A Review and Estimation of the Economic Performance of Off-grid Solar in Rwanda

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Abstract

Rwanda's electrical grid access grew from 6% in 2000 to 37% in 2019. Despite this remarkable growth in the energy sector and the economy, there is still a lot to achieve. In 2014, off-grid systems were introduced in the country and have grown to 14% of electrical users. Therefore, the current status of electricity access is 51% (where 37% is on-grid and 14% is off-grid). Half of the population still lives without electricity access. Grid connected customers face high electricity tariffs and frequent power outages.
Rwanda seeks to achieve universal electricity access (100% access) by 2024. The National Electrification Plan (NEP) details how universal access will be achieved by extending the national grid up to 52% and grow the off-grid industry up to 48% where 1.4 million households will be connected by off-grid systems and mini-grids. Many companies offer off-grid solar products to supply this growing market. A bulletin was created to guide new potential consumers in the process of comparing products and making decisions about which are the best fit products and the best economical investment. The bulletin details the decision-making process including simple and quick ways of making calculations of Levelized Cost of Energy (LCOE).

Descriptions and Definitions

An off-grid solar system is simply a solar system installed without connection to the electricity grid. The following are the main components of an off-grid solar system:

- Solar panel: The solar panel is the main power supply for the off-grid house..
- Charge controller: The charge controller manages the power going into the battery from the solar array. It also ensures the batteries do not overcharge.
- Batteries: (also could be named as power bank), store energy for later consumption. It has two types which are Lead Acid battery and Lithium-ion. Both chemistries work well with off grid solar. Capacity, cost, and life of the battery are important considerations.
- Load: these are commonly known as appliances and are powered by the system.

There are two kinds of off grid systems:

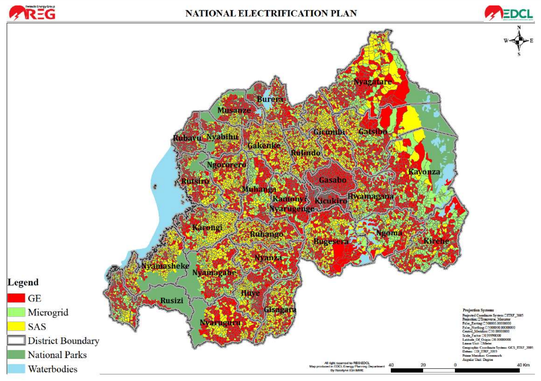
- ✓ Direct Current (DC) off-grid system (DC appliances)
- ✓ Alternate Current (AC) off-grid system: (AC appliances), an inverter would be needed to convert DC to AC power
- ✓ Inverter: An inverter is a device that converts DC (Direct Current) into AC (Alternate Current) and this enables you to power AC appliances.

TABLE 1: Multi-tier framework summary descriptions of different connection tiers for off-grid solar detailed in the Rwandan Rural Electrification Strategy

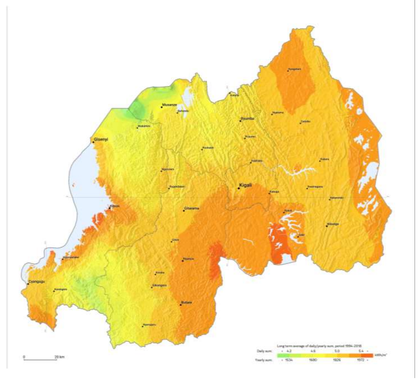
LEVEL	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Energy usage	Household lighting, radio, and phone charging	Household lighting, lighting, radio, phone charging, and basic appliances (e.g., televisions, fans)	Tier 2 plus medium appliances, such as low-power refrigeration	Tier 3 plus high-power appliances, such as pumps pumps for irrigation	24/7 power suited to commercial and and industrial uses
Minimum hours of access access per day	4 hours	4 hours	8 hours	16 hours	23 hours

This table above shows the Multi-Tier Framework prepared by the Rwanda's Rural Electrification Strategy (RES). The off grid must at least meet the conditions of Tier 1 category to be considered as electrified.

Off Grid Solar in Rwanda



The figure above is the masterplan for 2024 that shows the areas planned for Grid expansion(GE), Mini-grids, and Off-grid: Stand-Alone Solar (SAS). In the past there was uncertainty regarding what areas would be served by the national grid or rely on off-grid and mini-grid.



This figure above shows the solar resource for Rwanda. It shows the average daily sum of global horizontal irradiation (GHI) covering a period of 25 years (1994-2018). The data is from the Solargis model using satellite data (World Bank, 2019).

Results and Comparisons

Goals

Solar Customers should make a list of your needs and wants. Needs would be loads you must have and wants would be some appliances or services you wish to have. This list will help you when selecting from solar kit options offered by solar companies. The solar kit should meet all your needs, then depending on price you may consider if it is affordable to select a solar kit which includes some of your wants.

Comparison

It is advisable to only compare similar products. For example, you should not compare tier 1 and tier 3 products because they are significantly different.
Effective calculations/ ways of comparing systems are:

- Monthly costs
- Total cost

$$Downpayment + (Monthly\ cost\ \times\ Months)\ = Total\ Cost$$

- Annual energy estimate (Calculation Method) (kWh)

$$\text{System Capacity (Watts X 1000)}\ \times 5\ peak\ sun\ hours\ \times 365\ days\ \times Derate\ (0.75)\ = Annual\ energy\ (kWh)$$

  - Peak sun hours vary by region but the average for Rwanda would be 5 hours per day. These estimates are confirmed by comparison to the National Renewable Energy Laboratory (NREL) solar estimation model (System Advisor Model (SAM)).

- Levelized cost of energy (LCOE) (Rwf/kWh)

$$\frac{Total\ Cost\ (Rwf)}{Lifetime\ production\ (Annual\ production\ \times 10\ years)} = LCOE$$

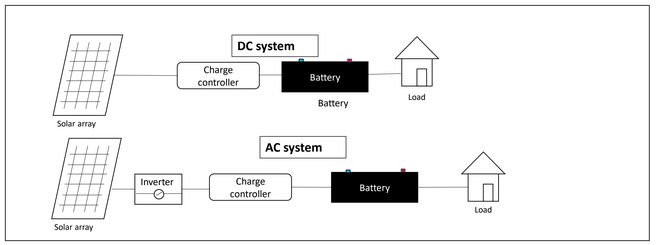
Tier 1 product example. This kit consists of appliances like radio, table lamp, lamps, battery and a solar array. These products above are offered by ENGIE Mobisol Rwanda. Source: https://www.mobisol.rw/rwanda/

Table 2: Estimated Solar Production for 100-Watt Solar Array

City	Estimated Energy Production from the System Advisor Model (kWh/year)	Peak Sun Hours per day (Global Horizontal Irradiation) (kwh/m2/day)	Estimated Energy Production from Calculation method using 5.0 peak sun hours	Percentage compared to SAM estimate
Kigali City	149	5.226	137	91.9%
Rusizi	134	5.085	137	102.2%
Musanze	127	4.669	137	107.8%
Huye	134	5.209	137	102%
Muhanga	148	5.085	137	92.5%
Nyagatare	143	5.247	137	95.8%
Rubavu	136	4.959	137	100.7%

Conclusions

Rwanda's vision of electrifying its entire population by 2024 will be achieved by adopting off-grid systems and mini-grids. Most of the off-grid systems that are being adopted are using solar energy. This bulletin was written to guide Rwandan citizens who will be adopting these off-grid solar systems to know what products they should pick based on their budget and their needs. Procedures were recommended for a potential off-grid solar system consumer to follow to decide which systems to use. Some forms of calculations and worksheets were proposed to help Rwandan citizens to pick the solar products of their best fit. The bulletin does not recommend any company's product because consumer's needs and budget differ.
It is important to know what is planned for your area in the National Electrification Plan. This will save consumers' money who were in areas that were planned to be connected to the grid or through mini-grids in a few years who had plans to buy off-solar systems. After making sure that you will need a Solar Home System (SHS), proceed with the system selection and economic analysis. It is crucial to understand your goals for now and 5 years ahead, to predict what is the best fit for your house. Needs may change over time; however, you need to think about expandable systems if you decide to buy SHS. This bulletin equipped consumers with simple and effective ways of calculation and comparing costs (Total costs and Levelized Cost of Energy) that can help them make good decisions of which solar products fit their needs and budget.
In my project I experienced the difficulty of finding data to compare solar products sold in Rwanda because of lack of effective communication of some companies where some may not provide certain information when they do not see one as a potential customer.



Acknowledgement

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