Mini Grids: Lessons Learned from Around the World

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What is a mini grid?

A mini grid is anything other than the main grid.

A mini grid is an electricity generation and distribution network that supplies electricity to a localized group of customers. Mini grids can be isolated from and/or connected to the main grid.
2nd Generation of Mini Grids
3rd Generation of Mini Grids

Solar hybrid generation system | Distribution system | Smart meters | Efficient productive loads
---|---|---|---
PV array | Battery block | AC bus |
Charge controller | Distribution line | Poletop hardware |
AC/DC inverter | Smart meter | AC load in village |
Generator | Residential | AC appliances |

Note: AC = alternating current; DC = direct current; PV = photovoltaic.
**1,794 Million US$**
Total Funding for Approved Projects

**710 Million US$**
World Bank: IDA, SREP, CIF, GEF

**1,084 Million US$**
Private Sector and Government

**31 Countries**

**35 Operations**
approved by World Bank board
Operations approved by World Bank board

430 Million US$
Total Funding for Projects under Preparation

378 Million US$
World Bank: IDA, SREP, CIF, GEF

52 Million US$
Private Sector and Government

21 Countries

15 Operations
approved by World Bank board

INVESTMENTS APPROVED  INVESTMENT PIPELINE
Part of a comprehensive knowledge package on mini grids that includes:

- 500-page book plus two volumes of annexes and case studies
- More than a dozen PowerPoint presentations on main findings
- Animations, infographics, and videos
- LiveWire publications
- Databases of 26,000+ mini grids globally, detailed costs, industry tracking
- Roster of Experts

English and French versions of the Executive Summary are available here:

https://openknowledge.worldbank.org/handle/10986/31926

For questions, please don’t hesitate to send an email to:
Jon Exel, jexel@worldbank.org
10 Building Blocks for Country Specific Mini Grid Industry Take-off

To Achieve Universal Access: 490 million people served at least cost by 210,000 mini grids, mostly solar-hybrids, requiring an investment of $220 billion.

- Solar Hybrid Mini Grids and Costing
- Geospatial Planning
- Workable Regulations
- Enabling Business Environment
- Income-Generating Uses of Electricity
- Access to Finance
- Local and International Private Sector Involvement
- Community Engagement
- Training and Skills Development
- Institutional Set-up / Business Models

Where We Are Today: 47 million people connected to 19,000 mini grids, mostly hydro and diesel-powered, at an investment cost of $28 billion. Plus: 7,500 mini grids planned, mostly in Africa, mostly solar-hybrid, connecting more than 27 million people at an investment cost of $12 billion.
1. Innovative Technology

- Installed Mini Grids
  - Solar & Solar Hybrid: 40%
  - Hydro: 30%
  - Diesel: 20%
  - Other: 10%

- Planned Mini Grids
  - Solar & Solar Hybrid: 50%
  - Hydro: 30%
  - Diesel: 20%
  - Other: 0%
2. Geospatial Planning

National Least-Cost Electrification Planning
Grid Extension | Mini Grid | Off-grid

Source: Myanmar National Electrification Program (NEP) Roadmap and Investment Prospectus, Castalia, 2014;
Source: Achieving Universal Access in the Kaduna Electric service area, World Bank, 2015
2. Geospatial Planning

Mini Grid Portfolio Planning
Magnitude Change in Costing | $3,200 per site

<table>
<thead>
<tr>
<th>No diesel constraint</th>
<th>Diesel limited to 20%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capital</strong></td>
<td><strong>Capital</strong></td>
</tr>
<tr>
<td>Size</td>
<td>(USD $)</td>
</tr>
<tr>
<td>Solar PV + installation</td>
<td>535 kW</td>
</tr>
<tr>
<td>Battery + installation</td>
<td>-</td>
</tr>
<tr>
<td>Diesel Generator</td>
<td>350 kW</td>
</tr>
<tr>
<td>Inverter</td>
<td>403 kW</td>
</tr>
<tr>
<td>MPPT Charge controller</td>
<td>-</td>
</tr>
<tr>
<td>Distribution network</td>
<td>17.3 km</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>868,840</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Network Design</th>
<th>Length (km)</th>
<th>Capital (USD $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weasel</td>
<td>13.4</td>
<td>160,735</td>
</tr>
<tr>
<td>Ferret</td>
<td>0.5</td>
<td>6,305</td>
</tr>
<tr>
<td>Rabbit</td>
<td>0.9</td>
<td>12,019</td>
</tr>
<tr>
<td>Horse</td>
<td>0.2</td>
<td>2,930</td>
</tr>
<tr>
<td>Dog</td>
<td>1.0</td>
<td>19,280</td>
</tr>
<tr>
<td>Dingo</td>
<td>0.4</td>
<td>10,233</td>
</tr>
<tr>
<td>Panther</td>
<td>0.5</td>
<td>12,454</td>
</tr>
<tr>
<td>Zebra</td>
<td>0.3</td>
<td>23,637</td>
</tr>
<tr>
<td>Other</td>
<td>0.2</td>
<td>36,793</td>
</tr>
<tr>
<td><strong>Sub Total</strong></td>
<td>17.3</td>
<td>284,386</td>
</tr>
</tbody>
</table>
3. Workable Mini Grid Regulations

Four Key Topics in Mini Grid Regulations:

1. **Entry** to the market – licensing, permits
2. **Retail tariff**—tariff charged to customers
3. **Technical and service standards**—quality of power, quality of supply, quality of commercial services - safety, equipment or construction quality, connection with the main grid, environmental sustainability
4. **Relationship with the main grid**—commercial options available for the mini grid developer when the main grid arrives
3. Workable Mini Grid Regulations

Non-Prescriptive Decision Trees

[Diagram showing decision paths for different scenarios involving subsidies and tariff regulations]
4. Enabling Business Environment

Standardized, Pre-Approved Templates

- **Nigeria ESMS**

- **Tanzania PPA**

- **Asset Transfer Template**
  (Under preparation by ESMAP)

Examples
4. Enabling Business Environment

Data-Based Technology Platforms

Odyssey Energy Solutions: https://www.odysseyenergysolutions.com/
5. Income-Generating Uses of Electricity

Impact of Increased Load Factor on LCOE

Source: ESMAP analysis.
Note: kWh = kilowatt-hour.
# 5. Income-Generating Uses of Electricity

**30+ Appliances with Payback of < 1 Year**

Need Suppliers and $1.3 Billion in Microfinance

<table>
<thead>
<tr>
<th>Sector</th>
<th>Activities / Appliances</th>
<th>Power required (kW)</th>
<th>Cost from supplier ($)</th>
<th>Payback period (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary industries</td>
<td>Egg incubator</td>
<td>80 to 160W</td>
<td>$50 to $100</td>
<td>1 to 3</td>
</tr>
<tr>
<td>(agriculture, fishing)</td>
<td>Grinder for pulses and beans</td>
<td>5.2 kW</td>
<td>$1,500 to $4,000</td>
<td>6 to 12</td>
</tr>
<tr>
<td></td>
<td>Water irrigation pump</td>
<td>3.7 to 22.4 kW</td>
<td>$200 to $1,000</td>
<td>3 to 6</td>
</tr>
<tr>
<td></td>
<td>Sterilizer (for dairy processing)</td>
<td>3 to 6kW</td>
<td>$600 to $2,000</td>
<td>1 to 3</td>
</tr>
<tr>
<td></td>
<td>Packager</td>
<td>250W to 3kW</td>
<td>$500 to $1,000</td>
<td>6 to 12</td>
</tr>
<tr>
<td>Light manufacturing</td>
<td>Electronic welding machine</td>
<td>3 to 7.5 kW</td>
<td>$200 to $300</td>
<td>6 to 12</td>
</tr>
<tr>
<td></td>
<td>Jigsaw</td>
<td>400W</td>
<td>$100</td>
<td>3 to 6</td>
</tr>
<tr>
<td></td>
<td>Electric drilling machine</td>
<td>400W</td>
<td>$20 to $50</td>
<td>3 to 6</td>
</tr>
<tr>
<td></td>
<td>Popcorn maker</td>
<td>1.5 to 2.1 kW</td>
<td>$50</td>
<td>1 to 3</td>
</tr>
<tr>
<td>Commercial and retail activities</td>
<td>Computer</td>
<td>15 to 100W</td>
<td>$250 to $800</td>
<td>3 to 6</td>
</tr>
<tr>
<td></td>
<td>Printer/scanner for stationery</td>
<td>0.5 to 2kW</td>
<td>$150 to $250</td>
<td>3 to 6</td>
</tr>
<tr>
<td></td>
<td>Sewing machine</td>
<td>200W</td>
<td>$30 to $100</td>
<td>3 to 6</td>
</tr>
<tr>
<td></td>
<td>Television for local cinemas and bars</td>
<td>50 to 200W</td>
<td>$100 to $200</td>
<td>1 to 3</td>
</tr>
<tr>
<td></td>
<td>(including decoder)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: ESMAP, Alibaba, Inensus.

Note: Chapter 5 of the main report provides the full table of 37 income-generating machines and other equipment.

kW = kilowatt; W = watt.
Extensive customer awareness campaigns increased load uptake in Bangladesh...

Yet there is 50 times more financing available to generate electricity than for promoting its consumption in Africa (RMI)
Institutional Framework / Business Models

### Typical Mini Grid Delivery Models

<table>
<thead>
<tr>
<th>Build-Own-Operate</th>
<th>PPP</th>
<th>Concession</th>
<th>Utility</th>
<th>Cooperative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private sector carries out all steps from design to operation and co-finances the mini grid alongside development partners, the government, investors, and lenders</td>
<td><strong>Contractual:</strong> Gov. builds and owns the mini grid and private sector operates it.</td>
<td>Government grants a concession to the private sector under a contractual arrangement usually for a pre-specified duration, with terms to which developers must adhere in exchange for service area exclusivity</td>
<td>The national utility carries out all steps from design to operation, or may contract with the private sector for some of these steps</td>
<td>Local communities co-finance (typically through grants) and own the mini grid, often contracting with a third party to design and build the system and train the community on operations and maintenance</td>
</tr>
</tbody>
</table>
**Some First Ideas for Mini Grid Delivery Models in Ethiopia**

### EEU EPC + O&M Contracts

- **EEU contracts with private for EPC & O&M for a portfolio of 100 mini grids located relatively close to the existing main grid to facilitate post-contract handover to EEU staff.**
- **Demand stimulation during O&M contract phase will increase economic viability for main grid arrival in the medium term.**
- **World Bank funding would reduce EEU outlays.**

**Objective:** 100 mini grids by 2025

**Cost:** $60 Million

**Public/Private Cost Share:** 100/0

### EEU PPP for Hybridization

- **Solar hybrid generation on existing EEU diesel mini grids tendered out to the private sector under a PPA with EEU, for a portfolio of about 25MW in solar PV plus storage. This would be a win-win for EEU (reduces diesel generation costs), customers (increases electricity availability to 24/7), and the private sector (reduces risks).**
- **It is also in line with the new investment law. World Bank funding would fill the viability gap between tariff required by private sector and tariff paid by EEU.**

**Target:** 100 mini grids by 2025

**Cost:** $50 Million

**Public/Private Cost Share:** 50/50

### Minimum Subsidy Tender

- **EEU would select 50 sites, divided into 2-5 portfolios, in areas where there is likely to be significant private sector interest. EEU would invite private sector developers to bid for minimum capital cost subsidies needed to build and operate the mini grid portfolios.**
- **World Bank funding would support market intelligence and portfolio preparation in addition to the capital cost subsidies. The Odyssey platform (https://www.odysseyenergysolutions.com/) would manage the process.**

**Target:** 100 mini grids

**Cost:** $60 Million

**Public/Private Cost Share:** 40/60

### Results-Based Financing

- **Private sector developers would be invited to submit proposals to build and operate mini grid portfolios in sites of their choosing, given a fixed per-connection subsidy paid partly upfront to offset capital costs and partly based on number of successful connections. The global mini grid industry fully supports this approach, and aligns with current private sector, regulatory, and policy momentum in Ethiopia. The process would be managed using the Odyssey platform.**

**Target:** 100 mini grids

**Cost:** $60 Million

**Public/Private Cost Share:** 40/60

### Assumptions

- **100 mini grids x 150kW per mini grid x $4,000 per kW**
- **500kW per mini grid of which 50% is PV+storage (based on 25MW PV+storage)**
- **100 solar + PV generation systems x 250kW generation capacity x $2,000 per kW**
10 Building Blocks

- Solar Hybrid Mini Grids and Costing
- Geospatial Planning
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