Session 2

Off-grid PV systems, Technologies and Innovations for rural area electrification
(experience in case of Ethiopia)

Presented by: Yonas Workie (Ind. Eng. MSc.), Managing Director of Sun Transfer Tech PLC
Off-grid population in Africa is far out pacing the extension of the grid, the number of people living off the grid has grown by 144 million on the continent since 2000. (Source: off-grid solar market trends report 2016 by Bloomberg and lighting global)

**Figure 1: Share of population without grid access (percent of total)**


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off-grid population

(Source: off-grid solar market trends report 2016 by Bloomberg and lighting global)

Figure 2: Off-grid population in sub-Saharan Africa (million)

<table>
<thead>
<tr>
<th>Country</th>
<th>Off-grid</th>
<th>On-grid with unreliable access*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nigeria</td>
<td>93</td>
<td></td>
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<tr>
<td>Ethiopia</td>
<td>67</td>
<td>4</td>
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<tr>
<td>Congo, Dem. Rep.</td>
<td>56</td>
<td>2</td>
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<tr>
<td>Tanzania</td>
<td>36</td>
<td>2</td>
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<tr>
<td>Kenya</td>
<td>32</td>
<td>2</td>
</tr>
<tr>
<td>Uganda</td>
<td>31</td>
<td>1</td>
</tr>
<tr>
<td>Sudan</td>
<td>26</td>
<td>5</td>
</tr>
<tr>
<td>Madagascar</td>
<td>19</td>
<td>1</td>
</tr>
<tr>
<td>Niger</td>
<td>160</td>
<td></td>
</tr>
<tr>
<td>Mozambique</td>
<td>151</td>
<td></td>
</tr>
</tbody>
</table>

Ethiopia:
Some study also suggest Off-grid population in Ethiopia is now more than 70 million, there are more than 14 million rural house holds which needs SHS.
Off-grid PV system technologies and innovation trend

- **Solar lantern**
- **Entry level portable lights**

  - All in one portable lamps
  - One or two lighting mode
  - Gives up to 5X brighter than kerosene lamps
  - Meets Lighting Global Minimum Quality Standards
  - Market target for such products are those rural areas with serious cash shortage.
  - Meets Lighting Global Minimum Quality Standards
  - Retail price 10 to 15 USD/ in ET

Fig 3: Entry level portable lights

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Off-grid PV system technologies and innovation trend

- Solar lantern
  - Larger portable light
  - Mid segment lanterns

- High brightness (up to 100lm) with up to 3 lighting modes
- Can charge cellphones
- Gives 20x brighter than kerosene lamps
- Meets Lighting Global Minimum Quality Standards
- Retail price 30 to 40 USD/ in ET

Fig 4: mid segment portable lights

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Off-grid PV system technologies and innovation trend

- **Solar lantern**
  - Larger portable light
  - Larger portable light

- **Has ultra brightness** (up to 300lm) with up to 5 lighting modes
- **Can charge cellphones**
- **Gives 30x brighter than kerosene lamps**
- **Meets Lighting Global Minimum Quality Standards**
- **Retail price** 41 to 52 USD/in ET

*Fig 5: larger portable lights*

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Off-grid PV system technologies and innovation trend

- **Pico Photovoltaic (PV) systems**
- **Solar home systems**
- **DC solar home systems**
- **Plug and play types**

- Usually 2 to 6 light points including cell phone charging, and radio connection capability, typical PV range from 5 to 20Wp.

- From 1 up to 3 lighting mode, very easy installation can be done by the end user.

- For lamp connection the products will have either cylindrical power jack or USB sockets

- Includes from 6 to 8 meters cable for each lamp

- Modularity option is there

- Meets Lighting Global Minimum Quality Standards

- Retail price 105 to 190 USD/in ET

Fig 6: plug and paly type of DC SHSs

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Off-grid PV system technologies and innovation trend

- **Solar home systems/bigger than Pico PV systems**
  - **DC solar home systems**
    - **Installed type**
      - Usually 12V based system: 20WP to 100WP
      - Has an option to connect more rooms of house with relatively improved length of cable
      - User has flexibility to choose number and type appliances to power: more light? Including TV/ radio /tape recorder
      - Pay as you go option
      - Retail price 272 to 900 USD/ some including TV/ in ET

![Fig 7: installed type of DC SHSs](image-url)
Off-grid PV system technologies and innovation trend

- Solar home systems/bigger than Pico PV systems
  - AC/DC solar home systems
    - Usually 12/24V based system: 100WP to 2 kWp
    - Low range: rural house holds
    - Bigger range: health centers, schools and offices
    - Also includes DC appliances like DC fridges
    - Retail price 1800 to 20500 USD/ some PV systems includes solar fridges/ in ET

Fig 8: installed type of AC SHSs

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Off-grid PV system technologies and innovation trend

- larger off-grid PV systems
  - Solar water pumping systems
  - Surface pumps
  - Submersible pumps

- Water requirement includes per capita water determination of per capita water requirements for the different group of users (people, livestock) and the total number of users in each group.

- Information about the water source including type (surface, well), water quality, water availability throughout the year, location and elevation of the source should be provided. Such data will be available from water source developers such as local government or NGOs.

- Water storage tanks are required for potable water supply systems. The water tank is usually sized to provide several days of the water demand. It is sized by multiplying the daily water requirement by the days of storage required.

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Off-grid PV system technologies and innovation trend

- Larger off-grid PV systems
- Solar water pumping systems
- Surface pumps

**Questioner for water pumping system sizing**

*Please check the two schematic drawings below for clarification of technical words*

- Country: ----------------------------
- Location: --------------------------
- Volume of water required per day (m³/day): -----------------------------
- Borehole/well diameter (inch): ------------------------------------------ only in case of borehole
- Pipe diameter (inch): ----------------------------------------------- (from borehole to reservoir)
- Borehole/well total depth (m): ---------------------------------------- only in case of borehole
- Static water level (m): ----------------------------------------------- only in case of borehole
- Pumping Water Level (m): ------------------------------------------- only in case of borehole
- Distance from the river/lake to the pump (m): ------------------------- only in case of surface pump
- (suction head)(m): ----------------------------------------------- only in case of surface pump
- Distance from borehole/water well/lake/river to tank (m): ------------
- Elevation difference/vertical head from pump up to water tank (m): ---------
- Tank height above ground level (m): --------------------------------------
- Tank volume (m³): -----------------------------------------
- Maximum steady state borehole yield (lit/s): ----------------------------

Fig 9: schematic drawing of surface water pump system
Off-grid PV system technologies and innovation trend

- larger off-grid PV systems
- Solar water pumping systems
- Submersible pumps

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Questioner for water pumping system sizing

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- Distance from borehole/water well/lake/river to tank (m):--------------------
- Elevation difference /vertical head from pump up to water tank (m):-------------------------
- Tank height above ground level (m):-----------------------------------
- Tank volume (m3):-----------------------------------------------
- Maximum steady state borehole yield (lit/s):-------------------------

Fig 10: schematic drawing of submersible water pump system
Off-grid PV system technologies and innovation trend

- **PV component Technology trend**
- **PV modules**

  - Multi crystalline panels are the most popular in the Market
  
  - The price of PV modules has come down in real terms from 75$/W in 1976 to 0.61$/W in 2015 (Source: off-grid solar market trends report 2016 by Bloomberg and lighting global)
  
  - Panels for off-grid solar home systems in developing countries like Ethiopia are usually 5 to 100WP and the cost of these panels has come down less than the standard one which are usually 200 to 300WP, this is because many of the steps involved in manufacturing of modules (lamination, tabbing, soldering) takes the same amount of time on the machine whatever the size it is. (Source: off-grid solar market trends report 2016 by Bloomberg and lighting global)

Fig 11: solar modules
Off-grid PV system technologies and innovation trend

- PV component Technology trend
- Solar battery

![Image of battery types](image)

Fig 12: solar batteries

- Traditionally, for off-grid PV systems we used lead acid batteries because these were the cheapest available in the market.

In the pasty five to six years advances made in lithium-ion based technology due to its widespread use in laptop computer and other consumer devices, which makes it cheap enough to be the preferred technology, besides cost, Lithium based batteries are providing longer life cycle and higher depth of discharge, has ability to store more energy per unit weight/size
Off-grid PV system technologies and innovation trend

- PV component Technology trend
- LED (light emitting diodes)

![Lighting, LED, CFL, High power LEDs]

Fig 13: DC lamps

- The advancement of LED technology for off-grid PV systems makes solar home systems cheaper compared to solar home systems with standard lamps. The efficiency of high power LED lamps already doubled from 70lm/W in 2007 to 135lm/W in 2013, which makes solar home system size to become significantly smaller size for almost equivalent brightness. (Source: off-grid solar market trends report 2016 by Bloomberg and lighting global)
Off-grid PV system technologies and innovation trend

- PV component Technology trend
- Charge controllers with Pay as you go Technology for off-grid energy access

## PYG Technologies

<table>
<thead>
<tr>
<th>On Network</th>
<th>Off network</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Solar products are connected directly to the cellular network via embedded M2M module + SIM.</td>
<td>• PAYG hardware does not connect with the GSM network.</td>
</tr>
<tr>
<td>• Customers pay via mobile money, software sends a message directly to the solar device to “unlock” prepaid services via the cellular network.</td>
<td>• Customers pay cash to appointed agents for prepaid energy voucher/credit/scratch card, which is validated via SMS. Software generates unique usage code manually entered into solar device.</td>
</tr>
<tr>
<td>• Typically requires a tight partnership with a MNO for SIM cards and access to discounted data/SMS/mobile money.</td>
<td>• Does not require a formal relationship with an MNO.</td>
</tr>
</tbody>
</table>

Indigo Duo’ (Azuri Technologies) using M-Birr mobile phone transfer

Suntransfer SHS using software generated code to be entered manually
Off-grid PV system technologies and innovation trend

- **PV component Technology trend**
- **Charge controllers with Pay as you go Technology for off-grid energy access**
  - How it works/ON Network type of PAYG systems

- **For example:** Angaza Design products, upon receipt of a mobile payment, the company’s software initiates a voice call to the end-customer’s registered mobile number, which the customer then holds next to the PAYG product to communicate proof-of-payment and usage authorization data via audio tones.

Fig 14: Loading proof-of-payment to the SoLite3 product (Angaza Design, Inc.) (Source: Access to Energy via Digital Finance: Overview of Models and Prospects for Innovation by CGAP 2014)
Off-grid PV system technologies and innovation trend

- **PV component Technology trend**
- **Charge controllers with Pay as you go Technology for off-grid energy access**
  - How it works/Off Network type of PAYG systems
- For example:
  - First: a technician use the programmer to load the charge controller

![Fig 15: Suntransfer sun control home charge controller with off network PAYG system](image)

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Off-grid PV system technologies and innovation trend

- **PV component Technology trend**
- **Charge controllers with Pay as you go Technology for off-grid energy access**
  - **How it works/Off Network type of PAYG systems**

- **For example:**
  - Then: four digit installation code and credit code will be inserted based on the selected duration of credit period by the end user.
  - Finally the credit period will be count down by the controller and if the end user didn’t pay its credit amount then the controller will shout down at zero credit days.

Fig 16: Suntransfer sun control home charge controller with off network PAYG system
Off-grid PV system technologies and innovation trend

- **PV component Technology trend**
- **Charge controllers with Pay as you go Technology for off-grid energy access**

Research by the IFC Lighting Africa initiative has consistently cited access to downstream financing for end-consumers as one of the three biggest barriers in the portable solar lighting market.

In East and West Africa, M-KOPA Solar and Azuri Technologies sell pico solar systems on a PAYG basis, financed over 12–18 months, which include 3–4 lights, mobile charging capabilities, and the ability to power one or more small DC appliances.

In Ethiopia PAYG technology (off network) was started around 2007/2008 in which radio frequency identification card (RFID) and program generated coddling were used on 12V based solar home systems and the only organization who started this technology in Ethiopia is solar energy foundation Ethiopia which is a Germany NGO, now Sun Transfer Tech plc is carrying on this experience to the business environment and already started implementing this technology on installed type of solar home systems 12V, with PV size from 20 to 100Wp.
Off-grid PV system technologies and innovation trend

**Technology trend in DC appliances for off-grid solar home systems**

It is more economical to use DC appliances rather than AC for off-grid rural households, as converting DC to AC in order to drive standard AC appliances leads to substantial losses and will not be affordable for rural households. Therefore, it is generally more economical to use DC appliances when it is powered by small solar home systems such as:

- Small Radios to 1 to 5 watt
- Tape recorders up to 20 watt
- LED solar TVs 15 to 23” (10 to 25 watt)
- DC fans
- DC fridge
Seminar on Supporting Sustainable Development Goal 7, Target 7.1
“By 2030 ensure universal access to affordable, reliable and modern energy services”

Bangkok, Thailand

Thank you!