Sustainable Operation and Maintenance

Models for Off-Grid Energy Technologies in Sun ESDS Displacement Settings

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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Programme description:
Support to UNHCR in the implementation of the Global Compact on Refugees
in the Humanitarian-Development-Peace Nexus
Energy Solutions for Displacement Settings (ESDS)

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Bonn, September 2021

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Abbreviations

ARRA	Administration for Refugees and Returnee Affairs
BoME	Regional Bureau for Mines and Energy
EaaS	Electricity as a Service
ESDS	Energy Solutions for Displacement Settings
EEA	Ethiopian Electric Authority
EEU	Ethiopian Electric Utility
GCR	Global Compact on Refugees
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
LCO	Levelized Cost of Electricity
MFI	Microfinance Institution
O&M	Operation and Maintenance
PIR	Passive Infrared
PV	photovoltaic
RET	Renewable Energy Technology
RCC	Refugee Central Committee
SACCO	Savings and Credit Cooperative Organisation
SRS	Self-Reliance Strategy

Energy Solutions for Displacement Settings
Ethiopia, Kenya and Uganda

Project Info: **SUN-ESDS**

The BMZ commissioned Global Program "Support to UNHCR in the implementation of the Global Compact on Refugees in the Humanitarian-Development-Peace Nexus (SUN)", implemented by GIZ, seeks to support UNHCR in its role as facilitator of the implementation of the **Global Compact on Refugees** (GCR) and the Comprehensive Refugee Response Framework (CRRF) in selected refugee contexts and sectors. The program is part of the German Special Initiative "Tackling the Root Causes of Displacement, (Re-)integrating Refugees". It currently provides advisory services to UNHCR on a global level and supports UNHCR in creating and mainstreaming knowledge on the operationalization of the GCR.

The Energy Solutions for Displacement Settings (SUN-ESDS) component works closely with UNHCR and local partners to provide energy solutions that cater to the needs of both refugee and host communities in our project countries- Uganda, Kenya, and Ethiopia. SUN-ESDS is also the German contribution to the **Clean Energy Challenge** issued by UNHCR in 2019 with the following objective: **"All refugee settlements and nearby host communities will have access to affordable, reliable, sustainable and modern energy by 2030."**

The SUN-ESDS project works through three intervention areas:

Improving the policy framework through providing advisory services to governmental stakeholders to promote the inclusion of refugees into national service delivery systems. The project collaborates with the affected communities, and governmental, non-governmental and private sector partners to develop more sustainable energy solutions.

Greening infrastructure in displacement settings through supporting the solarization of UNHCR offices as well as settlement/camp and communal infrastructure, thereby promoting more environmentally sustainable and cost-efficient energy solutions. The project develops energy delivery models that are attractive to the private sector.

Increasing energy access through developing self-sustaining markets for basic energy related services and products, improving access to finance and promoting participatory design processes benefitting households, social services, and small businesses of both refugees and host communities while reducing the pressure on the environment.

We contribute to the following SDGs

Executive Summary

Nguenyyiel Refugee Camp in Ethiopia's Gambella region, Kalobeyei Settlement in Kenya, Imvepi and Rhino Settlements in Uganda are four of the displacement settings in which GIZ's Energy Solutions for Displacement Settings (ESDS) supports UNHCR to improve the energy access for refugee, host community, and social institutions, and render, in an environmentally and economically sustainable manner, existing energy access solutions. The ESDS Project areas have no access to grid electricity. As a consequence, the population's main energy sources are: i) fossil fuel based (tadoobas, diesel generators, car batteries, torches, dry cells), ii) renewable (*individual use*: solar lanterns – received mostly through donations, solar home systems; *community use*: institutional solar, solar street lights). However, given the geographical remoteness of the displacement settings and the low-income of the host communities and the refugees, most of the renewable energy access has been achieved solely with a focus on products, based on humanitarian sector support, partnerships with private sector for piloting different approaches, or through the consumer's own acquisition of renewable energy systems. Little emphasis has been given to servicing the solar energy technologies, particularly through operation and maintenance (O&M) activities.

The O&M of renewable energy technologies, whether for individual or community use, can:

- **Maintain** the performance of the system, thus reduce its payback period
- **Increase** the usability of the system, thus **increase** appliance diversification and income generation opportunities
- **Increase** the end-user's ownership on the asset, thus **increase** energy access through renewable energy
- **Reduce** probability of abandonment through intensified use, thus reduce sources for e-waste
- Generate **business opportunities.** For example, the research showed that third-party repair services for pico-solar devices were thriving, creating informal livelihood opportunities for refugees and host communities.

The main challenges encountered by the consumer of energy (the private sector, the informal sector and the humanitarian and development actors) with the sustainable introduction and scale-up of O&M are:

- **Incentives** – the lack of incentives for consumers to operate and maintain their systems, for the private sector to offer after-sales services, and for the humanitarian and development sector to implement an energy service procurement approach,
- **Standardization** – of O&M practices vary across technologies, camps and settlements, stakeholders, while also monitoring the delivery and impact of O&M services,
- **Awareness** – for the consumer on the standards for O&M practices. The private-sector needs to provide consumers with capacity building, while the humanitarian and development sector needs to raise awareness on the importance of O&M for the sustainable implementation of energy access programs.

The humanitarian and development sector, not only as consumers of energy, but also as key actors for enabling a sustainable energy access in displacement setting, can improve the O&M of renewable energy technologies through a series of actions:

- **IMMEDIATE** – low threshold, rapidly implementable with low effort:
    - Technical solutions for:
        - Solar streetlights: installation of specialized hardware (GPS, alarms)
        - Solar PV for public facilities: utilization of excess electricity as a charging business to cover O&M expenses
    - Energy as a Service:
        - Solar lanterns and solar home systems: by incorporating specific training, after-sales services and recollection clauses in procurement contracts
    - Awareness and training: of consumers through visual materials displayed in public and crowded sites, and demonstration campaigns
    - Inter/intra-institutional working groups: setup in the humanitarian and development sector, to share knowledge, lessons learned and standardize approaches.

- **MEDIUM-TERM** – require preparation of action and planning:
    - Technical solutions for:
        - Solar streetlights: incentivize owners of SHS (both households and businesses) to acquire and install an exterior light to act as a safety light
    - Energy as a Service:
        - Solar lanterns: incorporating the informal economy in the servicing approach by training the informal sector on standardized O&M practices
        - Solar PV for public facilities: shifting from asset-based procurement to service-based procurement
    - Feasibility measurements: on the socio-economic characteristics of the displacement setting's end-user
    - Inter/intra-institutional working groups: a centralized repository of knowledge, populated with relevant information.

In addition, in the **MEDIUM-TERM**, tapping into the informal market (of skilled people, repairpersons) while standardizing O&M practices and raising consumer awareness can be done through a **voucher system for tracking and repairing renewable energy technologies.** Such a voucher could bring several benefits, as it represents i) a bottom-up method to formalize the repair market without major policy interventions, but with a conscious support of the consumer, the end-user who will experience a better servicing quality and will understand the difference between low-quality and quality-approved products and services; ii) a quick method for measuring the true energy access status – by recording each of the available systems, the actual tiered access to energy can be assessed.

To begin the process of standardizing O&M practices, two publicly available Excel-based tools have been developed: the Glossary of O&M and the Maintenance Plan. Designed in a simplified logical framework, the tools provide quick and easy understanding of information on the types of O&M practices, most frequent O&M processes, relevant terminology and share of responsibilities between end-users and trained personnel. In the **MEDIUM-TERM**, the two tools could be digitalized and combined with the voucher system, in a 3-in-1 mobile phone application.

Finally, to tackle the O&M challenges, all four categories of stakeholders need to build, in a bottom-up manner, their ownership on O&M practices, in a way in which burden is not put on budgetary constraints, causalities with the public sector are not created, and the private sector is enabled to sustainably create its market.

1 Introduction

1.1 Background of study

The BMZ commissioned global programme "Support to UNHCR in the Implementation of the Global Compact of Refugees in the Humanitarian-Development-Peace Nexus (SUN)", implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), seeks to support UNHCR as a facilitator of the GCR in the Humanitarian-Development-Peace-Nexus. The programme is part of the German Special Initiative "Tackling the Root Causes of Displacement, (Re-) integrating Refugees". It currently implements projects with UNHCR in specific displacement settings (Ethiopia, Kenya, Mexico, Niger, Rwanda, Mauritania and Uganda), provides advisory services to UNHCR on a global level, and support UNHCR in creating and mainstreaming knowledge on the operationalization of the GCR. Energy Solutions for Displacement Settings (ESDS) is one of four project components. It seeks to improve the energy supply through market-based approaches in displacement settings both on a household and camp/settlement-infrastructure level via advisory services to UNHCR on energy and the implementation of technical measures in specific displacement settings in northern Uganda, Kenya (Turkana County) and Ethiopia (Gambella Region). The overarching goal of the ESDS project is to improve the energy access for refugee and host community households and social institutions and render existing energy access in camps and settlements more environmentally and economically sustainable. Technologies that ESDS promotes in order to improve access to energy and related services for households, social institutions and camp operators, include:

- PV systems, including mini-grids, for UNHCR compounds
- PV stand-alone systems for businesses and social institutions, e.g. energy kiosks and health centres
- Off-grid PV systems for households, e.g. solar lanterns or solar home systems
- Solar energy installations for public infrastructure such as streetlights and water pumps.

One important component for establishing sustainable models for the usage of these technologies exists in Operation and Maintenance (O&M) which are essential to ensure their continuous functioning, lower the levelized cost of electricity (LCOE) and reduce electronic waste. Several challenges exist that render the O&M for energy access technologies complex in displacement settings, from the existence of language barriers among refugees, weak presence of solar companies, to the low profitability of operations in camps and settlements.

1.2 Objective of study

The objectives of this study are to:

- Identify and analyse O&M models for off-grid solar technologies, and examine barriers and opportunities for these models in displacement settings
- Analyse aspects of the warranty for household PV products and practices of possible return and warranty claims existing in ESDS' project sites and the role of reparability with the present and potential role of the informal sector therein
- Develop concepts for O&M business models for selected technologies that can be implemented in displacement settings
- Develop concepts for O&M models for community-owned assets
- Provide recommendations on improvements in the regulatory and business environment for sustainable O&M models for off-grid technologies and the role of GIZ and UNHCR
- Provide recommendation for a sustainable O&M strategy for UNHCR.

Due to the travel restrictions posed by COVID-19, this study is limited to desk research and interviews conducted with relevant stakeholders.

1.3 Methodology

Under this assignment, MicroEnergy International (MEI), through desk research (reports reviewed are listed in References) and virtual/phone interviews with key stakeholders, has taken stock of current O&M frameworks for solar off-grid technologies, and identified challenges with the O&M practices, in displacement settings of ESDS' partner countries, more specifically in:

- Ethiopia – Nguenyyiel Refugee Camp in Gambella region,
- Kenya – Kalobeyei Settlement,
- Uganda – Imvepi and Rhino Camp Refugee Settlements.

Following the findings, MEI has:

i) developed a series of recommendations for improving the O&M practices (see chapter 4) for the technologies mentioned below, and has,

ii) created two Excel-based tools (further explained in 5 Tools for Operation and Maintenance Practices), a glossary of the most common terminology utilized in O&M practices and an O&M plan for energy access technologies:
    - Individual level energy access technologies:
        - Solar Lanterns, usually up to 2.8 Wp (Tier 1)
        - Solar Home Systems, usually up to 300 Wp (Tiers 2 and 3)
    - Community level energy access technologies:
        - Solar Streetlights
        - PV Solar Systems in Public Facilities.

The technologies mentioned above have been selected based in consultations with ESDS and UNHCR.

2 Energy Access in Displacement Settings

2.1 The end-user

As of August 2021 [1], UNHCR reports that 82.4 million people worldwide have been forcibly displaced as a result of persecution, conflict, violence, human rights violations or events seriously disturbing public order [2]. Some of these people are settled in camps, others dwell in urban settlements or have a new home. Humanitarian agencies keep camps and settlements safe and provide them with basic provisions like food, shelter and energy.

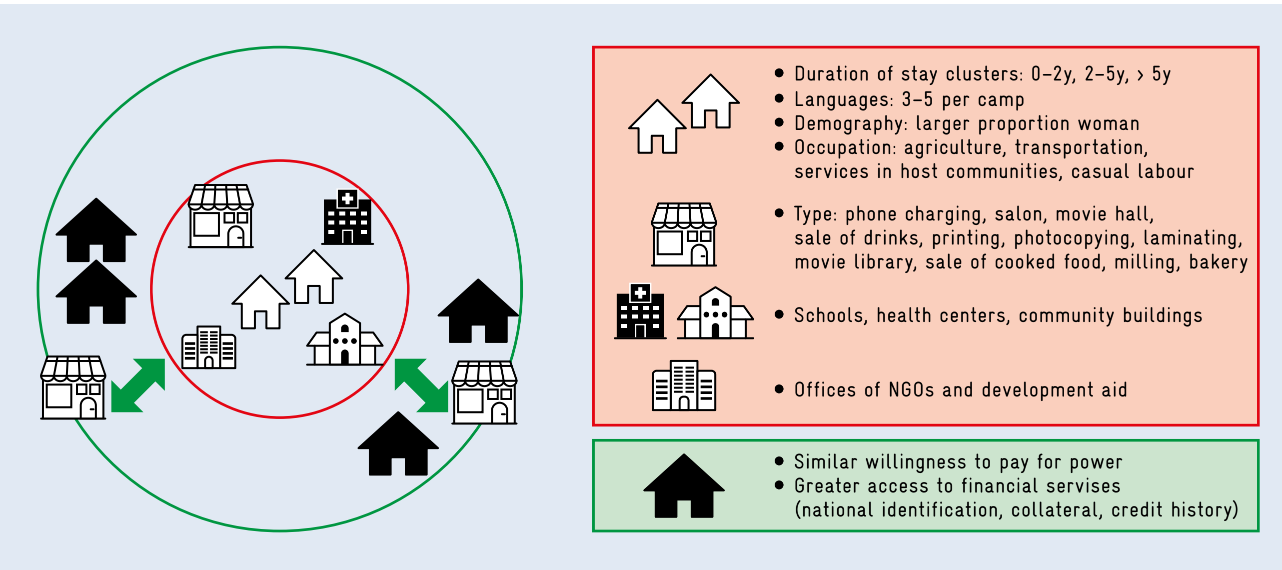
In such a context, access to energy is critical, not only for basic services (such as lighting or cooking), but also for economic development, health and safety. A study conducted by Dalberg and Vivid Economics [3] found that 80% of the displaced households use candles, battery powered torches or kerosene for lighting; this translates into 80% of the displaced population having access to electricity for lighting less than four hours per day. On top of the challenge of providing access, energy usage also needs to be maintained and stimulated, particularly for the long-term displaced refugees.

In 2019, UNHCR launched the Clean Energy Challenge, through which it aims to provide people in and around refugee camps with Tier 2 access to electricity and modern cooking by 2030.

> Achieving the goals set by the Clean Energy Challenge can only be done through a paradigm shift – moving from provision of goods and assets to provision of services, and through the integration of the private sector.

Below follows an overview of the categories of energy consumers in displacement settings. They are end-users who require electricity for lighting and powering appliances in their houses, businesses premises or offices. The end-users are represented by all the individuals (displaced persons, humanitarian and development sector staff, governmental representatives, host community population) located within the displacement setting (see Figure 1).

Figure 1. Displacement setting structure. Author's own depiction



The displacement setting consists of the refugee camp itself, and the community located in its vicinity (usually referred to as the host community). Between these two there are often socioeconomic trades, such as refugees working in the host community, and the host community owning businesses in the refugee camps. However, conflicts could potentially also arise between the refugee and the host community, usually due to the fight on the scarce natural resources, political conflicts or unequal integration of the two.

The **primary type of end-users** in both the host community and the refugee camp is represented by **households**. In terms of demography, the majority of the refugee households is headed by females, as their husbands had either been killed in conflicts or have headed back to the country of origin to secure household assets. The size of a household has a significant impact on the way of life, particularly as resources are usually limited. In general, the household sizes for both refugees and host community are similar. The livelihood strategy for refugees varies from country to country, and camp to camp. The main economic activities in the target camps are detailed in sections 2.2 – 2.4 of this report. However, in general, refugees engage in petty trade, agricultural activities, casual labour (e.g. transportation of people, cleaning, construction work), charcoal and firewood trade or have their own small businesses in the refugee camp (e.g. shops, restaurants, entertainment centres, barbershops).

The **second type of end-users** in refugee camps is represented by **businesses**, owned either by refugees or by the host community: shops with basic goods, agents for prepaid mobile phone scratch cards, restaurants, barber shops, tailor shops, bakeries, photocopy shops, mobile phone charging stalls, entertainment venues (with movies, news or sports).

A **third type of end-users** is **public or community buildings**, such as schools, health centres, or religious venues. These are run by the refugees with the support of humanitarian actors and development aid.

Forth are end-users such as **offices** of the humanitarian and development sector, located and operating in the camps.

Figure 2. Breakdown of estimated annual energy spending in camps and settlement by primary user type. Source [3]

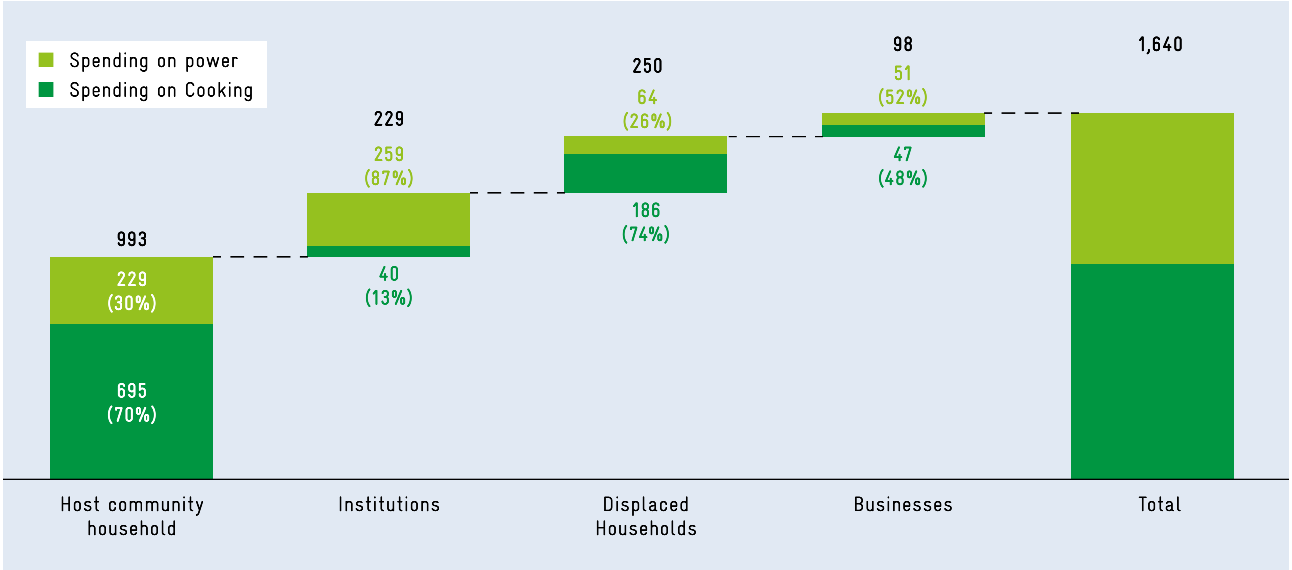


Figure 2 shows that the majority of estimated current spending on energy comes from host community households. Humanitarian and development offices represent the second largest share of spend; this is made up by power needs for office compounds, community infrastructure like hospitals, schools, water pumps, streetlights, and in-kind energy support for new entrants and vulnerable populations, such as torches. Displaced person households currently reflect around 15% ($250 million) of the overall demand for energy (both power and cooking), estimated at USD 1.6 billion. Businesses, while a vibrant part of many camps, currently spend relatively little on energy [3].

74% of total energy spending of displaced households goes to cooking [3]. For host community households, it is 70%. And this is despite the fact that many of these households depend on firewood collected from the surroundings. The remaining, approximately 30% of household energy spending, is primarily for basic lighting. At the onset of a crisis, displaced households are often provided with free solar lanterns. In some cases, they sell or barter these in exchange for cooking fuel [3]. In the longer run, free lanterns are often replaced with battery-powered torches, other solar lanterns, or makeshift LED lights attached to dry-cell batteries – all of which require continuous spending to ensure longevity.

In the following 2.2 – 2.4 section, an overview of the main stakeholders, socioeconomic characteristics and main energy sources are provided for the displacement settings considered in this study, namely: Nguenyyiel Refugee Camp (Ethiopia), Kalobeyei Settlement (Kenya), Rhino Camp and Imvepi Refugee Settlement (Uganda).

2.2 Ethiopia – Nguenyyiel Refugee Camp in Gambella

As of August 2021, Ethiopia hosts more than 795,108 [4] refugees and asylum seekers. The majority of refugees come from four countries: South Sudan, Somalia, Eritrea and Sudan [5]. Nearly all refugees have been in a displacement situation for more than five years. The camps in which they are located are in five regional states, near the borders of their respective country of origin: Afar, Benishangul-Gumuz, Gambella, Somali, and Tigray.

In Ethiopia, the institutional responsibility for the implementation of all policies related to refugees lays, since 1990, with the Administration for Refugees and Returnee Affairs (ARRA), which is also responsible for coordinating the implementation of the CRRF. With financial and technical assistance from UNHCR, ARRA administers refugee camps; it oversees the security in the camps, general food distribution, primary healthcare, education services and is the main liaison with relevant national ministries. In each of the refugee camps, ARRA works with the Refugee Central Committee (RCC), established from zone leaders and elders from the communities. RCC acts as the representative of the refugees, and liaises with ARRA and other NGOs, advocating for refugees' needs.

As of August 2021, there are approximately 348,121 [4] refugees in the Gambella region, spread among seven camps: Akula, Jewi, Kule, Nguenyyiel, Pugnido, Pugnido 2, Tierkidi. The Nguenyyiel Camp is located in Itang special woreda[1] and it is one of the newest (opened in 2016) and largest camps (approximately 82,722 refugees [5]) in Gambella. 51% of Nguenyyiel's population is represented by women, whilst 68% of the population is under the age of 18. Due to limited livelihood options, the primary activities in the camp consist of selling firewood, brewing local alcohol, and selling items from the food rations.

The Gambella Regional Bureau for Mines and Energy (BoME) oversees all energy activities in the region, however it mostly focuses on large energy infrastructure development, including rural electrification. A regional office of Ethiopian Electric Utility (EEU) has no plan to extend grid to weredas and kebeles where the refugee camps are located [6]. While the Ethiopian Electric Authority (EEA) regulates regional mini-grid development through regional energy agencies, BoME has no experience of regulating and implementing mini-grid projects in the region.

The current energy provision in the camp is through a single delivery model, in which energy products are procured in bulk and distributed by ARRA, UNHCR and RCC [6]. Firewood[2] and charcoal trading is one of the primary informal markets established between the host and the refugee community. As firewood is also employed for cooking, this has resulted in a long-standing conflict between refugees and host communities over deforestation. No local microfinance institutions (MFIs) have been engaged in financing energy products for refugees. Key stakeholder interviews revealed that, when it comes to formal financial inclusion access, Wegagen Bank Ethiopia started providing financial services for refugees [7]. Additionally, the Commercial Bank of Ethiopia, in a program supported by UNHCR, started supporting refugees living outside the displacement camps, by providing approximately 6,000 people with a basic access to a bank account [8]. The average monthly energy service expenditure in a refugee household was estimated to be about USD 17.9 (for cooking, lighting & phone charging) – which represents 25% of median household income [6].

1 An administrative division of Ethiopia, managed by a local government.

2 Household firewood consumption ranges on average between 1.5 kg to 2.65 kg per person per day.

2.3 Kenya – Kalobeyei Settlement

As of August 2021, Kenya hosts 529,854 [9] refugees and asylum-seekers. Kalobeyei settlement, situated at about 40 km of Kakuma, is the result of a multi-agency collaboration towards shifting the refugee paradigm, from relief and temporary settlement to self-reliance. Built in 2015, and hosting (as of August 2021) around 37,000 refugees [10], it exemplifies the goals of UNHCR's CRRF: supporting host communities, offering self-reliance and promoting a development-based approach to assistance. The majority of refugees comes from South Sudan, followed by Ethiopia, Burundi, DR Congo and Uganda.

Since 1992, Kenya has been host to refugees and asylum seekers. In 2017, Kenya adopted the CRRF as one of the pilot countries and has also endorsed the Global Compact on Refugees. The sub-region of Turkana West, home to Kakuma refugee camp and Kalobeyei settlement, houses, as of August 2021, 218,380 refugees [9]. The development of the Kalobeyei settlement is guided by the Kalobeyei Integrated Social and Economic Development Programme (KISEDP), led by the Government of Kenya, the Turkana County Government, UNHCR and partners [11].

Agriculture and trade of locally procured goods such as charcoal and firewood, with the host community, are the main economic occupations of the refugees. Majority of businesses located in the settlement are micro, small stores or dukas: barbershops, food, tailor shops, mobile phone charging. Asset ownership is very low, with only 0.7 per cent of the households owning a computer, 0.7 per cent a television, 0.5 per cent an own generator and 2.9 per cent a bicycle [10]. On average, 70 per cent of the camp's population owns a mobile phone. Most retail businesses (approximately 2,500 in Kakuma and Kalobeyei [11]) rely on wholesalers operating in Kakuma town and camp. Regarding formal financial inclusion access, many refugees have a bank account at Equity Bank, while some aid organizations such as the Danish Refugee Council and the Lutheran World Federation are providing loan support, however, still at a pilot phase.

With regard to the energy situation, the settlement's population relies on informal diesel-mini-grids and generators, standalone solar solutions, batteries and torches [12]. Kalobeyei settlement has a solar mini-grid; all the distribution and transmission infrastructure have been installed in both Kalobeyei Village 1 & Host Community. So far, 219 refugee households and business have been connected to the Kalobeyei Settlement mini-grid and 75 connections in the Host Community mini-grid in Kalobeyei town. The registration and connection process are still on going until the target of 280 connections in the settlement and 101 in Kalobeyei town is met. It is anticipated that once the power is turned on, there will be a high energy demand (power spike) of up to 1000 connections [13].

2.4 Uganda – Imvepi and Rhino Camp Refugee Settlements

As of August 2021, Uganda hosts in its 13 settlements approximately 1,503,601 [14] registered refugees and asylum seekers, displaced mainly from South Sudan, Somalia, Eritrea, Burundi, Rwanda and Democratic Republic of Congo.

Uganda has one of the most progressive refugee policies in the world. These policies enacted through the Refugee Department of the Office of the Prime Minister have made the goal of self-reliance central to the country's refugee regime. With Uganda's famous "Self-Reliance Strategy" (SRS), refugees in Uganda enjoy the right to work, freedom of movement within the country, access to basic services, and the right to live in local communities as well as in defined settlements. More recently, the 2016 Refugee and Host Population Empowerment (ReHoPE) strategic framework updated the SRS, outlining a model to support resilience and self-reliance for both refugees and host communities by integrating refugees in national development plans [15].

Imvepi Refugee Settlement is located in Terego district, while Rhino Camp settlement is located both in Terego and Madi-Okollo Districts. Both settlements host a total of approximately 200,000 refugees (Imvepi – 70,000, Rhino – 121,000) [16], with the majority of refugees from South Sudan, followed by DRC, Burundi or Central African Republic. The majority of the Rhino Camp Settlement population is represented by women (80%), with an average household size of eight members [17]. In Imvepi Refugee Settlement, 65% of the population is represented by women, while the average household size is seven members [17]. 62% of the population owns a mobile phone, while only 19% use internet due to low access to electricity which limits the coverage [16].

The main sources of income are represented by sale of agricultural produce, small businesses such as barber shops, phone charging, video and entertainment halls, sale of cooked food and sale of wood for fuel. Women also work in the host community, providing cleaning services, laundry or attending children [18]. Compared to Ethiopia, refugees in Ugandan settlements have a higher access to financial inclusion services; according to Dalberg and Vivid Economics [3], they have access to mobile money, whilst some banks and MFIs have begun to provide formal financial services.

In terms of the type of the sources of energy used for basic activities such as lighting or mobile phone charging, the most common are represented by solar lanterns, torches, and kerosene lamps (tadooba). Those who cannot afford a lighting product resort to the use of dried palm leaves and grass to make flames [17]. Firewood is mostly used for cooking purposes. According to a survey conducted by the Centre for Research in Energy and Energy Conservation [18] in the Imvepi Refugee Settlement and Rhino Camp Settlement, households spend on average per week UGX 1,000 – UGX 1,500 on their main fuel for lighting. Their main fuel sources for lighting represent disposable dry cells. Solar lanterns are mostly acquired either through donations or heavily subsidized by development agencies [17].

3 Operation and Maintenance of Renewable Energy Access Technologies in Displacement Settings

This study has assessed the operation and maintenance of the following renewable energy technologies:

Solar lanterns

There are two types of solar lanterns:

- Figure 3 [19], [20]: single light solar lanterns, with an in-built battery and either an in-built or an external PV panel,
- Figure 4 [21]: single light and one mobile phone charger.

A solar lantern meets Tier 1 on the MTF for a household if it provides at least 1,000 lumen-hours[3] (lmhr) / day and sufficient energy to keep a well-used mobile phone operational. Products that provide less than 1,000 lmhr per day, or do not provide mobile phone charging, are counted as meeting some fraction of a household's needs [22].

Figure 3. Single light solar lantern with external PV panel vs. in-built PV panel

Figure 4. Solar lantern with charging port

3 A measure of the total quantity of visible light emitted by a source per unit of time

Solar Home Systems

A Solar Home System (SHS) is a standalone PV system which typically includes one or more PV modules consisting of solar cells, a charge controller which distributes power and protects the batteries and appliances from damage, at least one battery to store energy for use when the sun is not shining, and in some cases, an inverter (which converts the electricity produced by the solar panel – Direct Current or DC to Alternating Current or AC) to power appliances. SHS can be categorized as follows:

- Component Based Solar Home Systems (C-SHS), as in Figure 5: C-SHS are those which usually fall under Tiers 2 and 3 of energy access, with system sizes ranging from 40 Wp to 500 Wp. The system's components (PV panel, battery, charge controller, inverter) come from different producers, are usually imported separately (as part of several distributors' supply chains) and installed by trained technicians who also offer full after-sale service.

Figure 5. Component based SHS installation. Source: [27]

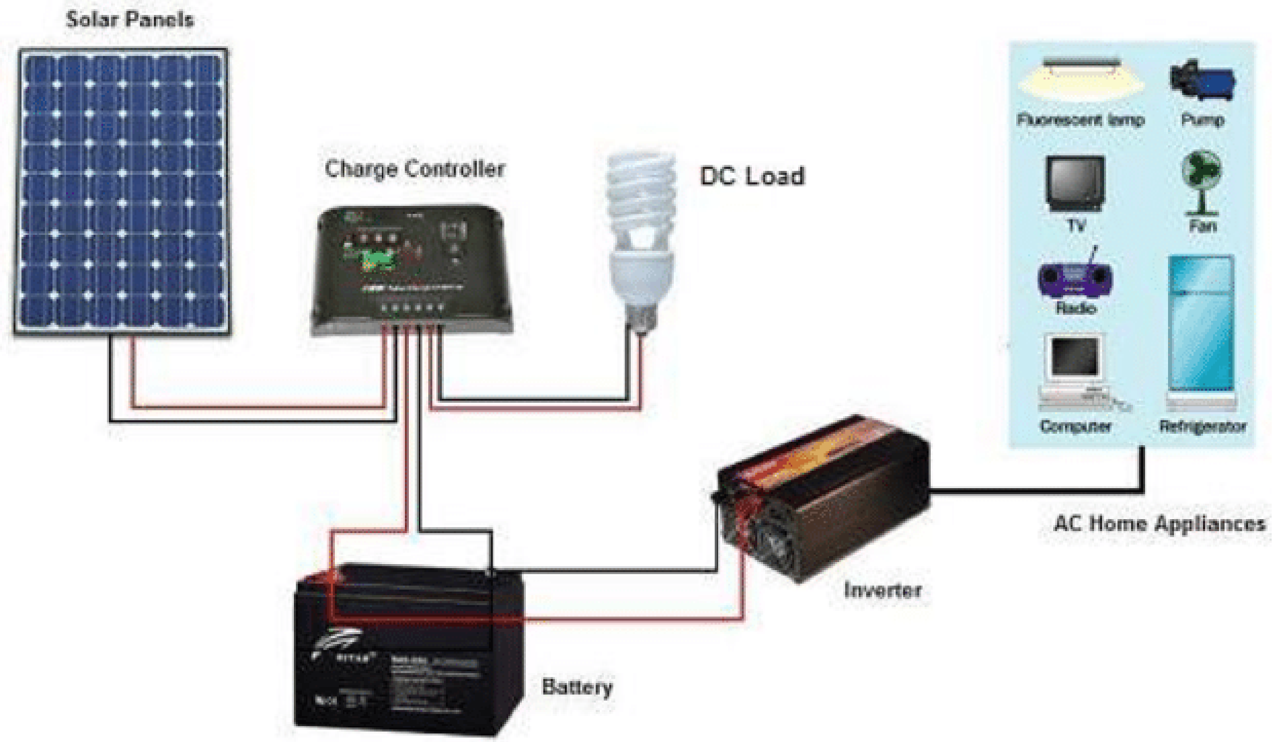


Figure 6. Plug and Play (PAYGO) Solar System. Source: Mobisol

- Plug and Play Solar Home Systems (PP-SHS), as in Figure 6: PP-SHS usually fall under Tier 2 and 3 of energy access, with systems sizes going up to 300 Wp. The battery and charge controller are usually combined in one component. PP-SHS's installation can be done by the end-user or by a trained technician. The most common type of PP-SHS is the PAYGO system, where the system is unlocked against mobile money payment; the PP-SHS is monitored remotely. PP-SHS commonly have a warranty of up to 3 years for the components and 25 years for the PV panel. PP-SHS, particularly PAYGO, are, the most expensive category of SHS.

Figure 7. Mix and Match solar system with improper installation. Source: MEI

- Mix and Match Solar Home Systems (MM-SHS), as in Figure 7: MM-SHS usually fall under Tier 2 and 3 of energy access, with system sizes going up to 300 Wp. The system's components (battery, PV panel, inverter, charge controller) are assembled in most cases, by the end-user, without prior technical knowledge or advice. The components of the system are not quality verified nor standardized; these are usually counterfeit and have deceiving signs ("Made in Germany").

PV Solar Systems in Public Facilities

Public facilities, such as the offices of the humanitarian and development sector, the offices of regional governmental authorities, schools, health centres, religious buildings, if off-grid, can be electrified with component based solar systems. The main differentiation between the household SHS and the public facility solar system is represented by the sizing of the PV panel and the battery; public facilities have higher energy needs and different consumption patterns (for example, health centres consume more electricity during the day, while households consume more electricity during the evening and during the morning).

3.1 Importance of operation and maintenance

In general, the operation and maintenance (O&M) of any asset enhance the likelihood that the asset will perform at or above its projected production lifespan and cost over time.

Similarly, the O&M of renewable energy technologies, whether for individual or community use, can:

- **Maintain** the performance of the system, thus **reduce** its payback period
- **Increase** the usability of the system, thus **increase** appliance diversification and income generation opportunities
- **Increase** the end-user's ownership on the solar asset, thus **increase** energy access through renewable energy
- **Reduce** probability of abandonment through intensified use, thus reduce sources for e-waste
- Generate **business opportunities**.

O&M practices are performed both by the end-users and qualified personnel, on the different components of a renewable energy technology (e.g. PV panel, battery, inverter, charge controller). The full list of recommended activities for O&M, by type of technology, and the tools and materials required for their performance, are available on **Energypedia**. Table 1 shows an overview of the main categories of O&M practices:

Table 1. Overview of O&M practices

Type of O&M practice	End-user	Qualified personnel
Operation	• Optimal timing for charging appliances or mobile phones during the day • Battery stored in a dry environment	
Preventive maintenance	• Daily PV panel charge, even on cloudy days • PV panels kept dry and free of dirt • Visual inspection of loose cables	• Check clamps and bolts panel structure • Check fuses and surge protections • Read volt and ampere meters
Regular inspection		• Integrity inspection • Electrical measurement inspection • Document inspection • Record electrical power
Repair		• Replace battery or liquid in battery • Replacement of faulty cables

In the displacement settings assessed in this report, **the main challenges for O&M**, revealed through desk research and interviews with stakeholders, can be categorized as:

1. **INCENTIVES for O&M practices** – on the *end-user* side, a lack of incentives generated by the absence of intrinsic ownership for the donated systems in particularly, and improper training; on the *private sector – the system distributors*, a lack of incentives generated by the business model itself (focused on the sale of products), by the target market uncertainty of the duration of stay and by a lack of monitoring tools; on the humanitarian and development actors side, incentives are limited by lengthy and bureaucratic procurement processes, budget limitations or a general focus on energy assets rather than energy services.

2. **STANDARDIZATION of O&M practices** – due to the diversity of brands, systems configurations and sizes, both for quality-verified and for low-quality products, there are no standardized materials or trainings on O&M provided to the *end-user; humanitarian and development actors* are currently lacking standardized tools for awareness raising on O&M importance, training and monitoring of impact of O&M practices, across countries and across camps.

3. **AWARENESS on O&M practices** – first time owners of solar systems, *end-users* might not be aware of O&M practices or, in lack of technical support, might try to repair the systems by themselves or on the informal market; at the same time, due to deceiving features, end-users might not be able to differentiate between quality-verified or low-quality systems.

Each of the three challenges mentioned above will be investigated for the main individual use technologies and detailed in the next section of this report.

Reparability

Reparability is a key activity performed as part of operation and maintenance practices. Understanding it as more than the act of fixing a malfunctioning component is critical. When an end-user in Kenya seeks out a repair service, they are making an intentional effort to extend the lifespan of a product (by choosing to repair it instead of replacing it with a new product), demonstrating the continued value of that product for them [23].

Figure 8. Informal repair shop. Source: Energy for Access Coalition

In displacement settings, the repair economy operates almost in its entirety without the use of electricity [24]. Repairs on micro-electronic components and printed circuit boards are carried out with screwdrivers and homemade soldering irons, heated with charcoal stoves before welding electronic components. In Kakuma, Kenya, Chatham House [24] found that the most common request for electric repairs involves broken wires and electrical connectors. The need to improvise for components or equipment is generated due to a lack of spare parts; spare parts needed to repair malfunctioning solar products are often not available in the camps, leading to long repair times. This discouraged people from purchasing products [25]. People are more than willing to seek out third-party repair service providers and pay for repair work. This applies both to out-of-warranty products as well as in-warranty products, particularly in contexts where the costs of time and travel involved in returning products to a vendor may appear higher than third party repair. A qualitative survey of energy access in two refugee camps in Burkina Faso and Kenya [23] showed that repair was a central rather than a peripheral part of refugee economies. The research showed that third-party repair services for pico-solar devices were thriving, creating informal livelihood opportunities for refugees and host communities. These repair economies connect refugee and host communities. Flows of spare parts and components into refugee camps completely bypass humanitarian agencies and energy companies, depend on individual links and access to market suppliers in towns and cities.

The proliferation of electrical repair services includes informal and ad-hoc repair work as well as formalized services established by people who have attended training programs run by humanitarian agencies.

Particularly in the displacement settings, repairing renewable energy technologies can:

- **Generate** jobs and formalize skills of the displaced population
- **Facilitate** the reuse of components, making more efficient use of scarce materials
- **Reduce** the production of waste by minimizing the loss of materials, through material separation, re-use and recycling
- **Enhance** the economic added value of the asset by expanding its lifespan
- **Reduce** need for legislative action
- **Increase** trust in off-grid technologies.

3.2 Technologies for individual level use

Across all the camps reviewed in this study, the most common renewable energy technologies (RET) used by the refugees and the host communities are:

Table 2. Overview individual use renewable energy technologies

RET		Features	Ethiopia	Kenya	Uganda
Solar Lanterns	Single light	Tier 0 or 1[4] (up to 3 Wp); usually 1 year warranty	d.light, Greenlight Planet, Little Sun, Solar Development	d.light, Greenlight Planet, Little Sun	d.light, Greenlight Planet, Little Sun
	Single light + mobile phone charging	Tier 0 or 1 (up to 12 Wp); usually 1 year warranty	d.light, Greenlight Planet	d.light, Greenlight Planet	d.light, Greenlight Planet, Barefoot, Solar Aid
Solar Home Systems (SHS)	Component Based (C-SHS)	Tier 2 and 3 (40 – 500 Wp) Components are imported separately and assembled locally; usually installed by trained technicians who also offer a full after-sales service; warranty per component up to 5 years;	No information	PV panel: Davis and Shirtliff, Sun Transfer, Chloride Exide, Kenya Solar Limited Batteries: Chloride Exide, ADH, J&L	PV panel: Davis and Shirtliff, Chloride Exide Batteries: Batteries Limited (UBL), Chloride Exide, J&L
	Plug and Play (usually PAYGO)	Tier 2 and 3 (usually up to 300 Wp); installed by the user or by a trained technician; system unlocked against mobile money payment; system is monitored remotely; usually up to 3 years warranty; usually, the most expensive category of SHS	HelloSolar[5]	Pawame, BBOXX, M-Kopa, Engie Access (former Mobisol)	Engie Access (former Fenix), M-Kopa, SolarNow
	Mix and Match (MM-SHS)	Tier 2 and 3 (40 – 500 Wp) locally assembled from components separately available in local markets, without any technical support; usually, no warranty	No information	PV panel: Sundar, Tundar, Oceanic Batteries: most common are Lead-Acid	PV panel: Sundar, Tundar, Oceanic Batteries: most common are Lead-Acid

4 The Multi-Tier Framework (MTF) defines energy access from the traditional binary count to a multidimensional and comprehensive definition of access and identifies the access rate based on the quantity of service available across six tiers (from 0 to 5).

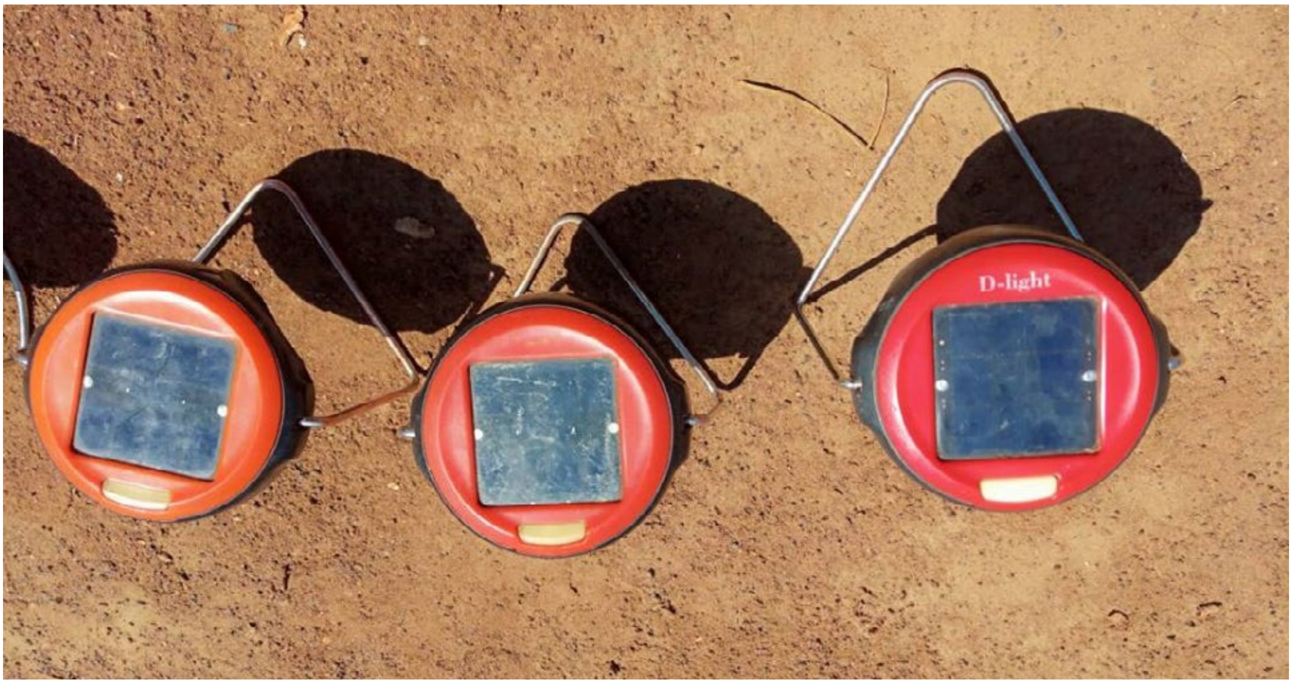
5 There is conflicting information as to whether there are any PAYGO systems in the Gambella region. Some reports state that HelloSolar is running a pilot in the refugee camp, while interviews with stakeholders revealed that no HelloSolar systems have been installed. At the time of the data collection, representatives of HelloSolar could not be reached.

3.2.1 Solar lanterns

INCENTIVES for O&M practices. The majority of quality-verified[6] solar lanterns are donated by humanitarian aid as part of refugee welcome packages. They are entry-level systems that can assure a maximum of four hours of light per day, and one mobile phone charging. Typically, their maintenance requires cleaning the PV panel and keeping the charging port clean of dust. But due to the fact that they are received for free, no *end-user* ownership on the system is enabled. Moreover, when they stop working, end-users usually discard them in landfills or simply store them under beds, in drawers and on top of cabinets. By putting products out of sight people transform the home from a site of use into a site of non-use; and in doing so 'users' become 'non-users' [26]. For the *private sector, particularly solar lantern companies*, solar lanterns are high volume – fast turnover products, for which the cost of replacing parts or maintaining under warranty would be much higher than the production costs. For *humanitarian and development sector*, the donation of solar lanterns is a low-threshold approach to on-boarding end-users into the usage of renewable energy technologies whilst providing a minimal access to electricity.

STANDARDIZATION of O&M practices. The quality-verified solar lanterns are the most easily replicated solar systems (see Figure 9), with an abundance of copycats and unbranded systems that can cost as little as USD 1 and have an unsurprisingly short life [26]. Affordability and access to cheap unbranded solar lanterns determine *end-users* to replace non-functioning systems rather than to repair them or claim warranty. For the *informal sector, represented by local shops and local repair-persons*, there is little or no access to spare parts or quality components that could enable a service – repair environment. Additionally, most repair-persons are usually self-taught and often improvise solutions for non-functioning systems.

Figure 9. Three unbranded copycats of the original d.light solar lantern Source: MEI



6 Systems which comply with Lighting Global or national standards and are regularly tested.

AWARENESS on O&M practices. As seen also in Figure 9, for end-users, there are few features which differentiate quality-verified from non-verified systems. Additionally, if the solar lanterns stop working or if users experience problems with their devices, a misperception on PV systems in general is created. Moreover, due to a lack of awareness on operation of solar lanterns, and general lack of access to electricity, studies conducted in several refugee camps report instances in which users have tried to bypass the lanterns' charging ports, in order to connect other appliances. The informal sector, due to the lack of training on and the lack of access to spare parts of quality-verified solar lanterns, cannot provide end-users with sufficient technical support or guidance on how to maintain and operate the systems.

3.2.2 Solar home systems

Component Based Solar Home System (C-SHS)

INCENTIVES for O&M practices. For *end-users*, affordability and duration of stay in the displacement setting are the key incentives for acquiring C-SHS, whose payback periods can vary between three and seven years (depending on the size of system and on the monthly repayment rate). Financial inclusion institutions (MFIs, banks) play a key role in tackling the affordability challenge. C-SHS end-users are trained by specialized staff on the maintenance and operation of C-SHS; after-sales services are included in the price of the system and while in warranty, malfunctioning components are usually replaced or repaired by the same company who installed the system. The *private sector, particularly regional or national companies*, are usually limited in their outreach and operational capacities. Unless there is a consistent demand in a location, companies usually do not market or lengthen their supply chain to reach the refugee settings, which are usually remote and have limited access to transportation infrastructure. The fluctuating duration of stay of refugees and the highly bureaucratic asset and service procurement process are dis-incentivising the *humanitarian and development sector* in assuring an energy access infrastructure based on C-SHS, **STANDARDIZATION of O&M practices.** The installation, operation and maintenance of C-SHS is standardized, but frequency of and specific processes can vary, depending on components. However, in most cases, *end-users* are trained on how to correctly operate and maintain their systems, with *private companies* frequently performing after-sales services. However, the variety of components and systems sizes makes it hard for the *humanitarian and development sector* to measure performance of systems, impact and their usability in displacement settings.

AWARENESS for O&M practices. Although several donor or *humanitarian and development sector* initiatives have tried to measure indicators such as energy access, demand and need for energy, affordability and willingness to pay, accessibility to camps or high refugee turnover have made it hard for an in-depth population scoping and a centralization of measurements. Without access to such information, *private sector* companies usually do not have the sufficient resources to conduct such studies before entering the displacement setting's marketplace.

Plug and Play SHS (PP-SHS)

INCENTIVES for O&M practices. For *end-users*, the proper operation and maintenance of the PP-SHS is incentivized through the payment plan and the ability to upgrade to a larger system. PP-SHS are usually the PAYGO systems which are unlocked once payments are made via mobile money; the end-user is trained by a technician or through a leaflet on how to operate the system and which preventive maintenance actions can be taken. More advanced PP-SHS have also the capability of sending an SMS to the user, reminding him or her on certain maintenance protocols. If the PP-SHS system is fully repaid within the contractual period, the end-user's credit worthiness improves and, depending on the PP-SHS provider, his or her status could be upgraded to a larger system. PP-SHS usually have in-built sensors or special security features that can signal when an end-user tries to tamper or bypass the system; in instances in which the end-users tries to fix the system by him/herself, the warranty period can be reduced or immediately cancelled or monetary penalties can be incurred. However, PP-SHS, particularly those larger than 50Wp, are still scarce in the displacement settings investigated in this report.[7] [28] has noticed that due to i) the long distance between a PP-SHS provider branch, where technicians are based, and the end-user's location, ii) absence of the provider's trained technician in the camp, iii) the high standardization and integration of the system, have created long lag times (between one to five weeks) from the moment an end-user reports a malfunction and until the issue is resolved. This in turn leads to the creation of misconceptions towards PP-SHS, default in repayments or forces the end-user to bypass the system, fixing it on the informal market. For PP-SHS providers, the *private sector*, the reluctance to increase the outreach and the support infrastructure within the refugee camps is related to the uncertainty with regards to the refugees' duration of stay, perceived increased risk of lending, increased cost of distribution operations and the little market information on the refugees' energy needs and ability to pay. PP-SHS, particularly the PAYGO ones, cater to the needs of those consumers who otherwise could not afford large upfront payments, by distributing costs over time; they highly depend on a pre-existing infrastructure (roads, internet or GSM coverage, access to mobile money and mobile phones).

STANDARDIZATION of O&M practices. The operation and maintenance of PP-SHS is standardized, and can only be performed by trained users or specialized technicians trained and hired by the PP-SHS distributor. However, there are no standardized recollection and disposal practices with regard to those systems which are out of use, locked or beyond warranty [29].

AWARENESS for O&M practices. Without training or support materials developed by the PP-SHS provider, the *end-user* has little awareness on how to operate and maintain the system. The *private sector*, represented by the PP-SHS provider, cannot utilize the "business as usual" approach to expand in the settlements, as there is little awareness with regard to the market socioeconomics and its stability.

7 Some of the reasons include lack of affordability, lack of access to mobile money, insufficient GSM coverage.

Mix and Match Solar Home Systems (MM-SHS)

INCENTIVES for O&M practices. Due to their lower prices, deceiving features (as seen in Figure 10, the PV panels have stickers claiming their production in Germany and hence trying to tap into the public's perception of quality products from Germany), and accessibility (most common in the small shops, nearest towns or in the host community), MM-SHS represent an unsustainable alternative to *end-users*. Usually installed by the end-users themselves, without any prior technical knowledge and safety concerns, the MM-SHS lack guidance on O&M. The *informal sector*, repairpersons, can usually improvise and fix the systems, however without any service guarantee. MM-SHS represent, for the formal solar distributors, the greatest competition; they also represent a challenge for the *humanitarian and development sector* or other donors who want to test different market-based approaches.

STANDARDIZATION of O&M practices. MM-SHS lack any compliance with national or international standards; in many cases, they actually either copy stamps or quality certificates; in other instances, the MM-SHS have deceiving features (e.g. "Made in Germany").

AWARENESS for O&M practices. *End-users* and non-specialized personnel cannot easily differentiate between the low-quality components and the certified or quality-verified products. In Kenya and Uganda particularly, where the market for solar components is mature, both low-quality and quality-verified products are found in remote areas, reaching the last mile, and often being displayed next to each other, with price constituting the only product differentiation. Many people attempt everyday fixes themselves, learning through trial and error, turning to friends and neighbours and passing on their acquired knowledge and skills to their children.

Figure 10. Low-quality PV panel with deceiving marketing (Solar Cell Made in Germany). Source: MEI

3.3 Technologies for community level use

Most displacement settings are managed by humanitarian institutions and have infrastructure like roads, schools, health clinics, offices of NGOs, streetlights and other buildings for community use. Renewable energy technologies for buildings (institutional solar PV) and solar streetlights are the two types of community level use technologies for which the interviewed stakeholders raised most of their challenges with.

3.3.1 Solar streetlights

A modern solar streetlight has embedded solar panel, inbuilt lithium-ion batteries, battery management system, night and motion sensors as well as automatic controls. The fully automatic device comes with LEDs, inbuilt and replaceable Lithium-ion battery and passive infrared (PIR) sensors. A typical solar streetlight is weather-proof and water-resistant, has low insect attraction rate and low glare. The embedded solar panel converts solar power into electricity which is stored in the inbuilt battery, and used for dusk-to-dawn lighting operations. Depending on the complexity of the system, solar streetlights have battery management systems which are facilitated by the presence of night and motion sensors. Due to their off-grid nature, solar streetlights incur minimal operational costs. Such

Figure 11. Solar street light in a refugee camp in Jordan. Source: IRENA

lights are wireless in nature and are independent of the national grid. Due to the absence of external wires, these lights do not pose any threat of accidents like electrocution, strangulation and overheating [30]. Compared to conventional street lights, solar streetlights need little maintenance; the type of maintenance required depends on the operation environment. The influence of dust can be seen directly on the solar panels, because the dust will mainly affect the absorption of sunlight radiation, thus impacting the solar panels' power generation efficiency. Normally, daily regular cleaning is not needed because rainwater washes away the dust attached to solar panels on rainy days; but in some particularly arid environments or regions, rainwater is insufficient. Users can clean the solar panels regularly according to the rain situation, such as once a quarter or once a year, depending on the rain and dust conditions of the installation site [31]. If the streetlights are installed near the seashore or in places of heavy corrosion with high salt fog, the batteries and solar panels should be inspected at least once a year. Batteries of solar streetlights do not require replacing or any other special maintenance during their service life; however, the performance of the battery may decline after five years (typical lifetime of Lithium-Ion batteries). Replacement of batteries should be considered after five years.

In a survey conducted in 2018 by the Moving Energy Initiative [26], one of the top three priorities, in terms of energy access, for the surveyed refugees of the Kakuma camp in Kenya, were street lighting (next to energy for households and energy for health facilities). Street lighting allows people to move around the camps in greater safety at night, particularly women and girls. Additionally, in areas with low levels of household access to lighting, they provide a source for studying.

However, solar streetlights are prone to be vandalized, due to the re-sale value of solar panels and batteries. Once vandalized or if components malfunction, they are either never repaired or are repaired after a very long period of time.

Similar to the individual use technologies, the main challenges with solar streetlights are:

- **INCENTIVES for O&M practices** – viewed as a public good, *end-users* (in this case, rather the end-beneficiaries) do not have any sense of ownership or accountability with regards to the maintenance and protection of the asset; for the *private sector*, solar street lights are a one-time product delivery, with no further contractual obligations for servicing through O&M activities;
- **STANDARDIZATION of O&M practices** – due to unclear share of responsibilities on O&M of street lights, there are no standardized procedures;
- **AWARENESS on O&M practices** – despite a high awareness on the benefits of solar street lights, both for *end-users* and *humanitarian and development sector*, there are no clear incentives for any of the stakeholders to operate and maintain the systems, and also no clear guidance on how to implement such practices.

3.3.2 PV solar systems in public facilities

According to [3], the yearly energy demand of humanitarian and development offices worldwide located in displacement settings amounts to USD 300 million. Most organisations have and still rely on diesel generators for power. Diesel represents 80% of the energy consumption of humanitarian organisations, while 20% of total is spent on solar and national grids, where they exist. Where solar systems are installed, they are usually wrongly sized [3] due to: i) procurement challenges or short-term procurement cycles; ii) familiarity with renewable energy systems; iii) expectations of energy demand increases. Main challenges with the O&M activities for institutional solar are:

- **INCENTIVES for O&M practices** – when agencies procure and own the solar asset, they must take responsibility for the on-going O&M; and this proves to be challenging due to staff rotation,
- **AWARENESS on O&M practices** – low awareness on importance of O&M,
- **STANDARDIZATION of O&M practices** – non-standardized practices for O&M and lack of guidance and training.

Figure 12. Solar system in a health centre. Source: Power for All

4 Recommendations for the Operation and Maintenance of Solar Technologies in Displacement Settings

As response to the three main challenges encountered, namely: lack of incentives, standardization and awareness, the following chapter describes a series of recommendations/proposed actions, categorized by:

- type of recommendation: technical solution, electricity as a service model, voucher System for tracking and repairing renewable energy technologies, awareness and training, feasibility measurements, intra/inter-institutional knowledge exchange,
- type of solar solution (individual or community use),
- effort of implementation (immediate or medium-term). Immediate actions are defined as the interventions which require the least amount of effort (administrative or process related changes) and of cost, and which can bring concrete and fast results. Medium-term actions are defined as the interventions which require cross-sectorial stakeholder consultation and collaboration, changes in operational and administrative procedures, and introduction of new tools and methodologies.

4.1 Technical solutions

4.1.1 Solar streetlights

In order to minimize system failures which are linked to theft and vandalism, immediate technical solutions that can be employed are:

- **IMMEDIATE ACTIONS:**
  - Hardware (e.g., fences and special bolts) and other measures, such as recording serial numbers of panels and other components and, for large procurements, embedding a project or organizational logo under the glass of the solar panel, may help as deterrents [32]
  - An alarm sensor inside[8] of the solar powered streetlight. If the light is touched by someone, it will trigger an alarm and the light will beep. Residents will be alerted if someone is stealing lights and take some measures. This solution is particularly useful for the streetlights installed in residential areas.
  - A GPS (Global Positioning System) inside of the integrated[9] solar streetlights. With the GPS, the location of the lamp can be monitored anytime. If the solar streetlights were stolen, it can be tracked very easily.

8 The price of an alarm sensor can vary depending on manufacturer, from USD 5 to USD 50 per sensor.

9 The price of a solar LED street light with integrated GPS varies, depending on manufacturer and site of order, from USD 400 to USD 700 per piece (light, pole, GPS, battery).

- **MEDIUM-TERM ACTIONS**:
    - Subsidize or incentivize owners of SHS (both households and businesses) to acquire and install an exterior light to act as a safety light. As both the light and the battery are on the premises of the household, there is a decreased risk of vandalism or tampering. The household could generate income by running this extra light or the acquisition price of the SHS could be reduced.

4.1.2 PV solar systems in public facilities

One of the *IMMEDIATE* technical solutions to tackle the wrongly sizing of the solar systems installed in offices is **usage diversification** through the creation of charging stations for batteries or appliances with batteries integrated and interconnection to neighbouring houses. Facilitating access to non-connected users may:

- Assure a constant flow of funds (from the sale of the surplus electricity generated by the solar PV system installed in the public facility) for covering O&M expenses which otherwise would need to be part of multi-annual budgets;
- Replace the risk of underutilizing the solar asset and hence reducing its payback period.

On the *MEDIUM-TERM*:

- depending on the country context, it may be necessary to couple the clean energy investments with particular de-risking measures, or ideally integrate them into the host country's overarching de-risking strategy. The economics of solar PV are affected more by the cost of capital than by the solar irradiation [33]. To this, a significant premium risk for the weak physical and administrative infrastructure are added, increasing drastically the cost of the solar technology.
- An energy demand and supply accounting tool for public facilities can be introduced. This tool should be easy to access and well known to all relevant stakeholders of the camps' energy ecosystems, e.g. by integrating it into existing manuals. Whenever possible, measurements should be taken to capture the load profile of the public facility over time, to decide whether the solar PV installations needs to be equipped with some form of storage system or if additional PV panels need to be installed to increase generation. Additionally, the tool could monitor the selling of electricity to the neighbouring consumers, the cash inflow and it could centralize the O&M processes. The data could be stored in a web-based, openly accessible repository that can be drawn on for statistical evaluation, e.g. to prioritize energy interventions. To speed up the process of developing the corresponding toolkits, UNHCR could draw on readily available open source code, or organize a dedicated hackathon event to have highly skilled, intrinsically motivated labour develop a low-cost but robust pilot solution that can be tested and further developed in the field [33].

4.2 Electricity as a Service

The Electricity as a Service (EaaS) model implies that electricity (and not the asset generating the electricity) is purchased from the energy service company via a long term contract, while the electricity generating asset is maintained by the energy service company. EaaS has several advantages, among which [34]:

- Project risks and responsibilities are transferred to energy service providers
- Financing for capital costs are transferred to energy service providers
- System warranties and service guarantees are provided by the energy service provider
- Enhanced access to know-how and experience from private sector.

4.2.1 Solar lanterns

To tackle the challenges of O&M with solar lanterns, two types of actions can be implemented:

- *IMMEDIATE:*
    - Enforcement of system warranties and service guarantees; UNHCR's technical specifications for procurement of solar solutions generally specify only the minimum criteria for product warranties (per system, per component), but no other incentives or penalties for enforcing contractual warranties
    - incorporation of recollection clauses in the procurement contracts; by forcing manufacturers to recollect used and non-functioning lanterns:
        - Their components could be recycled or refurbished for other systems, hence reducing the waste
        - End-users can be trained on the harm of improperly disposing solar lanterns in landfills or in their immediate environment
- *MEDIUM-TERM:* as there is little enforcement which can be placed on the private sector to provide O&M of solar lanterns, the informal sector could be trained on standardized approaches and frequent practices; as such, the reparability sector in the camp can be strengthened, while offering end-users a sustainable alternative to disposal.

4.2.2 Solar Home System (C-SHS and PP-SHS)

For those C-SHS and PP-SHS which are acquired through, for example, Result-Based Financing programs, one *IMMEDIATE* solution to counter the O&M challenge is the mandatory provision of after-sales servicing, end-user training and recollection clauses in the procurement process. As part of the verified results against which the financing is provided, apart from the number of installed or delivered systems, certain milestones such as the ones below can be considered key performance indicators for approving financing:

- Number of end-users trained on the O&M of their systems
- Number of flyers, brochures and training sessions on O&M
- Frequency of preventive maintenance practices
- Number of recollected components (in-warranty, out-of-warranty).

4.2.3 PV solar systems in public facilities

One possible *MEDIUM-TERM* solution for overcoming the challenges with solar systems in office and other community buildings is **a paradigm shift from asset-based procurement to electricity as a service.** By procuring services rather than assets, a longer-term relationship with a technical provider is assured. Such a relationship implies not only the correct sizing of the solar system and its installation, but also its after-sale services (which incorporate O&M practices and which also provide training to the end-user) and the disposal of the system at its end-of-life. In a typical servicing agreement, various leasing and/or fee-for-service models can be employed: fee-for-power or utility model (in which kWh are charged instead of the cost of the solar asset, for longer-term contracts) or A-B-C[10] models (in which the offices represent the Anchor).

4.3 Voucher System for tracking and repairing renewable energy technologies

In an ecosystem which lacks proper access to standardized O&M procedures, quality-approved spare parts and for which affordability (of quality-approved products and services) is low, the third-party repair services (informal sector) and energy micro-entrepreneurs[11] are thriving, creating informal livelihood opportunities for refugees and host communities [23], [24]. Tapping into this informal market while standardizing practices and raising consumer awareness can be done, in the *MEDIUM-TERM*, through a **voucher system for tracking and repairing renewable energy technologies.**

10 This model builds on three types of customers: i) Anchors (A) – these are daytime loads, predictable in nature, requiring constant delivery of electricity; ii) Businesses (B) – these are local commercial establishments for whom power is a critical input for expanding operations or improving productivity; iii) Community (C) – for them, affordability is a major issue, hence a constant power consumption would not be sustainable.

11 One of the most popular income-generating opportunities available to people in Kakuma is provided by the operation of a simple charging station for batteries and battery-powered devices.

Figure 13. Voucher system for tracking and repairing

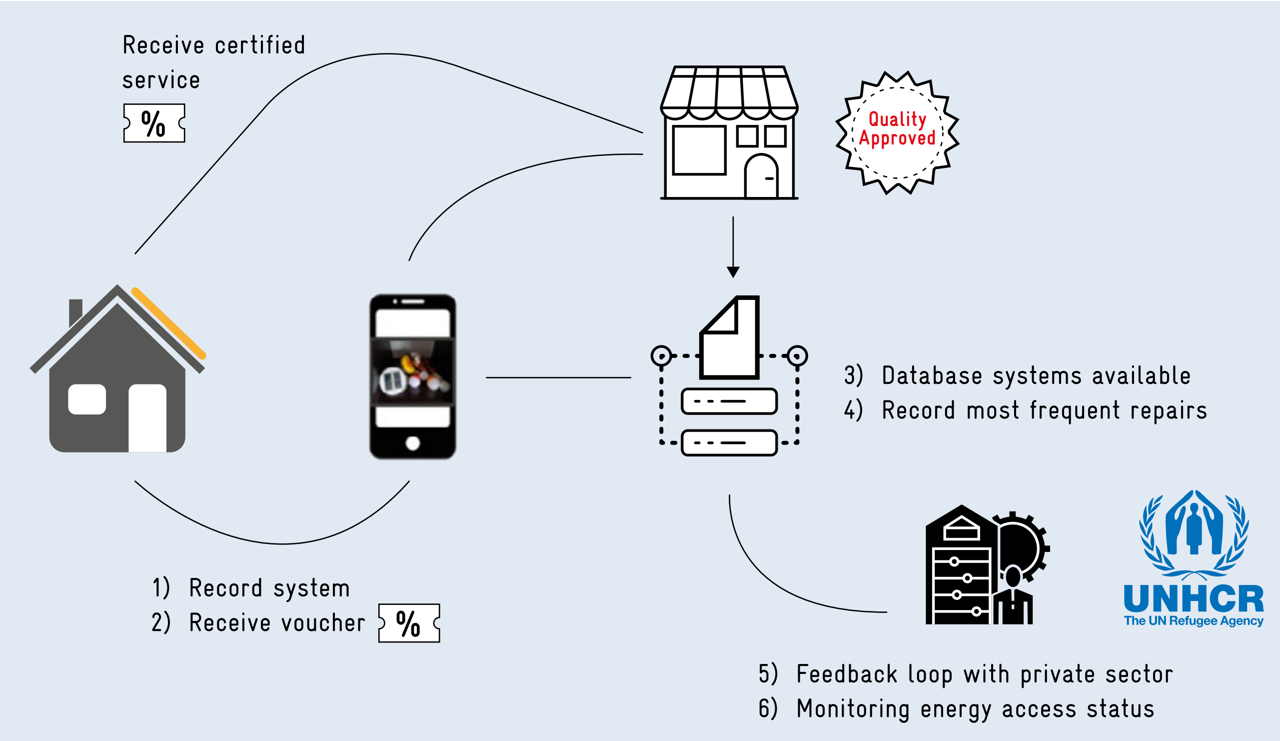


Figure 13 displays the schematic of how such a voucher could work, in 6 steps:

1. *Record solar systems* – energy representatives or technicians of the humanitarian agencies coordinating the camp activities can record, with the support of a mobile phone with a camera, each solar system they come across, irrespective of its brand, quality, method of installation or use.

2. *Assign repair voucher* – for allowing their system to be recorded, households and businesses would receive a repair voucher, with an unique identification number pertaining to the solar system – a free ticket that would grant them access to a repair facility for a one-time free service.

3. *Populate database of systems* – by recording each solar system in the camp, a database of systems can be created.

4. *Record most common services* – the households and businesses would be able to utilize their voucher in one of the Quality Approved shops – these are repair shops which have received a standardized training on repair, O&M and customer care, and have been vetted by the humanitarian agency with a seal/diploma which can be posted in the window shop. As each voucher has an unique identification number connected to the respective solar system, the database of systems will be complemented with information on the type of repair, the system's malfunction, spare parts and other maintenance actions.

5. *Feedback loop with private sector* – the database of systems available in the camp and their technical issues could represent a valuable market insight, both for the private sector and for the humanitarian agencies.

6. *Monitoring energy access status* – through such a system, the real access to energy can be tracked and monitored by recording each time a voucher is used.

The track and repair voucher could bring several benefits, as it represents:

- A bottom-up method to:
    - Formalize the repair market without major policy interventions, but with a conscious support of the consumer, the end-user who will experience a better servicing quality and will understand the difference between low-quality and quality-approved products and services
    - Eliminate low quality products by offering consumers an alternative – repairing their existing systems instead of acquisition of a new, cheaper system
    - Increase acceptance, affordability and ownership of solar systems by intermediating the demand (access to energy) with the supply (formalized services and quality-approved products).
- A quick method for measuring the true energy access status – by recording each of the available systems, the actual tiered access to energy can be assessed.
- An intrinsic method to formalize the repair market – without counting on public policy changes, by providing a standardized training and customer care skills to the already informal repairpersons, and then validating their skills with a Quality Approved seal, the displacement setting's economy can be stimulated and refugee's livelihood formalized.
- Market information – by populating the database of systems and their servicing, the humanitarian sector would have in its hands valuable information, particularly supportive for procurement procedures (when establishing standards for quality, conditions for number of systems, sizes of systems etc.) and RBF programmes (feedback loops with manufacturers/distributors on performance of systems).

In the medium to long term, the voucher system can be digitalized (more on this in 3-in-1 App for O&M practices, glossary and voucher system section of the report). Furthermore, the one-time free voucher can be expanded and included in other programs such as the work-for-food ones or as part of the monthly monetary support received by refugees. At the same time, the voucher system could also be an entry point for smart subsidies or a form of cash-for-work donation, supported by the humanitarian and development sector.

4.4 Awareness and training

4.4.1 Solar lanterns

Generally, solar lanterns require minimal end-user actions for their O&M. The most common practices are: keeping the PV panel free of dust, making sure the lantern is not placed in a humid environment, optimal times for charging the mobile phone, maintaining charging ports free of dust or water, making sure the charging port is not damaged (either by trying to bypass it in order to connect non-matching appliances or simply when opening the packaging of the lantern). Particularly when they are included in welcome packages for refugees, as an *IMMEDIATE* action, solar lanterns, irrespective of their brand, could be accompanied by visual materials (brochures, flyers) that display the best practices for O&M and guide the end-user on their disposal. Additionally, posters could be shown in the windows of business or repair shops to further raise awareness.

4.4.2 Solar home systems (MM-SHS)

Although generally, the quality of the each of the components of an MM-SHS is lower than C-SHS or PP-SHS, their performance and actual return on investment for the end-user can only be validated through a technic-economic investigation and surveying of energy system satisfaction. Assuming that the majority of MM-SHS have non-verified quality or low-quality components, their lifespan and system usage can be prolonged or maintained through O&M practices. As an *IMMEDIATE* action, raising awareness on such practices can be done through:

- Demonstration campaigns, held in market places, next to community buildings, at moments of high fluctuation of people
- Distribution of visual material and placement of posters in areas of interest.

4.4.3 Solar street lights

In some situations, however, basic security is a risk due to conflicts or other reasons. The most promising IMMEDIATE strategy may be to strengthen community and staff awareness and roles in ways that align their interests with system sustainability and their perception as beneficiaries of the systems. Community participation (e.g., via field surveys and consultations on implementing responsibilities, such as maintenance-costs contributions and system ownership) may be particularly effective in helping to protect the systems [32]. Awareness raising campaigns have made people open up more and report more cases of vandalism and stealing. Community policing and watch groups patrol solar lights at night and ensure that lights are maintained and cleaned (Uganda Rhino Refugee camp). The residents of Obudu explained that due to the village's strong leadership and sense of community, none of the solar lights was vandalized or had panels stolen. This shows that village demographics is a factor in terms of safety of Solar street lights [35]. In the camp for Rohingya refugees in Cox's Bazaar, Bangladesh community members and volunteers have been trained in care and maintenance of lights and how to build a sense of community ownership over them. Community maintenance groups has helped reduce these risks and foster a community-based ownership and working with all parts of the refuge community to decide where the lampposts go and train them to look after these [36].

4.5 Feasibility measurements

One of the most common challenges for enhancing the private's sector participation in energy access programs in displacement settings is the access to market information. The operational costs for a private enterprise for conducting its own data collection and analysis are too high relative to the perceived potential market share it could attain. As the humanitarian organizations are, ultimately, the ones coordinating and having most access to the displacement setting, on the *MEDIUM-TERM*, a series of in-depth data collection activities could be conducted on:

- Qualitative and quantitative measurement on:
  - Ability and willingness to pay for i) solar systems, ii) repair services
  - Access to formal and informal financing: SACCOs, MFIs, remittances
  - Cost with current energy expenditure and opportunity cost (e.g. for gathering alternative sources of fuel)
  - Range and quality of informal repairing and servicing in the setting
  - Disposal of solar system components
- End-user habits: disposal or retention?
- Informal collectors, informal recycling.

A repository of data points could be developed and made available to the private sector, to support the decision-making process and help enterprises adjust product-service offering.

4.6 Inter/intra-institutional working groups for knowledge exchange

Awareness raising and access to information represent a challenge not only for the end-user, but also for the humanitarian institutions active in the displacement settings. The topic of energy access, which incorporates not only access to electricity, but also cooking, productive use, is a complex one, addressing not only the initial access to a technology, but also maintaining demand and supply, increasing usage, building entrepreneurship, and disposing of end-of-life equipment. For each of these subjects, there are several initiatives and pilots tested in displacement settings across the world, by numerous humanitarian organizations and development aid institutions. In order to keep track of these, but also to assure cross-country/cross-region and inter-and intra-institutional collaboration, a series of actions can be employed:

- *IMMEDIATE* – creation of a series of working groups, which meet regularly and have:
  - Theme based meetings – for example, on the topics of first energy access, operation of different technologies and appliances, productive use, operation and maintenance, end-of-life of components
  - In- or cross-country participants – for the synchronization of processes, sharing of lessons learned and peer-to-peer communication of problems and solutions
  - External speakers – specialists on the topics under discussion, who can share latest innovations, expert opinions, best practices.

- *MEDIUM-TERM* – creation of a standardized repository, filled in a decentralized manner, with information on:
  - Challenges and innovative solutions
  - Local/regional contacts
  - Examples of best practices, case studies (both successful and un-successful)
  - Link to public resources: reports, videos, podcasts.

5 Tools for Operation and Maintenance Practices

As part of the immediate actions that can be taken in order to i) raise awareness, ii) standardize terminology and practices across settlements, iii) lower the knowledge threshold with the O&M of renewable energy technologies, two excel based tools have been developed. The tools can be accessed **here**. Once downloaded, the tools can be used offline, on mobile phones or computers, or their content can be printed.

5.1 Maintenance plan for off-grid solar PV solutions

The Maintenance Plan for Off-Grid Solar PV Solutions tool covers preventive maintenance, best use practices, common malfunctions and defects experienced for the Operation and Maintenance of: pico-solar PV systems, solar home systems (SHS), component based SHS and solar water pumps. The sections covered by the tool include the following:

Worksheet	Description
MP_PicoPV	Maintenance plan for Pico PV systems (<10W to 15W)
MP_SHS	Maintenance plan for Solar PV systems (10W - 350W)
MP_Pump	Maintenance plan for Solar Water Pump (SWP) System
Warranties	Typical warranty terms for Pico PV, Solar Home Systems (including component based and street lights), and Solar Water Pumps
Frequent Malfunctions	List of frequent malfunctions disaggregated by application, cause, maintenance action and resources required to complete recommended action
Protocols	This tab contains information applicable to all the applications, consisting of the following tables: - Procedures for Testing: Complimentary to 'Frequent Malfunctions' worksheet, indicating procedures for component testing - Technician Toolkit, listing O&M equipment for all fundamental procedures - Description of 'Skilled Solar PV Technician'

5.2 Glossary of Operation and Maintenance terminology

The structure of the Glossary covers multiple renewable energy technologies and storage applications. The terms in the Glossary are also mapped against different stages of product or system lifecycle. A description of the Glossary's individual sections follows below:

Worksheets	Description
Glossary	*The list of terms are defined in the context of :--* *(i) Solar photovoltaic applications, including storage* *(ii) Off-grid solutions, and therefore standalone applications* *(iii) Humanitarian context, that is, settlements / camps for forcefully displaced persons (where applicable)* *They are categorised by 'Product / System Lifecycle' and 'Applicability'. The filter provided can be used to sort relevant terms.*
Sources	*The definition of the terminology is derived from a combination of sources, which are listed under this table.*
Filters for Sub-group	**List of Applications and Related Services**
Product / System Lifecycle	
Stages	MAN: Manufacturing
	OPN: Operation
	MAI: Maintenance
	EOL: End-of-Life
All off-grid solutions	
Solar products and systems	Solar Lanterns
	Solar Home Systems (SHS)
	Solar Pumping Irrigation System (SPIS)
	Rooftop Solar PV System (RSPV)
	Solar Street Lights
Off-grid Storage	Solar batteries - Lithium Ion
	Solar batteries - Lead Acid, Flooded / Valve Regulated
Fuel generators	Diesel Generators
	Petrol Generators
Components	Solar PV panel
	Solar inverter
	Charge controller
	Battery
	Balance of system (cables, connection box, protective equipment, etc.)
Financial services for solar products	Pay-as-you-go
	Voucher based payment
	Micro-credit

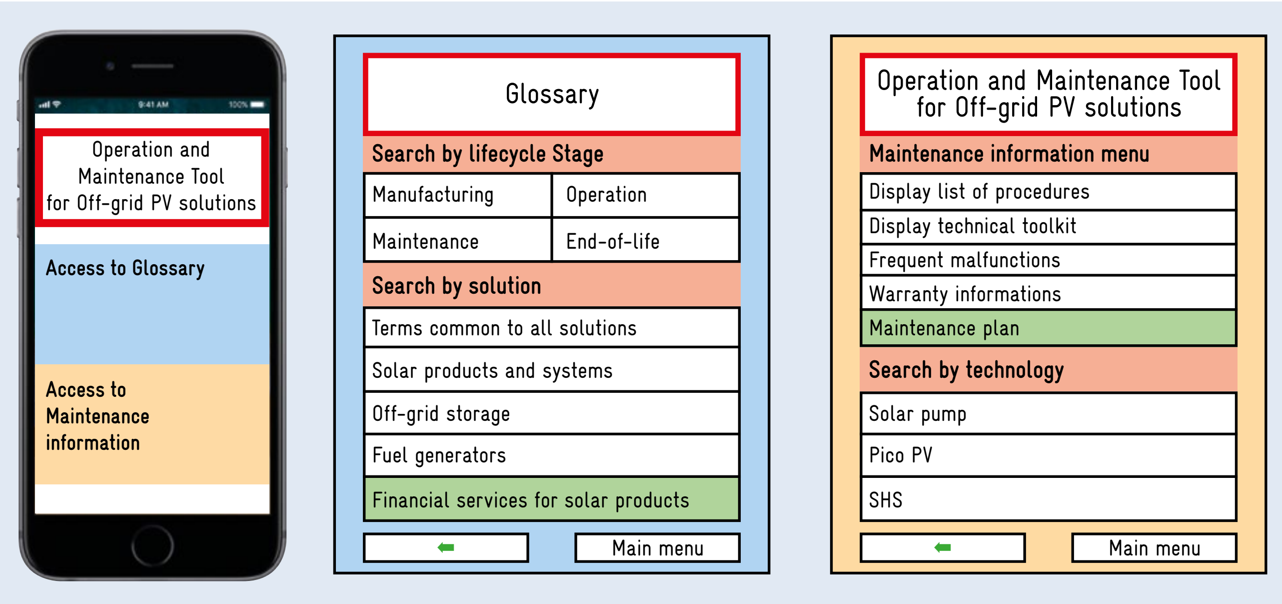
5.3 Digitalization potential of O&M tools with smart mobile solutions

2-in-1 Mobile App for O&M practices and glossary

The two Excel-based tools, the Glossary of O&M and the Maintenance Plan, have been developed in a simplified logical framework that would allow for their smooth transformation into mobile phone applications, accessible both online and offline. In such way, both tools could also be integrated into one common app, as in Figure 14. 2-in-1 App for O&M practices, which can allow for:

- Centralized monitoring of most frequently accessed topics and terms
- Decentralized monitoring of maintenance and operation protocols
- Centralized monitoring of the most common renewable energy technology malfunctions
- Easy and fast content update and/or correction
- Monitoring of the impact of the operation and maintenance activities
- Easy on-boarding of new personnel with little or no technical knowledge.

Figure 14. 2-in-1 App for O&M practices and glossary

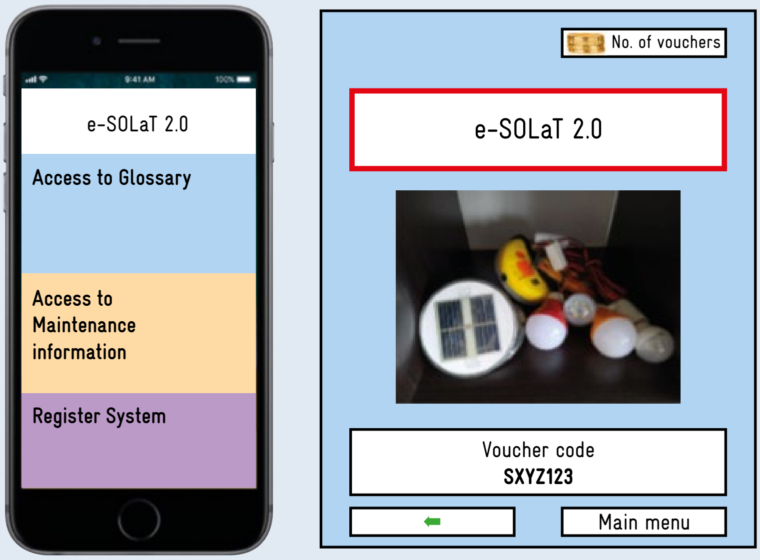


3-in-1 App for O&M practices, glossary and voucher system

In the medium-run, the app for O&M practices and glossary can be further expanded with a digitalized version of the voucher system, as recommended in 4.3 Voucher System of this report. Entitled e-SOLaT, the app could allow users to register renewable energy technologies by simply photographing them and automatically assigning vouchers to their owners. Such an app would require a mobile phone with a camera; the app could be used offline, and its content uploaded once it connects to the internet. In the medium and long-run, e-SOLaT can:

- Allow development aid and other donors to easily identify and track the types of renewable energy systems and their performance
- Assure transparency in the performance monitoring of renewable energy systems
- Eliminate in a bottom-up manner the low-quality products
- Track the needs for technical training, access to tools and materials for the reparability of the renewable energy systems
- Create, across countries and across displacement settings, a database of renewable energy systems (quality, status, performance).

Figure 15. 3-in-1 App for O&M practices, glossary and vouchers



Possible voucher coding	
Solar Pumps	PAAA000
Pico PV	LAAA000
SHS	SAAA000

References

[1] U. N. H. C. for Refugees, "UNHCR - Refugee Statistics," *UNHCR*. https://www.unhcr.org/refugee-statistics/ (accessed Oct. 06, 2021).

[2] U. N. H. C. for Refugees, "Figures at a Glance," *UNHCR*. https://www.unhcr.org/figures-at-a-glance.html (accessed Aug. 31, 2021).

[3] Dalberg and Vivid Economics, "Access to more: creating energy choices for refugees," Shell International, Jul. 2020.

[4] "Country - Ethiopia." https://data2.unhcr.org/en/country/eth (accessed Aug. 31, 2021).

[5] WINS Global Consult GmbH, "Context and Conflict Analysis for Gambella, Ethiopia," ESDS, Sep. 2020.

[6] Dertos Trading and Consultancy PLC and GIZ, "Ethiopia: Analysis of Regional Regulations, Stakeholders and Energy Assessment Gaps," ESDS, Sep. 2020.

[7] F. Carver, F. Gebresenbet, and D. Naish, "Gambella regional report. 2018 - 2019 refugee and host community context analysis," UKaid, Danish Refugee Council, Dec. 2020. [Online]. Available: https://cdn.odi.org/media/documents/Gambella_regional_report_20182019_refugee_and_host_community_context_analysis.pdf

[8] GSMA, "Humanitarian cash and voucher assistance programmes in Ethiopia: Context analysis and capability assessment of the mobile money ecosystem." https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2021/03/Ethiopia_CCD_Report.pdf (accessed Aug. 31, 2021).

[9] "Country - Kenya." https://data2.unhcr.org/en/country/ken (accessed Oct. 08, 2021).

[10] A. Betts, N. Omata, and O. Sterck, "The Kalobeyei Settlement: A Self-reliance Model for Refugees?," *Journal of Refugee Studies*, vol. 33, no. 1, pp. 189–223, Mar. 2020, doi: 10.1093/jrs/fez063.

[11] UNHCR, "The Kalobeyei Integrated Socio-Economic Development Programme. Phase One: 2018 - 2022 Comprehensive Refugee and Host Community Plan in Turkana West, Kenya," UNHCR, 2018. [Online]. Available: https://www.unhcr.org/ke/wp-content/uploads/sites/2/2018/12/KISEDP.pdf

[12] K. Groen, S. Hounsell, H. Merjin, and J. M. Njogu, "Access to Energy for (Micro) Businesses in Kakuma Refugee Camp and Kalobeyei Integrated Settlement," endev, Nov. 2020.

[13] UNHCR, "UNHCR Monthly Operational Update," Aug. 2019. https://reliefweb.int/sites/reliefweb.int/files/resources/1%20%2031%20August%202019_%20Operational%20Update%20for%20Kakuma%20and%20Kalobeyei_.pdf (accessed Aug. 31, 2021).

[14] "Country - Uganda." https://data2.unhcr.org/en/country/uga (accessed Oct. 06, 2021).

[15] N. Omata, "Uganda's Refugee Policy: Recent Trends and Challenges | bpb," *bpb.de*. https://www.bpb.de/gesellschaft/migration/laenderprofile/305651/uganda (accessed Sep. 08, 2021).

[16] L. Thin and B. Lewin, "Handbook. Communication and Marketing Strategy for off-grid energy products in Uganda," GIZ, 2020.

[17] Asigma Project and Data Management Services Ltd, "Energy Analysis Report - Sustainable use of natural resources in the refugee context in Uganda," GIZ, Uganda, 2018.

[18] Centre for Research in Energy and Energy Conservation, "Baseline Assessment for Market-Based Energy Access for Scale Up Projects in Refugees Settlements in Uganda," GIZ, May 2020.

[19] "VeraSol Product Database - Solar lantern." https://data.verasol.org/products/sek/sino-l2t?viewall=true (accessed Oct. 08, 2021).

[20] "VeraSol Product Database - Solar lantern In-built PV panel." https://data.verasol.org/products/sek/yl-sm100?viewall=true (accessed Oct. 08, 2021).

[21] "VeraSol Product Database - Solar lantern with charging port." https://data.verasol.org/products/sek/sino-sali?viewall=true (accessed Oct. 08, 2021).

[22] "Improving the accuracy of our impact reporting through the Multi-Tier Framework," *Lighting Africa*, Nov. 01, 2016. https://www.lightingafrica.org/improving-accuracy-impact-reporting-multi-tier-framework/ (accessed Oct. 08, 2021).

[23] R. Spear, J. Cross, J. Tait, and R. Goyal, "Pathways to Repair in the Global Off-Grid Solar Sector," Efficiency for Access, 2020.

[24] O. Grafham, G. Lahn, J. Cross, M. Douglas, and C. Martin, "Energy and Displacement. Eight Objectives," *Chatham House – International Affairs Think Tank*. https://www.chathamhouse.org/2019/11/energy-and-displacement-eight-objects/1-introduction (accessed Apr. 10, 2021).

[25] K. Groen, "Promoting Market Based Energy Access for Cooking and Lighting in Kakuma Refugee Camp," GIZ, SNV, Jul. 2020.

[26] D. Corbyn and M. Vianello, "Prices, Products and Priorities. Meeting Refugees' Energy Needs in Burkina Faso and Kenya," Practical Action, Jan. 2018.

[27] "Fig. 2. Typical solar home system components [13].," *ResearchGate*. https://www.researchgate.net/figure/Typical-solar-home-system-components-13_fig2_347433706 (accessed Oct. 07, 2021).

[28] A. Kundu and K. Ramdas, "Timely After-Sales Service and Technology Adoption: Evidence from the Off-Grid Solar Market in Uganda," *SSRN Journal,* 2019, doi: 10.2139/ssrn.3477210.

[29] Mercy Corps, Mastercard, and Center for Inclusive Growth, "Paying for Darkness. Strengthening Solar Markets for Refugees in Uganda," Mercy Corps, Nov. 2019.

[30] S. Zafar |, "Unending Benefits of Solar Street Lights | BioEnergy Consult," Jun. 13, 2021. https://www.bioenergyconsult.com/solar-street-lights/ (accessed Oct. 07, 2021).

[31] Luxman, "How to Maintain All In One Solar Street Lights," *LUXMAN,* Sep. 25, 2019. https://www.luxmanlight.com/how-to-maintain-all-in-one-solar-street-lights/ (accessed Oct. 07, 2021).

[32] The International Bank for Reconstruction and Development, World Bank, and Africa Renewable Energy Access Program, "Photovoltaics for Community Service Facilities. Guidance for Sustainability," World Bank, Washington D.C., 63225, 2010.

[33] J. Ossenbrink, P. Pizzorni, and T. van der Plas, "Solar PV systems for refugee camps. A quantitative and qualitative assessment of drivers and barriers," Group for Sustainability and Technology, ETH Zurich, Jan. 2018. [Online]. Available: https://ethz.ch/content/dam/ethz/special-interest/mtec/mtec-department-dam/news/files/solar-pv-in-refugee-camps

[34] UNITAR and GPA, "How to Insure Long-Term Activities in Short-Term Funding: A Guarantee Mechanism in Humanitarian Energy Contracts." https://www.humanitarianenergy.org/assets/resources/HNPW_Technical_Meeting_on_Guarantee_Mechanism_for_Energy_Contracts_-_27_April_2021.pdf (accessed Oct. 07, 2021).

[35] UNHCR, "How Night-Time Street Lighting Affects Refugee Communities. A Population-based assessment of community lighting in Northern Uganda's Rhino Camp refugee settlement," Dec. 2017.

[36] "Lighting up the lives of Rohingya refugees," *Elrha.* https://www.elrha.org/project-blog/lighting-up-the-lives-of-rohingya-refugees/ (accessed Sep. 10, 2021).

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