Case Studies

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Dushanbe, Tajikistan
Rwanda – computer-based planning

Central Planning
Rwanda’s electrification strategy

- The Electricity Access Roll Out Program (EARP) established to increase the number of households with access from 12% 2011 to 70% by 2017

- Electrification program developed with computer-based modeling

- EARP appointed SOFRECO to assist the Planning and Design Unit to design capital investment program to achieve this goal

- Electricity, Water, and Sanitation Authority (EWSA) responsible for implementing on-grid aspects of the plan

- Ministry of Infrastructure will manage off-grid implementation

Source: Republic of Rwanda, 2016
Computer-based planning

**Inputs**
- Satellite imagery
- Topographic
- Infrastructure
- Electrical system
- Administrative
- Demographic
- Economic

**Outputs**
Least-cost development plan considering:
- Existing and new settlements
- Demand growth
- Important infrastructure, consumer densities, distance from network
- Natural obstacles and environmental constraints
- Infrastructure costs
Inputs – Satellite imagery

Though 2 to 3 years old, EWSA provided quality satellite images
The database also includes topographic data such as roads, rivers, lakes, etc.
Inputs - Infrastructure

- EARP and SOFRECO conducted field studies to update infrastructure databases
- This information is used to spatially identify, locate, and prioritize infrastructure for electrification

<table>
<thead>
<tr>
<th>Zone</th>
<th>Cell office</th>
<th>District office</th>
<th>Health Center</th>
<th>Primary school</th>
<th>Secondary school</th>
<th>Hospital</th>
<th>Market</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central</td>
<td>72</td>
<td>1</td>
<td>17</td>
<td>53</td>
<td>43</td>
<td></td>
<td>13</td>
<td>218</td>
</tr>
<tr>
<td>Eastern</td>
<td>426</td>
<td>6</td>
<td>119</td>
<td>282</td>
<td>244</td>
<td></td>
<td>68</td>
<td>1235</td>
</tr>
<tr>
<td>Southern</td>
<td>380</td>
<td>8</td>
<td>142</td>
<td>853</td>
<td>309</td>
<td></td>
<td>10</td>
<td>1989</td>
</tr>
<tr>
<td>Western</td>
<td>408</td>
<td>4</td>
<td>64</td>
<td>523</td>
<td>57</td>
<td></td>
<td>8</td>
<td>1209</td>
</tr>
<tr>
<td>Northern</td>
<td>644</td>
<td>5</td>
<td>157</td>
<td>551</td>
<td>298</td>
<td></td>
<td>4</td>
<td>1890</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1930</strong></td>
<td><strong>24</strong></td>
<td><strong>470</strong></td>
<td><strong>2262</strong></td>
<td><strong>951</strong></td>
<td><strong>22</strong></td>
<td><strong>168</strong></td>
<td><strong>6541</strong></td>
</tr>
</tbody>
</table>
Power system planning

• Divide country into MV/LV transformer zones
• Identify least-cost generation and transmission investments to meet future demand
• Confirm planned investments are feasible with load flow studies
Design of each transformer zone

Load forecasts for each transformer zone based on national statistics and input from EARP’s planning department to estimate potential consumers.

<table>
<thead>
<tr>
<th>Load category</th>
<th>Rating (KVA)</th>
<th>% Growth 2012-17</th>
<th>% Growth 2017-22</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household</td>
<td>100 watts</td>
<td>300 watts saturation after 6 years</td>
<td></td>
</tr>
<tr>
<td>Business center</td>
<td>10</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Primary school</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Secondary school</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Health center</td>
<td>10</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Hospital</td>
<td>20</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Cell office</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>District office</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Factories</td>
<td>20</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Market</td>
<td>8</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>
Design of each transformer zone

Transformers and low voltage cables are then sized to serve long-term load projections.
Establish priority regions

EARP divided the country into zones and established priority areas for electrification

<table>
<thead>
<tr>
<th>Priority</th>
<th>Zone</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>South</td>
<td>Fewest existing connections</td>
</tr>
<tr>
<td>2</td>
<td>North</td>
<td>150km MV lines under development for 14,000 new connections</td>
</tr>
<tr>
<td>3</td>
<td>Western Eastern</td>
<td>150km MV lines already under development 500 km lines under development for 50,000 new connections</td>
</tr>
<tr>
<td>4</td>
<td>Central</td>
<td>Kigali area</td>
</tr>
</tbody>
</table>
Procurement

• Transformer zones were grouped into 146 “lots” for tenders

• Contracts were organized into the following groups
  – 75 Engineering, Procurement, and Construction (EPC) contracts covering greenfield areas
  – 71 MV/LV contracts targeted to local construction teams using materials supplied by EWSA
  – MV/LV contracts implemented by EWSA construction teams
Challenges to EARP

• Institutional
  – Securing funding for new projects
  – Capacity of EARP to manage projects and contracts
  – Capacity of EWSA construction teams

• Technical
  – Meeting deadlines for new generation additions
  – Achieving balance of generation sources

• Creating dynamic planning tools
  – Maintaining GIS database with each project
  – Maintaining AutoCad single line drawings with each projects
  – Updating distribution planning and coordination based on changing generation plans and load data
Progress to date (March 2017)

- Electricity access has doubled to 31% (67% in Kigali) as of January 2017
- 80 rural micro-grids are operational
- Licenses for off-grid development have been issued to install 250,000 solar home systems
- Private investors have committed to build new generation projects from 2015 to 2040 with support from the Rwanda Development Board
Peru – utility micro-grids

Micro-grids
Electricity access in Peru

- Peru has the second-lowest level of electrification in South America
- 70% of households in low-access rural areas have no electricity supply
- Rural populations are very disperse, making grid extension infeasible

Source: Julio Eisman. Acciona Foundation. Peru Microenergia
Utility business model

- Utility company (Peru Microenergía) owns and maintains rural micro-grids
- Consumers pay an affordable, regulated tariff in exchange for basic electricity service
- Regulated cross-subsidy from grid-connected consumers cover the viability gap
- Peru Microenergía hires, trains, and supports local community members as technicians
Basic Service

- Lighting: 3 low energy bulbs
- Communication: mobile phone charging, radio
- Entertainment: TV
- At least 4 hours/day

**Basic technical characteristics**

1. PV solar panel: 60Wp-85Wp (12Vdc).
2. Battery: 100 Ah/12Vdc
3. Controller: 10A/10A/12 Vdc
4. Lights: 3x11W / 12Vdc CFL
5. Average available energy: 7.24 kWh/month

Source: Julio Eisman. Acciona Foundation. Peru Microenergia
Focus on community involvement

1. Community meetings for information
2. Agreements with Municipalities
3. Pilot installations
4. Trainings & PV Electrification Committees
5. Installation
6. Operation

Source: Julio Eisman. Acciona Foundation. Peru Microenergia
Success factors in Peru’s off-grid program

• Regulated tariffs promote **affordability** for rural consumers
• High levels of **community involvement** ensure consumers understand the service and technology
• Training and hiring **local technicians** reduces maintenance costs and promotes local economic development
• Technology and business model are **scalable and portable** if demand grows or central grid arrives
• Utility-based model supports **coordination between central and distributed investment plans**
Grameen Shakti (Bangladesh) – financing SPLs

Standalone home systems
Grameen Shakti business model

- Grameen Shakti sells and finances solar home systems to rural households in Bangladesh
- Consumers can choose from a wide range of system sizes and financing options to fit their needs
- Created rural supply chains and extensive decentralized network for after-sales support
- Focus on training and expanding in-country workforce to support off-grid solar deployment

SOURCE: http://www.gshakti.org
Sample range of system and price options

<table>
<thead>
<tr>
<th>Services</th>
<th>Equipment*</th>
<th>Package Price (USD)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total</td>
<td>1-year installment</td>
<td>2-year installment</td>
</tr>
<tr>
<td>2 lights</td>
<td>10W panel, 2 x 2.5 W LEDs, 15AH battery</td>
<td>72</td>
<td>84</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td>3 lights, 15” TV</td>
<td>40/42W panel, 3 x 3 W LEDs, 40/45AH battery</td>
<td>205</td>
<td>229</td>
<td>240</td>
<td>265</td>
</tr>
<tr>
<td>6 lights, fan, 15” TV</td>
<td>75W panel, 6 x 3 W LEDs, 80AH battery</td>
<td>319</td>
<td>343</td>
<td>365</td>
<td>411</td>
</tr>
<tr>
<td>7 lights, 2 fans, 15” TV</td>
<td>130/135W panel, 7 x 3 W LEDs, 130AH battery</td>
<td>470</td>
<td>494</td>
<td>518</td>
<td>558</td>
</tr>
</tbody>
</table>

**Down Payment**
- 25% of Total
- 20% of Total
- 15% of Total

**Service Charge (flat rate)**
- 9% of Total
- 10% of Total
- 12% of Total

*All systems include charge controller, frame, and cables*
Micro-utility business

- Micro-utility system designed for very poor households that cannot afford complete solar home system
  - One entrepreneur installs the system at their house and is responsible for making installment payments to Grameen Shakti
  - Energy is shared with neighbors who pay usage fees to owner
  - More than 50% installment payment covered by fees collected from other users
- More than 1000 micro-utility systems in operation
Grameen Shakti service model

- Focus on building local capacity with over 12,000 young people employed
- 1,500 branch offices, representing every district in Bangladesh
- Engineers, technicians live in local villages for on-site service
- 45 village technology centers, all managed by women engineers, train local technicians and energy entrepreneurs
- Decentralized services include installation, maintenance, repair, financing, and training
- Trusted brand, entrepreneurs from technology centers advertise they are Solar Technician Certified by Grameen Shakti
Gram Oorja (India) – independent micro-grids

Micro-grids
Electricity access in India

- 68% of India’s population resides in rural villages
- Only 10% of villages are connected to the central grid
- 8% of rural villages have 100% household connections
- Of those with connections, available power is generally limited to < 2 hours/day

Source: Jain et al. (2015)
Darewadi, Maharashtra

- Village population around 220
- Remote hamlet not on government records
- Location, terrain, and disperse population make it unlikely candidate for grid extension
- Local trust managed by villagers responsible for project operation, maintenance, and tariff collection
- Consumers pay one-time connection charge (~$13)

Source: Gram Oorja Private Solutions Ltd
Project details

• 9.36 kW solar PV micro-grid
• Household services
  – Domestic lighting
  – Mobile charging
  – Appliances (TV, computers, radio)
• Productive uses
  – Flour mill
• Community services
  – Street lighting
  – Water pump

Source: Gram Oorja Private Solutions Ltd
Success factors in Gram Oorja’s off-grid program

- Villages are **unlikely candidates for grid extension**
- High levels of **community involvement** ensure consumers understand the service and technology
- Project requires **support from community** members including creation of village trust to operate and manage micro-grid and collect tariffs
- System is **scaled to match service needs** of the community
OMC (India) – anchor clients

Micro-grids
Anchor client business model

• OMC Power builds, owns, operates and maintains solar plants > 25 kW
• OMC contracts with telecoms companies to power their mobile towers
• Anchor client provides steady revenue to cover operations costs
• Excess power sold to local communities with no grid access
• Village entrepreneurs are hired to connect local households
• OMC rents consumer products (lanterns, fans, TV) and provides battery charging for mobile devices
M-KOPA (Africa) – Pay as you go

Standalone home systems
Pay as you go services in Africa

The pay as you go model for solar lighting services (portable lights and solar home systems) has proven successful in sub-Saharan Africa. Here are some pay-as-you-go companies for solar lighting services:

- **Senegal**: Oolu Power
- **Sierra Leone**: Azuri
- **Ghana**: PEG Ghana, Azuri
- **Togo**: Azuri
- **Malawi**: Azuri
- **Zimbabwe**: Azuri
- **Nigeria**: Nova Lumos
- **South Africa**: Azuri, Kingo
- **Ethiopia**: Azuri, Mobisol, BBOXX
- **Rwanda**: Mobisol, BBOXX
- **Uganda**: Fenix International, BBOXX, Azuri, M-KOPA, Village Power, SolarNow, SunTransfer, M-KOPA, Mibawa
- **Kenya**: M-KOPA, Mibawa
- **Tanzania**: Mobisol, Fenix International, M-KOPA, Off-grid Electric, Eternum energy, EEG energy

Source: Bloomberg New Energy Finance
M-Kopa business model

- M-Kopa sells solar home systems in Kenya, Tanzania and Uganda
- Business model designed to reach bottom-of-the-pyramid customers living on less than $2 per day
- Customers pay a deposit to take the system home and daily payments a period of one year to own the system
- Daily payments are made through M-PESA, a local mobile phone-based money system
- Systems are distributed and sold through network of over 2,500 local dealers
- Over 450,000 systems sold, with 500 new households added each day
M-Kopa products

- 8 W solar panel
- Control units with Lithium Battery
- 4 x 1.2 W LED lights
- Rechargeable torch
- Rechargeable FM/USB radio
- 5-in-1 phone charge cable
- Custom charge cable
- $30 deposit + $0.5 per day

- 20 W solar panel
- 20” digital TV
- 3 LED lights with cables and switches
- 1 LED rechargeable torch
- Rechargeable FM/USB radio
- 5-in-1 phone charge cable
- $80 deposit + $1.24 per day

Source: M-Kopa Solar http://www.m-kopa.com/products/
Successful features of M-Kopa model

- Payments are spread over time making them affordable to consumers
- Systems are distributed and sold through local shops
- Payments use popular mobile money platform, reducing collection costs and non-payment rates
- Systems have 2-year warranty in case household situations or needs change
- Households eventually own the system
Thank you

www.nrel.gov

Publication Number
• Source: Julio Eisman. Acciona Foundation. Peru Microenergia http://www.accioname.org
• “Gram Oorja Solutions Private Limited”. http://www.gramoorja.in/index.html
• “M-Kopa Solar” http://www.m-kopa.com/products/