mini-grids. Solar street lamps | 20 | 1.75 years | 2722 | China | 80 | 1000% |
| Asia Solar | From pico-solar products to projects > 10 kW | 170 | 5 years | 7822 | China | >1,000 | >200% |
| Earth Renewable Energy Company | SHS, 1-3 kW systems | 25 | 12 years | 3700 | China | 1,000 | 40% |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Myanmar Mahar Htun | SHS | 6 involved in PV. (60 total) | None | 0 | Myanmar company builds systems for them (OEM) using parts from China | 233 | N/A |
| SolaRiseSys | PV for telecom, SHS, mini-grids, lanterns | 50 | 4 years | 10208 | China | not divulge | not divulge |

Companies the team met with reflect a wide variety of experience, from complete beginners in solar (Myanmar Mahar Htun) to veterans with more than ten years of experience (Earth Renewable Energy Company) or over 100 employees (Asia Solar). Most companies play at least the role of systems integrator, balancing cost and performance to select off-the-shelf components for integration into a functioning SHS. Some, such as Asia Solar, go further than this, designing their own charge control and inverter circuits, having them mass-manufactured in China, and then assembling the circuit board components together with battery in a metal box.

All companies were expecting considerable growth in this 2014-5 fiscal year, and all stated they would benefit from trade financing to ease cash flow constraints arising from the time lag between ordering equipment and receiving payment for installed systems.

Overall, the companies visited appeared professional and serious, and as such provide an excellent base for expanded quality SHS deployment in the country. Companies who are fairly new to SHS would benefit from a beginning course on SHS best-practice design and installation; while those at more advanced stages would benefit from a more advanced course on the same topic.

## 4.5 ICT and solar electricity in Myanmar

Cell phone service is expanding rapidly in Myanmar, both in terms of new entrants and especially in terms of expanded coverage. The consultant met with one cell phone operator (Telenor) and two tower companies (Apollo Towers and Pan Asia Towers). Tower companies build the towers and provide power (or will provide power) on contract to the cell phone providers.

There are a number of areas where telecom and solar electricity intersect with interesting opportunities for expansion of provision of electrical services to rural areas.

### 4.5.1 Solar hybrid systems to power towers

All cell phone towers need very high degrees of electricity service reliability, with uptime of 99.5 to 99.7%. Tower companies pay steep penalties if they are not able to meet these target uptimes. For this reason, most towers – even those with grid connections – have diesel backup.

Off-grid towers typically have two diesel generators as well as batteries. Cell phone tower loads are typically fairly constant, and vary from 1.2 kW to 3 kW depending on the type of equipment installed. Delivering diesel fuel to remote sites, and providing maintenance to remote diesel generators is very expensive. These relatively small loads and high maintenance costs make PV-diesel hybrid systems a good business decision in many cases. Telenor is already using hybrid PV-diesel systems. Apollo and Pan Asia's equipment can accommodate PV and they are either planning to incorporate PV (Pan Asia) or open to using PV (Apollo) if it lowers electricity costs.

### 4.5.2 Cell phone towers as anchor customers for village mini-grids

Within in the next 5 years cell phone companies will be rapidly expanding. Telenor alone plans to increase number of towers by 7000 to 8000, with more than half of these in rural areas. It is not clear, however, how many of these were located close enough to villages to serve as the anchor loads. Cell phone companies are interested in a model in which the cell phone tower is an anchor customer and power is provided to villagers, but the cell phone companies themselves will not take a proactive role in developing this as it is not their core business. Telenor's Head of Technology Strategy, Sian Tuang Tan, said that they have talked to a couple companies but have yet to encounter one that seemed both interested in providing villagers with power and that also understands the reliability requirements of Telenor's towers. He believes the opportunity is there for a good mix, but so far no one has stepped forward with a good proposal to them.

Tower companies are also interested, but at this point have not had the bandwidth to develop business plans and address technology issues as they are focused entirely on meeting ambitious tower construction schedules. Tower companies also raised the issue of lack of a regulatory framework for mini-grids and small power producers. As part of Myanmar's emerging electricity regulatory framework there is a need for rules that provide detailed guidance on[14]:

- how to legally develop mini-grids and sell electricity directly to retail customers;
- what processes are required for licensing and registration;
- how to set retail tariffs for sales to retail customers;
- what options exist if the national grid expands into the service area of the mini-grid.
  - Under what conditions can the mini-grid purchase electricity at wholesale from the utility? What wholesale tariffs apply?
  - Under what conditions can the mini-grid generator sell electricity to the main grid? What feed-in tariffs apply?
- who pays for interconnection costs and upgrades to the utility network, if required, for interconnection.

[14] For more on this issue, see: *SPP Regulatory Framework Options in Myanmar: Final Report to the International Finance Corporation*. https://palangthai.files.wordpress.com/2014/11/finalreport-myanmarsppregulatoryoptions1.pdf

#### 4.5.3 Solar PV for charging cell phones

Solar electricity is well-suited to charging cell phones, but cell phone companies and tower companies that the author met are not planning any proactive cell-phone charging infrastructure roll-out as it seems that villagers already procure their own solar panels to charge cell phones in unelectrified areas (in addition to DRD's work in this area).

#### 4.5.4 Cell phone network to transmit mini-grid system performance data

Telenor's technology already accommodates necessary data transfer capability, and presumably the situation is similar with competitors Ooredoo and MPT. All new Telenor towers are equipped with at least "H" (2.75 G) and in populated areas, "H+" (3.5 G) data capability. The electricity systems that power cell phone towers actively monitor diesel levels, battery voltage, electricity consumption data, and send this at frequent intervals back to headquarters.

#### 4.5.5 Electricity purchases via "Mobile money"

Telenor is planning to roll out mobile banking. Currently they are waiting for a license from Ministry of Finance. Telenor has mobile banking in other places (Pakistan, Bangladesh) so no new technology needs to be developed. Once the Ministry of Finance provides approval no additional regulatory approvals should be necessary to apply mobile banking to automated electricity purchases if another company wanted to use their platform to sell electricity services.

In all of the areas discussed above, telecom or tower companies have important roles to play in potentially reaching segments of the rural electricity market. Even though these companies are thoroughly engaged in expanding cell phone service as their core business, it will be important to maintain open communications and encourage these companies to keep these rural electrification considerations in mind as they build out infrastructure so that compatibilities are in place when the time is ripe for them or other private sector entities to develop the areas discussed above.

# 5 Recommendations and points for discussion

Based on the field visits and international practices, there are a number of recommendations (or at least points of departure for further discussion) for improving the sustainability and scalability of rural electrification through solar electricity under an expanded program. These cover a wide range of areas, from policy, planning and regulation; to technical aspects of SHS design and implementation; to financing and subsidies; and organizational capacity development.

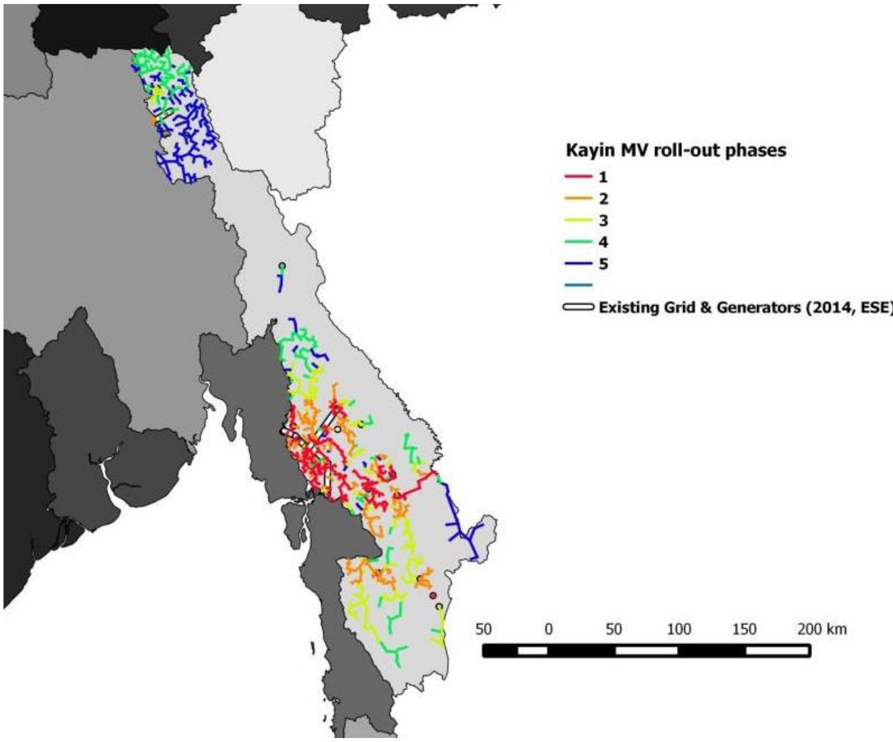
## 5.1 Policy, planning and regulation

### 5.1.1 Include NEP geospatial plan in village selection

Activity: Adjust DRD SHS village selection process to include consideration of the National Electrification Plan. Ideally Burmese versions of the appropriate NEP geospatial planning documents should be shared with DRD staff at all levels from Naypyidaw down to the township level. Moreover, a clear criterion for village eligibility vis-à-vis the NEP should be chosen, for example DRD will only support SHS for villages not expected to be served by the grid within three (five?) years.  The township level committee, in coordination with the local office of ESE, will serve as the primary filter to ensure that villages selected are consistent with the NEP and grid expansion plans. But cross-checking at DRD district and state levels will be useful as well.

Reason needed: As the NEP was only recently completed, as yet it has no connection with the selection of villages to participate in the DRD SHS program. This runs the risk of repeated selection of villages that may be quickly connected to the main grid. Assuming that ESE's grid expansion follows the trajectory outlined in the NEP, then DRD's SHS village selection process should integrate NEP geospatial planning as well. Doing so will make better use of limited SHS budgets. At the same time, the NEP should be regularly updated to include results from grid- and off-grid expansion so that it is useful planning tool that reflects reality.

*Figure 14: Roll-out of medium voltage (MV) grid in Kayin State in the NEP. Deployment of SHS should coordinate with the NEP's phased grid expansion. Source: Columbia Earth Institute, 2014. Electrification Planning for Myanmar: Methodology and Sample Results for: Kayin State and Chin State. March 19, Nay Pyi Taw, Myanmar*




### 5.1.2 Integrate sources of funding beyond DRD budget

Activity: Develop an institution or a financial account within DRD that can pool multiple sources of funding earmarked for rural energy support. This would include funding for SHS as well as community hydropower and other technologies and approaches related to expansion of energy access in rural areas.

In a number of African countries (Tanzania, Mali, Senegal), this takes the form of a Rural Energy Agency (REA), a semi-autonomous agency under the Ministry of Energy, that channels government funds, fees from levies for rural electrification, and donor funds all in a transparent way and uses these to further national goals of rural energy access. Many of these functions are already performed by DRD, but DRD might find it useful to learn more about REAs to see if there are useful practices and functions that may make sense for DRD to adopt.

Reason needed: Coordinated funding for rural energy access is necessary to avoid confusing proliferation of projects and programs working at cross purposes, duplicating efforts in some areas and leaving gaps in others. Donors are generally much more willing to contribute to a fund when they see that it receives contributions from domestic sources and are confident that it is well-managed.

## 5.2 Technical

### 5.2.1 Revise DRD SHS specifications to safeguard reliability and sustainability;

Activity: Reform the DRD SHS specifications to require equipment that meets certain quality standards, and that the system is correctly installed.

Reason needed: Current DRD specifications are insufficient to ensure quality.

Any revision of the DRD specifications needs much more attention on quality standards. This can be accomplished by requiring participating products to have been certified in World Bank off-grid programs in other countries (e.g. the IDCOL program in Bangladesh), or that have achieved some other appropriate international certification (e.g Global Lighting certification for plug-and-play kits, IEC 61215 certification for PV modules, etc.). To encourage domestic SHS industry and technology development, it is recommended that the World Bank support costs of product testing (e.g. in the CQC laboratory in China) for local Myanmar products that pass initial engineering tests and hold promise for meeting quality standards.

### 5.2.2 Revise DRD SHS system design to improve efficiency, reliability

Activity: improve SHS system design, increasing reliability and efficiency through removing inverter, enabling reduction in PV, battery capacity

Reason needed: An inverter is not needed for lights, TV, cell phone charging, fan. A system designed without an inverter can be smaller (because it no longer needs to overcome inverter inefficiency) and the system is more reliable because small inexpensive inverters are particularly failure-prone.

Table 6 below provides a recommended system configuration that provides roughly equivalent services to existing DRD systems with more robust, but similar, equipment. A detailed critique of existing specifications accompanied by a proposed improved SHS specification is included in Appendix D. Note: fixing this “single system” specification would no longer make sense if the DRD redesigns the SHS program to partially subsidize SHS across a broad range of capacities (see 5.3.1 below).

*Table 6: summary of suggested revised “Option B” specifications for DRD SHS based on component capacities. See Appendix D for full version.*

| Qty | Item | Capacity | Warranty | Notes |
|---|---|---|---|---|
| 1 | Solar panel | 60 peak watts | 10 years | All inverters, charge controllers, LED lights, solar panels, and batteries must be accepted in one of the following quality control programs.<br>a. Products certified for use in a World Bank program anywhere in the world (currently Bangladesh’s IDCOL |
| 1 | Deep cycle battery | 60 Ah | 2 years | |
| 1 | Charge Controller | 10 A | 10 years | |
| 1 | LED lamp | 8 to 10 watts | 10 years | |
| 2 | LED lamps | 3 to 5 watts | 10 years | |

| Qty | Item | Capacity | Warranty | Notes |
|---|---|---|---|---|
| | | | | program and Global Lighting for plug-and-play kits).<br>b. Products having quality marks issued by other agencies should submit information on these quality marks so that DRD can decide whether they are acceptable. |
| | Wiring & installation | All wiring copper stranded. All wiring except wiring directly to lights should be least 2.5 $mm^2$. Wiring to LED lamps up to 5 watts must be at least 0.5 $mm^2$. Kits should accommodate PV-to-controller wire lengths of at least 8 meters. Outdoor wiring must be UV-resistant. | N/A | Installation consistent with "IEC 62257-9: Recommendations for small renewable energy and hybrid systems for rural electrification" |

## 5.3 Financing and subsidies

Financing and/or subsidy design has been an essential component for scale-up of off-grid electricity services in a number of programs. Broadly, these can include subsidies to buy down the cost to users of the SHS, and trade financing to installation companies to help cover cash flow challenges of expanding installation business. In an expanded program, financing and subsides may well draw on financial sources beyond those that the Myanmar government can provide, highlighting the importance of an entity that can integrate multiple funding sources (see 5.1.2 above).

### 5.3.1 Redesign DRD SHS program to reduce subsidy amount, increase sustainability

Activity: Currently DRD tenders the installation of SHS in rural areas with 100% of the cost covered by government budget and little assurances that companies will provide ongoing support. Consider redesign of DRD SHS program to reduce subsidy amount, increase customer choice, integrate with commercial sales of SHS, and enhance sustainability through mechanisms that can help ensure maintenance is performed. Subsidy programs can be designed to reduce gradually and ultimately disappear.

Reason needed: 100% give-away programs use up precious government funds quickly for dissemination of equipment that can be paid for by household cash flows from reduced expenditures on diesel and candles if customers are confident that the SHS is reliable. In international experience, 100% give-away programs have problems that users (who received the system for free) are less inclined to take very good care of the system than someone that helped paid for it. In Myanmar the high prevalence of user-purchased SHS, and the substantial savings on candles and oil lamps engendered by SHS already indicates a high willingness and ability to pay for SHS.

A fundamental redesign requires answers to a number of difficult questions:

#### *5.3.1.1 Should there be user subsidies? If so what amount?*

Bangladesh's IDCOL program, subsides were initially $90 per SHS. As of April 2014 they have been reduced to $20 per SHS and are only provided for SHS up to 20 watts. In Tanzania, an SNV/KfW program subsidizes lead-acid pico-solar kits at about $10 per watt. A South African government-financed scheme subsidizes about 80% of the cost to users. The Lighting Global program provides no subsidies to users, focusing instead on voluntary quality standards.

There are legitimate concerns that user subsidies undermine markets by creating unreasonable expectations of price, by creating selection bias between subsidized and unsubsidized products, and that when the subsidy goes away users are reluctant to invest. These concern need to be balanced against the benefits of subsidies in reaching poorer populations that would be unable to afford an unsubsidized product, and the ability of carefully implemented subsides to leverage product quality.

In order to determine what levels (if any) of user subsidies are appropriate and (if appropriate) to develop a targeted subsidy program, more research is needed on willingness to pay for SHS, on the elasticity of demand with respect to price, and whether subsides are needed to reach the targets of PV SHS usage by 2030.

#### *5.3.1.2 Should there be subsidies for market development? If so what amount?*

Subsidies for market development are subsidies directly to businesses to help pay cover the cost of marketing and setting up a presence in rural markets that otherwise would be difficult to serve commercially. Subsidized loans can also be made available to companies both for trade finance (to cover gap in cash flow between purchasing components and final sale of equipment- see 5.3.2 below) and refinancing micro-finance loans to consumers.

#### *5.3.1.3 How should specifications be designed? Fixed capacity vs. service level, or none?*

Under the current DRD program, specifications are fixed at a single system type: 80 watt PV, 65 Ah battery, 300 watt inverter, etc. This has the advantage of simplicity and standardization of components, but locks all customers into a single system size regardless of their family size and electrical needs.

One approach is to use specifications that simply set a minimum system size (20 watts PV panel is used in IDCOL's SHS program) and provide a subsidy appropriate for a system of that size (e.g. US$25 subsidy in 2012, now $20). The 20 watt system in this example must provide power for two 5 watt lamps plus a cell phone charger all for 4-5 hours of operation, and must have sufficient battery storage for 3 days reserve. Until 2012 the $25 subsidy could be applied to larger systems (50 watt, 85 watt PV). This arrangement helps ensure that poorer families (who can only afford smaller systems) receive the highest subsidy when calculated as a percentage of system cost and avoided providing higher subsidies to richer families who could afford bigger systems.

Another approach is to set specifications for service level: e.g. sustainable rainy-season operation of 3 lights each 180 lumen lights for 4 hrs/night. But leave the details of system design open (with the exception of meeting quality standards) to allow innovation (including super-efficient lights) that allows for downsizing of the solar panel and other components. While service level specifications allow more flexibility, they may be difficult to verify in the field since measuring lumen output of lamps requires special equipment, and since the measurements must be taken over a number of days to ensure that the system has sufficient storage.

If the DRD decides to eliminate subsidies entirely, it may be appropriate to have no set specifications, but rather rely on a "truth-in-advertising" type program like "Lighting Global" to provide product testing and issuance of quality certifications for solar kits purchases directly by users. Indeed, by communicating quality through a certification by a trusted organization, Lighting Global or IDCOL's list of approved products provides valuable information to all parties (DRD, installers, users) about which products are high quality.

##### *5.3.1.4 How to ensure long-term service follow-up*

Equipment breaks. In order to ensure that a failure of a single component does not cascade into the failure of the whole SHS, and in order to ensure that equipment warranties are meaningful, consideration should be paid to arrangements that ensure long-term service follow up.

In Bangladesh's IDCOL program, IDCOL operates a call center to address warranty failures. Households experiencing problems with their SHS call the center directly. Complaints lodged to IDCOL are recorded and forwarded to the installing partner organization (PO). The PO, in turn, takes remedial measures directly with the household, and IDCOL has detailed information to follow up if necessary.

### 5.3.2 Trade finance

Activity: Provide a trade finance facility to qualified solar companies. Considering delays in payment that SHS companies report in getting paid, consider a loan tenor of at least up to 6 months.

Reason needed: Solar companies face considerable cash flow challenges between wholesale equipment purchases and when they receive payment from the DRD.

## 5.4 Environmental and social

### 5.4.1 Battery recycling

Activity: More research is necessary to understand:

- whether existing informal battery recycling incentivized by the commercial value of lead in old batteries adequately ensures that SHS lead acid batteries are reliably removed from villages when they fail;
- the extent to which lead acid batteries from SHS as well as cars, trucks, motorcycles are properly recycled;
- what happens to acid from old batteries and whether it is a significant environmental hazard;
- whether recycling programs, if any, will be able to scale up in response to the increases in old batteries that will eventually be the result of expanded scale-up of SHS in Myanmar.

Research in Bangladesh suggests that informal sector recycling of SHS batteries is inadequate and that most lead from batteries is released to the environment.[15]

If it is found that the battery disposal problem is not adequately addressed, DRD may need work with township level to design programs to work with the private sector to ensure removal and responsible recycling.

Battery recycling is made more complicated if Li-ion batteries (more common in pico-solar plug & play kits) are deployed, as the techniques for lithium extraction and markets for recycled lithium are probably beyond the reach of domestic Myanmar recyclers.

Reason needed: Lead is a potent neurotoxin and it is important to ensure that discarded SHS batteries do not pollute the environment. Sulfuric acid from batteries is also a potential hazard.

## 5.5 Organizational process and institutional capacity

A variety of trainings are needed, including training for DRD (central, state, district and township levels); trainings for companies and technicians that install SHS; and trainings for SHS users.

### 5.5.1 Training for DRD

Activity: Provide targeted training to the DRD on SHS. Topics to include:

- SHS principles of operation
- Main failure modes
- Running a SHS business (cash flow, marketing, engineering)
- Quality certification
- Specific information on how quality equipment and installation can help mitigate certain failure modes.
- Designing and running a sustainable program

[15] Batteiger, Alexander 2014. "Towards a Waste Management System for Solar Home Systems in Bangladesh." Symposium UC Berkeley April 10-12. https://energypedia.info/wiki/Towards_a_Waste_Management_System_for_Solar_Home_Systems_in_Bangladesh

- How to select quality products -- incorporating experience or exposure to good quality products
- How to do better procurement
- Outreach and information to consumers
- SHS inspection and performance monitoring engineering

Reason needed: DRD is responsible for off-grid electrification but its engineering strengths lie largely in civil and mechanical engineering, and DRD staff at all levels have little specific knowledge in solar electricity. Training is needed at all levels -- central level, state level, district level, and township level.

### 5.5.2 Develop training and certification for installers of solar home systems

Activity: Identify one or more training institutions and conducting a train-the-trainer course and accreditation procedure to accredit institutions to teach a course of between 4 to 7 days on SHS focusing on the particular model(s) that are installed under the DRD program. Technicians that pass the training program would be certified to install systems that receive subsidies under an expanded DRD program.

Tasks include developing a training manual; lectures; in-class exercises; practical sessions; examinations and facilitators guide. The content would follow accepted established international curriculum for SHS installer certification.

Some candidate topics for the DRD installer training:

1. How a SHS works
2. Basic electrical units (power, voltage, current, resistance)
3. AC vs. DC -- what they are, conversion efficiency, and why DC lights and TV are better for SHS
4. Electrical consumption of different loads (LED lights, incandescent, TVs, DVDs, rice cookers, etc.)
5. What a controller does and why you shouldn't bypass it
6. How to correctly orient a solar panel and why poor orientation compromises power production.
7. Solar panels, shading, and dust
8. Battery safety
9. Maintenance and care of solar home systems
10. Solar home system vs. battery/kerosene economics
11. How to make good wire connections
    a. Splices: avoid if possible, how to do them if necessary. Avoid especially splices that will be exposed to rain and drips
    b. Connections from PV panel
    c. Connections to battery
12. Choosing proper wire sizes
13. Wire insulation – with particular focus on degredation from UV light and rain

14. Lead acid battery chemistry including discussion of sulfation and electrolysis of water component of electrolyte when fully charged
15. Deep cycle vs. car batteries and why deep cycle batteries are much more appropriate for SHS
16. What kind of labeling (e.g. brand name, country of origin, basic specs, certifications) you should expect to see on SHS components and why to avoid those with no labels.

Reason needed: All installations visited in the course of this research had shortfalls that compromise long-term safe and efficient SHS performance. These field visits indicate that the companies involved in SHS (whether participating in the DRD program or not) would benefit from systematic training of all installation technicians. In-person hands-on training helps provide rigor for certified technicians.

### 5.5.3 Library of best-practice SHS videos

Activity: Create a library of 3-10 minute videos of best SHS practices calibrated to the Myanmar context.

The content would draw from the list in 5.5.2 above. These video will have excellent graphics and be very practical and simple, concise, and interesting. Videos will be available in Burmese and other languages if appropriate. The videos would be developed and refined with using a process that coordinates with, and follows topics closely aligned with, DRD installer trainings. The process should incorporate at least one revision process to fine-tune content to the village audience.

DVDs will distributed through a number of channels, including DRD staff at all levels (NPT, state, district, township); companies involved in DRD SHS; provided to shops that sell PV SHS privately for sale at low price or given away to customers; given to NGOs involved in rural development; and other channels as appropriate. Upload videos to YouTube and Facebook. Encourage copying.

Reason needed: A video format covering the content takes advantage of the fact that DVD players and smart phones are already very common in villages, is a medium easily copied, and helps create opportunities for best practices to be widely distributed.

### 5.5.4 Training booklet & videos for village SHS users

Activity: Create a simple pictorial booklet for best SHS user practices, calibrated to the Myanmar context. This should have excellent graphics and be very practical and simple, concise, and interesting. Create channels to disseminate videos of selected topics suitable for user education (e.g. the first 10 topics in 5.5.2 above)

Consider broadcasting portions on TV channels that reach rural audiences as public service announcements, similar to a successful "wash your hands" sanitation TV campaign that ran in rural areas in the past few years.

Reasons needed: Poor understanding by system users of SHS installation, operation, and maintenance severely compromises system performance. Booklet format is familiar and useable even in unelectrified areas. A video format takes advantage of the fact that DVD players and smart phones are already very common in villages.

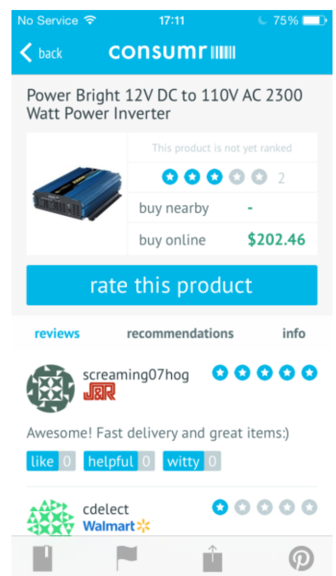
### 5.5.5 Public exposure to quality products

Activity #1: Convene or facilitate exhibitions in which manufacturers can showcase quality equipment;

Activity #2: Use multiple media channels (magazine and newspaper, internet, radio, TV, public forums) to provide information on products that pass quality standards. Recommend draw from:

- IDCOL's list of approved SHS components[16]; and
- Global Lighting's website of products that have met Lighting Global Quality Standards. [17]

Reason needed: Widespread use of reliable, affordable SHS will be more achievable if the Myanmar private sector and the general public has information about the best products available.




### 5.5.6 Provide assistance in development of business plans

Activity: Provide assistance to Myanmar companies to develop business plans.

Reason needed: Myanmar businesses involved in solar electricity may benefit from assistance in strategic planning including focus on identifying business goals and markets, identifying finance needs and options, and how to best to perform marketing.

### 5.5.7 Burmese smartphone SHS product review app

Activity: Create (if necessary) and market a Burmese-language smart-phone app for solar product review and discussion. Could be modeled after Amazon-type reviews, or "Consumr" App[18].

Reason needed: Consumers have little information at their disposal to make important decisions on solar equipment. Beyond word-of-mouth, there is no way for users to share experiences with others regarding specific SHS and solar lantern products. Smart phones are common, even in rural areas, and Facebook is particularly popular among Burmese people. The technology platform exists for transparent user-generated reviews and information about products available in the market place.

[16] http://www.idcol.org/download/260275fd02d802e8ded266af02d51ea5.pdf
[17] https://www.lightingglobal.org/products/?view=grid
[18] http://www.consumr.com/

# Appendix A: Survey form for DRD offices

1. Name of Government office:
2. Contact person:
3. Address:
4. Email:
5. Cell phone
6. Role in deployment of SHS:
7. Number of staff:
8. solar sector experience:
9. Number of solar home systems built to date in area of jurisdiction:
10. Procurement process:
11. Major issues:

## Appendix B: Survey form for village household surveys

**Field observations:**

1. Date of visit
2. Time of visit
3. Customer name:
4. Customer address:
5. Date of installation:
6. Supply company name:
7. Installation company name:
8. Total number of households in village
9. Total number of households receiving SHS
10. Non-household buildings (e.g. schools, etc.) receiving SHS
11. How was SHS allocated (if not enough)

**Customer Characterization**

12. Number in household:
13. Type of housing:
14. Education levels and occupation of main income earners:
15. Average monthly household income:
16. Is income seasonal?
17. If income is seasonal, what months? (leave blank if not seasonal)
18. How was SHS obtained?
19. Was payment required to receive SHS?
20. SHS related expenses since installation (lights, new battery, etc.)?
21. What do you do when something in the system is not working?
22. Before getting SHS -- average monthly non-heat energy expenditures:
23. Before getting SHS – for what purposes were monthly non-heat energy expenditures used?
24. After getting SHS -- average monthly non-heat energy expenditures:
25. After getting SHS – for what purposes what were monthly non-heat energy expenditures?

**Installation and operation**

26. Is the system working correctly at present?

27. Does the householder have and understood the User's Manual?
28. Is the householder adequately trained to maintain the system?
29. Is SHS used for productive purposes? (if no, skip to next section)
30. Productive use applications
31. Productive use frequency in the village
32. Owned and operated by men or women?
33. Estimate income generated.

**User Feedback and Observations:**

34. How many hours per day are three LEDs used?
35. How many hours per day are two LEDs used?
36. How many hours per day is one LED used?
37. How many LED lamps have failed?
38. How long does a typical LED lamp last?
39. How many hours per day is fluorescent tube light used?
40. How many fluorescent tube lamps have failed?
41. How long does a typical fluorescent tube light last?
42. What appliances if any are operated through the inverter?
43. How many hours per day are inverter-operated appliances are used on average?
44. How many times does the power has shut off by itself in an average in a month?
45. How many days does it remains shut off before it restarts?
46. How has life has changed due to availability of electricity
47. How did they pay for the SHS?
48. How are they paying for repairs and spare parts?
49. What do you do when something stops working?
50. How Supply and Installation Company is contacted in case of problems and how company response has been?
51. What recommendations for improvement would the consumers propose?
52. User views on solar home system?

**Technical SHS Characterization**

**Solar panel**

53. Solar panel make:

54. Solar panel model:
55. Solar panel wattage:
56. Solar panel rated Voc
57. Solar panel rated Isc
58. Solar panel rated Vmp
59. Solar panel rated Imp
60. Solar panel serial no.
61. Global Solar Radiation in the Plane of Array
62. Weather conditions
63. Ambient temperature
64. Solar panel measured Voc
65. Solar panel measured Isc
66. Mounting structure
67. Solar panel orientation
68. Solar panel tilt
69. Solar panel observations

**Battery**

70. Type of battery
71. Brand
72. Model
73. Battery rated Ah
74. Terminal Volts (no load)
75. Cell Volts (if applicable)
76. Hydrometer readings (if flooded battery)
77. Voltage loss between controller to battery
78. current flow when measuring voltage loss (above)
79. battery enclosure
80. Age of battery (months):
81. battery observations

**Light fixtures**

82. Qty of LED lamps

83. AC or DC and volts
84. LED Lamp current (amps)
85. LED voltage loss from controller or inverter
86. LED observations
87. Qty of fluorescent lamps
88. AC or DC and volts
89. Fluorescent lamp current (amps)
90. Fluorescent lamp voltage loss from controller or inverter
91. Fluorescent lamp observations

**Controller**

92. Make
93. Model
94. Rating (amperage & voltage)
95. Includes LVD?
96. Describe monitoring (LED lights, meter, etc.)
97. LVD setpoint
98. High voltage disconnect setpoint
99. Controller observations

**Inverter**

100. Make
101. Model
102. Rating (wattage)
103. inverter observations

**Outlet & wiring**

104. Number of outlets
105. Describe outlets
106. PV to controller wire size (mm2)
107. PV to controller wire length (m)
108. PV to controller wire type (e.g. stranded copper)
109. PV to controller wire insulation
110. Describe wiring penetration to house

111. controller to battery wire size (mm2)

112. controller to battery wire length (m)

113. controller to battery type (e.g. stranded copper)

114. controller to loads wire size (mm2)

115. controller to battery wire lengths (m)

116. controller to loads type (e.g. stranded copper)

117. wiring interconnection type and condition

118. wiring observations

**Usage observations**

119. Is the system installed correctly without defects?

120. Are there signs of excessive wear and tear suggesting premature failure in components?

121. Is there any indication of the consumer tampering or misusing the SHS?

# Appendix C: Survey form for SHS businesses -- Supply Sector Characterization and Assessment

SHS equipment suppliers, installers and maintenance survey questionnaire

1. Name of Company:
2. Owner (s) of the Company:
3. Address :
4. Email:
5. Cell phone:
6. Type of product/ service offered and pricing
7. Number of staff:
8. solar sector experience:
9. Other areas of work (outside of solar home systems):
10. Number of solar home systems built to date:
11. Sourcing of components
12. Amount of domestic value addition
13. Assessment of quality of products, components and user documentation
14. How sales are made?
15. volume of sales (kyat/year)
16. Sales trends
17. principal customers
18. How warranties are honored and service and spares are provided?
19. Skill level and experience of staff
20. How staff are trained?
21. Major issues in the industry and support needed for improvement

# Appendix D: Review of DRD SHS specifications

## 1 Background

The World Bank was asked to review a draft of specifications (see box 1) for solar home systems to be deployed under the FY2014-5 DRD SHS deployment. The deployment is planned to exceed 170,000 systems across 21 states/regions at an estimated to cost a total of approximately 37,000 million kyats (US$38.5 million).

*Box 2: DRD SHS specifications*

**Specification for Solar Household System(2014-2015)**

1☐ LED 3 Watt (2)No☐ 20 Watt Lamp (1) No Household System

| | | | |
|---|---|---|---|
| | | | **Limited Warranty** |
| (1) | 80-90 Watt Solar Pannel | - (1) No☐ | (5-10)Years |
| (2) | Battery 12 Volt (65) Ah | - (1) N0☐ | (1-2)Years |
| (3) | Controller (10)Ah(12V-24V) | - (1) No☐ | (5-5)Years |
| (4) | Inverter 300 Watt | - (1) No☐ | (5-5)Years |
| (5) | Cable (5)Meter | - (3) No | |
| (6) | LED 3 Watt | - (2) No | |
| (7) | 20 Watt Lamp | - (1) No | |
| | (When -TV-21"Flat LCD is ON 20Watt Lamp has to be OFF) | | |
| ( 8) | Phone Charger | - (1) No | |
| ( 9) | Total Cost | - (200000) Kyats | |

The specifications as written carry high risk of installation of solar home systems that perform poorly in the long run due to improper design, improper installation, poor quality components and materials, or combinations of all three.

The specifications should be improved considerably in two key areas.

1. Provide more detailed specifications to ensure quality: the specifications as written should contain more information ensure quality from bidders.
2. System redesign to eliminate inverter: reliability and performance will be improved considerably at zero or minimal cost increase by specifying efficient and reliable 12-volt DC loads (LED lights, LED TV) thus enabling removal of the inverter entirely from the system. This, in turn, provides much more cushion for the solar panel to perform in suboptimal conditions (shading and dust encountered in villages). Already most SHS companies encountered are providing DC LED lights, so in some ways the inverter is

already redundant. Money saved by removal of inverter should be used to focus on quality components and quality installation including more attention to wiring.

This review is informed by experiences of a similar solar home system deployment by the Thai government in 2004-5[19]; procedures and standards followed in Bangladesh's successful IDCOL SHS deployment[20], and simple Excel-based modeling of the DRD system design to validate panel and battery size considering loads and reasonable assumptions for solar insolation. Section 2 of this review discusses the existing DRD SHS specifications line by line, identifying specifications that should be added or refined to improve quality and improve chances of long-term sustainable operation of the solar home systems. Section 3 presents a proposed improved set of specifications which copies text liberally from the Bangladesh IDCOL "TSC Standards" document[21] with modifications to the Myanmar context.

# 2 Discussion of specifications[22]

## 2.1 System design revision

We used an excel spreadsheet (embedded below in Table 7 below) to check solar panel wattage and battery capacity. We assumed a single 9 watt LED light is used 3 hours per night, and two 3 Watt LED lights are used 5 hours per night, and the TV and cell phone charger are used 1 and 2.5 hours per day respectively. Based on measurements in the field of actual short circuit current compared to rated short circuit current, it appears that existing DRD SHS mostly use modules that substantially underperform. Therefore, in modeling these systems we derated the PV module substantially, assuming it only puts out 60% of its power. This may still be too favorable, since most panels encountered in the field actually produced less than 50% of rated current.

[19] Threatened Sustainability: the Uncertain Future of Thailand's Solar Home Systems. Andrew Lynch, Chris Greacen, Salinee Tavaranan, Fredrik Bjarnegard. Paper commissioned by EU. 6 June 2006. http://www.palangthai.org/docs/SHSReport6June06.doc

[20] http://www.idcol.org/home/downloads

[21] http://www.idcol.org/download/a86508e6f1ecc4bf3ac0f1c8ed6038cb.pdf

[22] The first line: "1 LED 3 Watt (2)No 20 Watt Lamp (1) No Household System" is confusing as the quantities appear to contradict quantities in later sections of the specifications. For example this line appears to indicate one LED, but line 6 of the specification indicates two. In the remainder of this document we assume that that this line is incorrect and loads are as specified in lines 6, 7 and 8.

*Table 7: spreadsheet model of DRD SHS design assuming 80 watt solar panel and inverter*

| Qty | Load | Watts each | Watts total | Hours per day | Watt hours |
|---|---|---|---|---|---|
| 1 | LED 9w | 9 | 9 | 3 | 27 |
| 2 | LED 3w | 3 | 6 | 5 | 30 |
| 1 | tv (12 inch with DVD) | 18 | 18 | 1 | 18 |
| 1 | cell phone charger | 5 | 5 | 2.5 | 12.5 |
| | Totals | | 33 | | 87.5 |
| | | | | | |
| Battery efficiency | | 85% | | | |
| Wiring efficiency | | 97% | | | |
| Inverter efficiency (85%. If no inverter: 100%) | | 85% | | | |
| Battery, wiring & inverter total efficiency | | 70.1% | | | |
| Total adjusted watt hours per day | | | | | 125 |
| Nominal system voltage | | | | | 12 |
| Adjusted amp-hours per day | | | | | 10.40 |
| Peak Sun Hours | | | | | 3.99 |
| Amps of solar power required | | | | | **2.61** |
| Rated Imp (amps) per solar panel (80 watt: Imp = 4.5) | | | | | 4.50 |
| Solar panel derating | | | | | 60% |
| Realistic Imp | | | | | 2.70 |
| **Number of solar panels** | | | | | 0.97 |
| Rounded up… | | | | | 1 |
| Isc per panel | | | | | 5.06 |
| **Minimum controller current (amps) = 1.2 x Isc** | | | | | 6.07 |
| Maximum number of days of autonomy | | | | | 3 |
| Max allowable depth of discharge | | | | | 0.5 |
| **Battery ampere-hours** | | | | | 62 |

Based on this analysis:

- A substantial revision will provide improved reliability, more efficiently, at lower cost. Switching to 12-volt LED lighting only and using an efficient 12 volt LED TV allows the system to eliminate the inverter and therefore use a smaller solar panel (60 watts) and somewhat smaller battery (55 Ah). To build in a certain amount of over-sizing to account for dust, unavoidable shading, and possible extended cloudy periods encountered in villages, we derated the PV modules to 70% of rated output. Please see Table 8 below.

*Table 8: spreadsheet model of improved design with no inverter and 50 watt solar panel.*

| Qty | Load | Watts each | Watts total | Hours per day | Watt hours |
|---|---|---|---|---|---|
| 1 | LED 9w | 9 | 9 | 3 | 27 |
| 2 | LED 3w | 3 | 6 | 5 | 30 |
| 1 | tv (12 inch with DVD) | 18 | 18 | 1 | 18 |
| 1 | cell phone charger | 5 | 5 | 2.5 | 12.5 |
| | Totals | | 33 | | 87.5 |
| | | | | | |
| Battery efficiency | | 85% | | | |
| Wiring efficiency | | 97% | | | |
| Inverter efficiency (85%. If no inverter: 100%) | | 100% | | | |
| Total efficiency | | 82.5% | | | |
| Total adjusted watt hours per day | | | | | 106 |
| Nominal system voltage | | | | | 12 |
| Adjusted amp-hours per day | | | | | 8.84 |
| Peak Sun Hours | | | | | 3.99 |
| Amps of solar power required | | | | | **2.22** |
| Rated Imp (amps) per solar panel (60 watt: Imp = 3.46) | | | | | 3.46 |
| Solar panel derating | | | | | 70% |
| Realistic Imp | | | | | 2.42 |
| **Number of solar panels** | | | | | 0.92 |
| Rounded up… | | | | | 1 |
| Isc per panel | | | | | 5.06 |
| **Minimum controller current (amps) = 1.2 x Isc** | | | | | 6.07 |
| Maximum number of days of autonomy | | | | | 3 |
| Max allowable depth of discharge | | | | | 0.5 |
| **Battery ampere-hours** | | | | | 53 |

## 2.2 Solar panel

*Box 3: DRD solar panel specifications (exactly as written in DRD specifications)*

(1) 80-90 Watt Solar Pannel - (1) No☐ (5-10)Years

As discussed above, if system redesign can be accommodated by using LED lights and LED TV and eliminating the inverter the solar panel can be downsized to 60 watts with no loss in performance.

Five years warranty for a solar panel is far too low. While 10 years is acceptable, it should be noted that warrantees for solar panels in USA and Europe are typically 10 years for materials and workmanship and 20 to 25-year for power performance.
In addition to solar panel size and warranty, the section of the specifications for solar module should include information about the module mounting structure, hardware used, mounting angle, and directions on suitable locations for mounting module. Candidate text copied from the Bangladesh IDCOL specifications are included in suggested revised specifications in Part 3.
Specifications should require PV panels that are either built to IEC standards (IEC 61215 certification for crystalline modules and IEC 61646 for thin-film modules) or are built in a facility that makes modules that pass these standards. According to the US National Renewable Energy Laboratory, "Modules that pass these qualification tests are much more likely to survive in the field and not have design flaws that lead to infant mortality"[23]. If an IEC 61215 or 61646 certified module is not available then at the least the manufacturer should provide a manufacturer's compliance certification which states that a larger IEC-certified module is built using same materials at same production line (with ISO 9001 certification).

Also acceptable would be to specify that if the product/component is already accepted for use in an existing World-Bank-financed project, such as Bangladesh RERED, it can be sufficient certification. Bangladesh has published such a list.[24]

Not requiring modules with these qualifications will likely mean that Myanmar's SHS are built with low-quality substandard modules that may fail within 10 years or less. Please see part 3 of this document for suggested revisions.

## 2.3 Battery

*Box 4: DRD battery specifications*

| | | | |
|---|---|---|---|
| Battery 12 Volt (65) Ah | - | (1) N0☐ | (1-2)Years |

As discussed above, we recommend a downsized system with LED lights/TV and no inverter – allowing a 55 Ah battery to provide up to 3 days of autonomy. IDCOL in Bangladesh requires 2 days of autonomy.[25]

Batteries are often the weak link in a solar home system and it is essential to have good quality. Ideally these should be type-tested in a local laboratory as is done in Bangladesh.[26] If these batteries are available in Myanmar, it might be worthwhile considering simply adopting the portion of this list that has batteries between 50 to 60 Ah.

[23] http://www.nrel.gov/docs/fy12osti/54714.pdf
[24] http://www.idcol.org/home/downloads/solar.
[25] See section 1.2 of http://www.idcol.org/download/a86508e6f1ecc4bf3ac0f1c8ed6038cb.pdf
[26] See http://www.idcol.org/download/260275fd02d802e8ded266af02d51ea5.pdf for a list of approved batteries in Bangladesh.

Also, the battery warranty period (1 to 2 years) is low compared to Bangladesh (5 years). Bangladesh requires tubular plate deep cycle batteries, and they have performance well and their 5-year warranties are honored. If local batteries are used, these should be tested following the procedure outlined in Appendix B.
Please see part 3 of this document for suggested revisions.

## 2.4 Controller

*Box 5: DRD battery specifications*

| |
|---|
| Controller (10)Ah(12V-24V) - (1) No☐ (5-5)Years |

The controller is measured in amperes (A), not ampere-hours (Ah). The redesigned system suggested in part 1 could save some money by using a smaller controller with current maximum of only 5 A (although 10 A will also work).[27] Since the SHS system has a 12 volt nominal system voltage, there is no need for 12/24 volt controller – one with 12 V functionality alone is sufficient.

Controllers used in this program must include both a high and low voltage disconnect function to protect against excessive battery charge and discharge. Specifications should include specifications for voltage settings, low voltage disconnect settings and amperage, and protection against reverse polarity and lightning.

Controllers are a very important, not very costly, and easily imported component. For this reason, consider requiring controllers that have been either type-tested in the Bangladesh SHS program[28] or that can demonstrate compliance with PV GAP specifications.[29]
Please see part 3 of this document for suggested revisions.

## 2.5 Inverter

*Box 6: DRD inverter specifications*

| |
|---|
| Inverter 300 Watt - (1) No☐ (5-5)Years |

Please consider removing the requirement for an inverter for the following reasons:

- **12 volt loads including efficient LED lamps and LED TVs are widely available:** quality LED lamps are widely available designed for 12-volt operation. If the intention of the inverter is to power a TV, consider that 12 volt LED TVs are widely available and reliable. Efficiency of 12-volt TVs are higher and electronic noise (buzz) lower than AC TVs. A 15.6” LED TV that won the Global LEAP

[27] using criteria that controller current should be 1.25 times Isc
[28] See extensive list at http://www.idcol.org/download/260275fd02d802e8ded266af02d51ea5.pdf
[29] http://www.iecee.org/pv/pvrs/PVRS6A.pdf

competition costs less than $100 and consumes only 5.5 watts. This is available from a Thai company very interested in exporting to Myamar.[30] LED “laptop” TV/DVD players with screen sizes 11 to 12 inches appear to be widely available in rural Myanmar markets already imported from China or Thailand.

- **reliability:** inverters fail (water intrusion, insects, lightning damage, reverse polarity, etc). If the system relies on an inverter to provide AC power for lights, then the failure of the inverter means that the house is without functioning lights.
- **safety:** electricity from inverters at 230 volts can shock and kill. 12-volt electricity has insufficient voltage to electrocute.
- **energy savings benefits**: inverters are typically around 90% efficient when operating near full load, with lower efficiencies at low loads. Even with no load, inverters consume substantial idle current. Removing the inverter from the system effectively provides an increase of 10% or more of end-use electricity, allowing the same services to be provided with smaller PV module and battery size.
- **cost savings (possible):** removing inverter may lower costs, even after possibly higher cost of 12-volt lighting.
- **users may still add their own inverter if they choose to:** by providing a 12-volt receptacle (see section 2.6 below), users may plug in their own inverter if they chose to.

If the inverter is removed, then all remaining devices, switches, and wires must reflect this choice.

Please see part 3 of this document for suggested revisions to the text.

## 2.6 Cable

*Box 7: DRD wire specifications*

| | | |
|---|---|---|
| Cable (5)Meter | - | (3) No |

Correct choice of wire size and quality installation of wiring is absolutely essential for efficient operation of the solar home system. The section on wiring should include discussion of acceptable voltage drop (4% per circuit), wire type, wire lengths, and wire connection practices. Wiring of a 12 volt receptacle should be included as well.

DRD may wish to consider requiring that installation, including all wiring, should be completed following recommendations in 62257-9-6 Part 9-6: *Selection of Photovoltaic Individual Electrification Systems (PV-IES*). Please see part 3 of this document for suggested revisions.

[30] http://www.fosera.com/products/power-line/tv.html

## 2.7 LED light

*Box 8: DRD LED light specifications*

| LED 3 Watt - (2) No |
|---|

The LED light specification should specify minimum efficiency, voltage range, and warranty. LED lights should have passed the Global Lighting minimum requirements[31], or better, won the Global LEAP awards.[32]

Having high quality LEDs is essential, as it helps ensure that the LED will provide efficient lighting for years in service. These will be somewhat more expensive, but more than make up for the higher price by lasting many times as long.

Please see part 3 of this document for suggested revisions.

## 2.8 20 watt fluorescent light

*Box 9: DRD 20 watt fluorescent light specifications*

| 20 Watt Lamp - (1) No |
|---|
| (When -TV-21"Flat LCD is ON 20Watt Lamp has to be OFF) |

The 12-volt 20 watt cfl should be replaced with a 12-volt 8-10 watt LED lamp. LED lights are considerably more efficient and have longer lifetimes. The specifications should indicate efficiency and warranty period. These are already used in some DRD SHS in Myanmar. See remarks in 2.7 above.

Please see part 3 of this document for suggested revisions.

## 2.9 Phone charger

*Box 10: DRD 20 watt fluorescent light specifications*

| ( 8) Phone Charger - (1) No |
|---|

We suggest this be deleted – phone charger with appropriate phone-charging interface should be purchased by user and plugged into the SHS 12-volt outlet. Or, better, the system specification should require a USB port.

---

31 https://www.lightingglobal.org/activities/qa/standards/
32 http://www.cleanenergyministerial.org/Portals/2/pdfs/LEAP_Awards_2014BuyersGuide.pdf

### 2.10 Installation standards

Consider requiring that installation should follow the appropriate portions of IEC 62257-9: Recommendations for small renewable energy and hybrid systems for rural electrification.

### 2.11 Overall system warranty

The specifications should include a system warranty that covers installation and workmanship. This warranty is in addition to the equipment warranties of various components. Bangladesh has a six months warranty against manufacturers' defects on all system-integrated parts and labor excluding fuses or end-use devices such as luminaries or lamps and seems a good choice for Myanmar. Thailand's SHS had a 2-year system warranty, but it was seldom enforced. In order to ensure warranty compliance, there should be a mechanism, such as a performance guarantee backed by a Bank Guarantee. If there is evidence that the warranty is not being honored, the performance guarantee is triggered resulting in money owed to the bank.

Each system installed should include a warranty card and an operator manual delivered to the householder at the time of installation with the warranty claim procedure explained. A simple example warranty card example from Thailand is shown in Appendix A.

### 2.12 User's manual

At the occasion of commissioning, each household receiving a SHSs should receive an illustrated user's manual to enable them to perform basic maintenance and understand capabilities and limitations of the system. Installer should explain these issues verbally with householder upon final inspection and commissioning of the installation. Details about what the manual should cover are discussed in section 3 below.

### 2.13 Total cost

*Box 11: DRD requirement for total cost*

| |
|---|
| ( 9) Total Cost - (200000) Kyats |

A price cap can be set, but considering the requirements discussed in this review the price may rise to more than 200,000 kyats.

## 3 Candidate revised specification for solar home systems (2014-5)

### 3.1 Preamble

The following specifications are for solar home systems (SHS) deployed under the DRD SHS program for fiscal year 2014-5. The system is designed to provide reliable electricity for two small LED lights (>240 lumens each) for five hours per day; one large LED light (800 lumens or more) for 3 hours per day; one LED TV (12 watts, 20 inch) two hours per day; and one cell phone charger 2.5 hours per day. The specifications include important quality certifications that help ensure that equipment is of good quality and will not fail prematurely.

## 3.2 solar module

i. The solar home system should include one (1) module of certified rated capacity of at least 60 watt (peak).

ii. The following are applicable standards for PV modules:

- International Electrotechnical Committee (IEC) 61215: Crystalline Silicon Terrestrial PV Modules Design Qualification and Type Approval
- IEC 61646: Thin Film Silicon Terrestrial PV Modules Design Qualification and Type Approval IEC 60904-1: Photovoltaic Devices Part 1 Measurement of PV Current-Voltage Characteristics
- Institute of Electrical and Electronics Engineers (IEEE) 1262: Recommended Practice for Qualification of Photovoltaic Modules
- PV Global Approval Program (PV GAP) recommended standards are preferred.
- If the chosen module is not IEC 61215 or 61646 certified, then in lieu of IEC 61215 or 61646 certification the manufacturer may provide a manufacturer's compliance certification which states that the proposed module comes from a factory that manufactures a larger IEC 61215- or 61646-certified module and is using same materials at same production line (with ISO 9001 certification).

iii. Also acceptable is proof that the product/component is already accepted for use in an existing World-Bank-financed project, such as Bangladesh RERED. See http://www.idcol.org/download/260275fd02d802e8ded266af02d51ea5.pdf. The module should carry at least a 10-year warranty performance warranty which states that if power output drops to less than 90% of rated output, the module will be replaced with a module of equal or higher capacity, at no cost to the owner.

iv. Each module must be labeled indicating at a minimum: Manufacturer, Model Number, Serial Number, Peak Watt Rating, Voltage and Current at peak power, Open Circuit Voltage and Short Circuit Current of each module.

v. The module must ensure waterproof sealing for the solar cells. Module must be framed in such a way as to allow secure connection to the module mounting structure.

vi. Each module must be factory equipped with weatherproof junction box with terminal strip that allows safe and long lasting wiring connection to the module.

vii. The mounting structure will hold the photovoltaic module(s). The module(s) must be mounted on a support structure made of corrosion resistant material that assures stable and secure attachment.

viii. The structure must be mounted at a fixed angle and oriented to maximize the useful energy supplied to the user over the year (for Myanmar, the panel should be facing south with a tilt angle measured from horizontal equal to the latitude of the installation location (+/- 5 degrees).

ix. The structure will incorporate corrosion resistant hardware for all external connections.

x. The modules can be roof or ground-mounted: In case of roof-mounted modules, minimum clearance between the PV module and the roofing material must be at least 20 cm. For pole mounted modules it is recommended that the module mounting structure be supported on top of a pole of at least 5m height. The mounting structure must be anchored to the building and not to the roofing material. For ground-mounted modules, a metal, concrete or treated wood pole must be used with the modules to be placed at the top of the pole. The modules must be at least 4 meters off the ground and the pole must be anchored in concrete or tightly packed soil at least one meter deep in the ground. The pole and mounting structure must be sufficiently rigid to prevent twisting by the wind or if large birds alight on the module.

xi. The panel should be mounted clear of vegetation, trees and structure so as to assure that they are free of shadow throughout day light hours during each season of the year.

## 3.3 Battery

i. The SHS shall include a single 12-volt battery of capacity 50 to 60 Ah.
ii. The battery shall either be on the list of approved batteries from the IDCOL program in Bangladesh, or must pass the Interim Battery Acceptance Short Test Procedure (below).
iii. The battery shall have a 5-year limited warranty:
    a. Battery capacity will not be less than 80 percent of the rated capacity over the period for 5 years for systems. Cycle life of the battery (i.e., before its residual life drops below 80 percent of the rated AH capacity), at 25 degree C must exceed 1500 cycles when discharged down to an average depth of discharge (DOD) of 70 percent at the discharge rate of 10 hours.
    b. The maximum permissible self-discharge rate is 5 percent of rated capacity per month at 25 deg C.
iv. The battery must be housed in a vented compartment. All parts of the compartment subject to battery acid contact must be acid resistant. This compartment must be built strong enough to accommodate the weight of the battery. Access to the battery compartment by children must be prevented.

## 3.4 Controller

i. The SHS shall include a charge controller with both high and low voltage disconnect functions.
ii. The charge controller input current rating must be greater than 120% of the module's rated short circuit current.
iii. Controller shall either be able to demonstrate compliance with PV GAP PVRS 6A (http://www.iecee.org/pv/pvrs/PVRS6A.pdf ) recommended specifications for controllers; or have been type-tested to comply with the IDCOL controller requirements (http://www.idcol.org/download/260275fd02d802e8ded266af02d51ea5.pdf), or has been qualified for use in Bangaldesh RERED Project
iv. The charge controller set points must be factory preset with the set points applicable to the specified battery characteristics.
v. Charge Controllers should be dust and insect proof.
vi. Maximum current draw of the controller, when no indicator LEDs are lit should not exceed 20 mA and 50 mA with LED.
vii. The model number, serial number, rated voltages and currents, and set points should be printed on the visible side of the charge controller casing.

viii. Battery, high voltage disconnect 14.3±0.2 volts (for lead acid batteries), or as specified by the manufacturer. Charge controller specifications must include the type of the battery to be used with it.

ix. Reverse current leakage protection is recommended using logic-derived methods.

x. The SHS must be protected against damage caused by short circuit at panel terminals and load terminals when battery is connected to the charge controller, and reverse polarity of battery or panel connections. Over-current protection must be provided. Lightning induced surge protection is recommended.

xi. The load must be controlled by a low voltage disconnect (LVD) device. The LVD must be capable of handling at least 150 percent of the maximum expected continuous load (e.g., assuming all end use devices are simultaneously on). It should be factory preset to disconnect and reconnect voltages corresponding to the safe operation of the battery under ambient temperature conditions. For example, for a lead acid battery, a disconnect voltage of 11.6 Vdc +/- 0.1 Vdc and reconnect voltage of 12.6 Vdc +/- 0.2 Vdc is required.

xii. Each charge controller should be capable of handling at least 120 percent of the rated current at PV, battery and load terminals for at least for 1 hour without being damaged. Overload of Charge Controller will be the actual current that exceeds 120% of the rated current.

xiii. Charge Controller should be capable of withstanding 25V at PV terminal when battery and load is disconnected.

xiv. The technical specification of the charge controller must mention the input voltage range (PV panel side), input current (PV panel side), battery nominal voltage, LVD and HVD, rated output current (load side). The panel must have reverse polarity protection, output short circuit and over load protection.

xv. Efficiency of the charge controller should be at least 90%.

xvi. Warranty: Charge controller or energy meter should be replaced in case of any performance deviation from the specifications mentioned above over the period of 5 years.

## 3.5 Inverter

Strongly consider removing inverter requirement as discussed in section 2.5.

(If DRD feels it is essential to keep the inverter, then use these specifications:

i. SHS shall include 300 watt inverter

ii. Modified sine wave or better AC output at 240 V and nominal 50 Hz is required.

iii. Efficiency of the inverter shall be at least 90%.

iv. Inverter shall be include short-circuit and overload protection and be protected from dust and insects.

v. Inverters should comply with PVGAP specifications.

## 3.6 Wiring

Wiring practices include the following:

i. Stranded and flexible insulated copper wiring must be used. Sample of wires for the sub circuits are as follows:

- From PV module to Charge controller : 2.5 sq. mm
- From Charge Controller to battery: 2.5 sq. mm
- From Charge Controller to socket outlet : 2.5 sq. mm
- From Charge Controller to all other loads (e.g. lights) : 0.5 sq. mm.

ii. Wiring should be sufficient to allow installation of solar panel within 8: meters of controller. Wiring to lights should allow for installation of lights in separate rooms up to 8 meters from controller.
iii. Each light must have a separate switch
iv. All wiring must be sized to keep line voltage losses to less than 3% including each sub-circuit and to allow the circuit to operate within the rating of the wire. Cables used for wiring must have three years of warranty.
v. For SHS permanently installed on a structure, all exposed wiring (with exception of the module interconnects) must be in conduit or be firmly fastened to the building structure. Wiring through roofing, walls and other structures must be protected through the use of bushings. Wiring through roofing must form a waterproof seal.
vi. Field-installed wiring must be joined using terminal strips or screw connectors. Soldering or crimping in the field must be avoided if at all possible. Wire nuts are not allowed. The rated current carrying capacity of the joint must not be less than the circuit current rating. All connections must be made in junction boxes. Fittings for lights, switches, and socket outlets may be used as junction boxes where practical.
vii. A 12 Vdc socket outlet should be installed for a radio/CD player, TV or similar appliance and must be rated to carry at least 5 amperes of DC current.
viii. A USB port should be provided that is compatible with USB Battery Charging standards.[33]

## 3.7 LED light

i. The SHS must have two 3-watt LEDs and one LED of 8 to 10 watts, each controlled by a separate wall-mounted switch. The larger lamp must provide area lighting.
ii. LED lights used shall have passed Lighting Global (https://www.lightingglobal.org/activities/qa/testmethods/) minimum requirements or, better, have been chosen as winners in the Global LEAP awards.
iii. Minimum lumen output of LED Lamp/lantern should be 80 lumen/watt.
iv. LED should have 3 year warranty, and should provide minimum 80% of the initial lumen output after 3 years (or 5000 hours considering the lower value of usage).
v. Color of LED light must be white.
vi. Over the input voltage range of 11.6-14.4 V, input power of the LEDs must not vary by more than 15% of the rated power.
vii. Fixed LED lamp/lantern should not be placed at a height more 8 feet from the ground.
viii. Temperature of the heat sink of the driver circuit of the LED luminaries should be tested and at still air condition, increase in temperature of the heat sink should not be more than 20 Degree Celsius after one hour operation.

## 3.8 Installation standards

i. Consider requiring that installation should follow appropriate portions of "IEC 62257-9: Recommendations for small renewable energy and hybrid systems for rural electrification".

[33] http://en.wikipedia.org/wiki/USB#Mobile_device_charger_standards

## 3.9 Overall system warranty

i. Each SHS should have a six-month overall system warranty against manufacturers' defects on all system-integrated parts and labor excluding end-use devices such as lamps.

## 3.10 User manual

i. The solar home system (SHS) supplier must provide a User's Manual intended for the customers and will be included with each of the packaged systems.

ii. The manual must be in Burmese. Sketches or graphics should be used to make the manual easy to understand.

iii. The manual should include the following:

a. How the SHS works: battery charging by the array, functions, battery low voltage protection, and battery overcharge protection. The relationship between energy available on a daily basis and sunlight conditions should be clearly and simply explained.

b. A description of all user interactive hardware including disconnect switches and status indicators.

c. Procedures for proper system operation, including a list of load limitations and any problem loads. These procedures should include suggested operation, including load conservation during periods of inclement weather, and/or a low voltage disconnect event. The adverse effect of panel shading and the importance of preventing it must be explained.

d. Basic maintenance to be done by user.

e. Any user maintenance items.

f. Emergency shut down procedures and recommendations for extended periods of system non-use.

g. A user trouble-shooting guide.

h. A block diagram showing the main components.

i. Name address and telephone number of dealer/ supplier who is responsible for warranty and service claims

j. Name address and telephone number of DRD Office to be contacted if dealer/supplier does not meet its obligations.

## 3.11 Qualified products.

i. All inverters, charge controllers, LED lights, solar panels, and batteries must be accepted in one of the following quality control programs.

a. Products certified for use in a World Bank program anywhere in the world.

b. Products with a valid Golden Sun Quality Mark issued by CQC China.

c. PVGAP Quality Mark issued by IECEE.

d. Products having quality marks issued by other agencies should submit information on these quality marks so that DRD can decide whether they are acceptable.

## Appendix E: Sample warranty card

**SOLAR HOME SYSTEM WARRANTY CLAIM**

**DATE CLAIM FILED:**

**CLAIM FILED BY:**

**Claimant Information**

Date Claim Info Collected:

Name and Last Name:

Address Number:

Village:

Ward:

State / District:

Further Claimant Information:

**Product Information**

| **Malfunctioning System Component(s):** | **Serial Number** | **Brief Description of Problem** |
| --- | --- | --- |
| **1)** | | |
| **2)** | | |
| **3)** | | |

| **CLAIM SENT TO:** | **CLAIM REPORT COPIED TO:** | |
|---|---|---|
| Attn: (name of appropriate official) | Attn: (name) | Attn: (name) |
| (Institution) | (Institution) | (Institution) |
| (Address), | (Address), | (Address), |
| (City, State, Code) | (City, State, Code) | (City, State, Code) |
| Tel: | Tel: | Tel: |
| Fax: | Fax: | Fax: |

## Appendix F: Interim Battery Acceptance Short Test Procedure

Perform the test sequence as given below in Table 1 while maintaining the battery temperature between 20-25 deg C.[34] The tests must be conducted on 3 batteries that are randomly selected, at a testing center acceptable to the PMO. Record the data in Table 2. If the test results vary by more than 10% of each other, for the three batteries, an additional two batteries should be tested to achieve better statistical significance. This test will take approximately 17 days to perform using automatic battery testing equipment.

**Table 1 Interim Battery Acceptance Short Test Procedure**

| Capacity Test No. | Step | Current/voltage Setting | Current/voltage Limit | End-of-step Criteria | Remarks |
|---|---|---|---|---|---|
| | Initial charge | + $I_{10}$ | | U=2.4 V/cell | Constant current charging |
| | Initial charge | 2.4 V/cell | + $I_{10}$ | Duration 8 hours | Constant voltage charging. |
| 1. C10 Test | 1st discharge | -$I_{10}$ | | U<1.8 V/cell | |
| | Rest Period | 0 A | | I hour | Battery on open circuit |
| | 1st recharge | + $I_{10}$ | | U=2.4 V/cell | Constant current charging |
| | 1st recharge | 2.4 V/cell | + $I_{10}$ | Duration 8 hours | Constant voltage charging. |
| 2. C10 Test | 2nd discharge | -$I_{10}$ | | U<1.8 V/cell | |
| | Rest Period | 0 A | | I hour | Battery on open circuit |
| | 2nd recharge | + $I_{10}$ | | U=2.4 V/cell | Constant current charging |
| | 2nd recharge | 2.4 V/cell | + $I_{10}$ | Duration 8 hours | Constant voltage charging |
| 3. C10 Test | 3rd discharge | -$I_{10}$ | | U<1.8 V/cell | |
| | Rest Period | 0 A | | I hour | Battery on open circuit |
| | 3rd recharge | + $I_{10}$ | | U=2.4 V/cell | Constant current charging |
| | 3rd recharge | 2.4 V/cell | + $I_{10}$ | Duration 8 hours | Constant voltage charging |
| 4. C10 Test | 4th discharge | -$I_{10}$ | | U<1.8 V/cell | |
| | 4th recharge | + $I_{10}$ | | U=2.4 V/cell | Constant current charging |
| | 4th recharge | 2.4 V/cell | + $I_{10}$ | Gradient of current is 0 A/s, but maximum 36 hours[35] | Constant voltage charging |
| *Alternative for 4th recharge depending on availability of equipment* | | | | | |
| | *4th recharge* | *+ $I_{10}$* | | *U=2.4 V/cell* | *Constant current charging* |
| | *4th recharge* | *2.4 V/cell* | *+ $I_{10}$* | *$I < 0.1 \times I_{10}$* | *Constant voltage charging* |
| | *4th recharge* | *$0.1 \times I_{10}$* | | *Capacity charged in 4th recharge > 112% of capacity discharged during 4th discharge* | |
| 5. $C_{10}$ Test | 5th discharge | -$I_{10}$ | | U<1.8 V/cell | |
| | Rest Period | 0 A | | I hour | Battery on open circuit |
| | 5th recharge | + $I_{10}$ | | U=2.4 V/cell | Constant current charging |
| | 5th recharge | 2.4 V/cell | + $I_{10}$ | Duration 8 hours | Constant voltage charging |

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[34] Depending on the battery temperature (or ambient temperature in the laboratory during the tests) a correction of the capacity is necessary if the temperature deviates by more than 3 deg Kelvin from 25°C. A correction factor of 0.6% per Kelvin is commonly used (see formula below). The formula can be applied for temperatures between 10 and 35°C. The pass criteria must be fulfilled for the temperature corrected values.

$$C_{10}^{25°C} = \frac{C_{10}^{T_{measured}}}{1+0.006\cdot(T_{measured}-25°C)}$$

[35] Note that the end of the constant voltage charging is reached only when the battery current has not changed for two hours. If this criterion has not been reached after 36 hours of the charging process, continue with the next step of the test procedure.

| Table 1 Interim Battery Acceptance Short Test Procedure | | | | | |
|---|---|---|---|---|---|
| **Capacity Test No.** | **Step** | **Current/voltage Setting** | **Current/voltage Limit** | **End-of-step Criteria** | **Remarks** |
| | 6. $C_{20}$ discharge | -0.5 x $I_{10}$ | | U< 1.8 V/cell | |
| | Rest Period | 0 A | | I hour | Battery on open circuit |
| | 6th recharge | + $I_{10}$ | | U=2.4 V/cell | Constant current charging |
| | 6th recharge | 2.4 V/cell | + $I_{10}$ | Duration 8 hours | Constant voltage charging |
| | 7. $C_{100}$ discharge | -0.1 x $I_{10}$ | | U< 1.8 V/cell | |
| | Rest Period | 0 A | | I hour | Battery on open circuit |
| | 7th recharge | + $I_{10}$ | | U=2.4 V/cell | Constant current charging |
| | 7th recharge | 2.4 V/cell | + $I_{10}$ | Duration 8 hours | Constant voltage charging |
| | 8. $C_5$ discharge | -2 x $I_{10}$ | | U< 1.8 V/cell | |
| | Rest Period | 0 A | | I hour | Battery on open circuit |
| | 8th recharge | + $I_{10}$ | | U=2.4 V/cell | Constant current charging |
| | 8th recharge | 2.4 V/cell | + $I_{10}$ | Duration 8 hours | Constant voltage charging |
| 6. $C_{10}$ Test | 9th discharge | - $I_{10}$ | | U< 1.8 V/cell | |
| | Rest Period | 0 A | | 1 hour | Battery on open circuit |
| | 9th recharge | + $I_{10}$ | | U=2.4 V/cell | Constant current charging |
| | 9th recharge | 2.4 V/cell | + $I_{10}$ | Duration 8 hours | Constant voltage charging |

| TABLE 2 Interim Battery Acceptance Short Test | | | | | | | |
|---|---|---|---|---|---|---|---|
| Battery Company: | | Brand & Model Number: | | Samples obtained from: | | | |
| Battery type: (Select type) | | Battery rated voltage: | | Date Samples collected: | | | |
| For Flooded battery: Select one: | □ Battery filled onsite<br>□ Battery obtained fully charged | Nominal Ah Rating: C20 | | Nominal Ah Rating C10 | | | |
| Testing Period: Start/end dates | | Testing Engineer: | | Approved by: | | | |
| No. of samples. | | Signature & Date: | | Signature & Date: | | | |
| Discharge Capacity Test | Discharging Current (A) | End-of-Discharge Voltage (V/cell) | Battery Temperature (deg C) | Measured & Corrected Capacity[36] (Ah) | | | Pass Criteria |
| | | | | Average | Max | Min | |
| 1. $C_{10}$ Test | 1 x $I_{10}$ = | | | | | | |
| 2. $C_{10}$ Test | 1 x $I_{10}$ = | | | | | | |

[36] Depending on the battery temperature (or ambient temperature in the laboratory during the tests) a correction of the capacity is necessary if the temperature deviates by more than 3 degrees from 25°C. A correction factor of 0.6% per degree is commonly used (see formula below). The formula is valid for temperatures between 10 and 35°C. The pass criteria must be fulfilled for the temperature corrected values. The capacity correction is as follows:

$$C_{10}^{25^\circ C} = \frac{C_{10}^{T_{measured}}}{1 + 0.006 \cdot (T_{measured} - 25^\circ C)}$$

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 3.1 $C_{10}$ Test | 1 x $I_{10}$ = | | | | | | |
| 4 $C_{10}$ Test | 1 x $I_{10}$ = | | | | | | |
| 5. $C_{10}$ Test | 1 x $I_{10}$ = | | | | | | Measure Capacity ≥ 100% Nominal Capacity |
| $C_{20}$ Test | 0.5 x $I_{10}$ = | | | | | | |
| $C_{100}$ Test | 0.1 x $I_{10}$ = | | | | | | |
| $C_5$ Test | 2 x $I_{10}$ = | | | | | | |
| 6. $C_{10}$ Test | 1 x $I_{10}$ = | | | | | | Measured Capacity ≥ 95% Nominal Capacity |
| * Maximum and minimum values for the batteries (at least three) represented in “average” value. | | | | | | | |
| Comments: | | | | | | | |