Global Market Potential for PV-based Mini-Grids in Developing Countries

Paul Bertheau
Reiner Lemoine Institut gGmbH
Berlin, Germany

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Off-Grid Markets
ICM - Munich
• **Renewable Energy Mobility**
  – Mobility concepts based on RE

• **Renewable Energy Technology**
  – Small wind power applications
  – Technical integration of RE

• **Renewable Energy Systems**
  – Optimization of energy systems
  – Energy transition processes
  – Off-grid energy systems

**Scientific research and support for a transition towards 100 % renewable energies**
Off-Grid Systems

- Simulation and optimization of renewable energy systems
- Analyses with geo-information systems (GIS)
- Resource assessment (solar, wind, hydro)
- Market potential analyses & feasibility studies

Decentralized energy systems with high shares of renewable energies
Motivation

- 1,200 mn people without access to electricity

- Electricity access shares remain low although much effort is undertaken

- In some developing countries significant parts of GDP are spent on subsidizing electricity prices
Access to electricity is a basic need and prerequisite for:
- Education
- Health care
- Economic development

Different electrification approaches:
- Centralized approach:
  - Grid extension
- Decentralized approach
  - Solar home systems
  - Diesel generator
  - Hybrid systems (e.g. PV-battery-diesel)
• Prices for crude oil have increased over the last years and are expected to do so in the future
• Costs for PV have been plummeting in the last years improving the economic feasibility additionally to its obvious ecological advantages

- High economic pressure on existing electrification schemes based on oil / diesel
- Renewable energies become an interesting option for remote locations

➢ Upgrade of diesel grids with RE technology to reduce the dependency on fossil fuels and provide environmentally sound power supply
Aim of the study:
Quantify the potential for decentralized PV power by comparing the power generation costs of diesel only systems to PV based hybrid systems.

Research question:
Where are PV- diesel or PV-battery-diesel systems more cost effective than diesel only systems?

National diesel price + Road network + Solar irradiation = Cost-optimized hybrid mini-grid
Subsidization and taxation of diesel have strong effects on costs (e.g. MENA-region).

Transportation costs affect mainly remote rural areas or islands (e.g. outback of Australia, Himalaya region, Caribbean)

* 1 l diesel corresponds to approx. 3 kWh\textsubscript{el}
Rural electrification based on PV-battery-diesel grids is cost-effective.

Remote areas profit intensively from decentralised energy supply.

Subsidization of diesel makes PV improvident.
Diesel-only systems dominate in regions with very high subsidies on diesel.

The better the solar radiation and the higher the diesel costs the higher is the optimal PV share (e.g. Sub-Saharan Africa).
In many regions, mostly in Africa, Australia and South America attractive payback periods of 5 – 7 years can be reached.

In extremely remote areas very lucrative payback periods of less than 4 years arise for PV Mini-Grids.
Comparative Country Ranking for Rural Electrification

Used criteria and weighting factors:

**A: „Market potential“**

- Electrification rate [worldbank, IEA, UNDP] (30%)
- Rural population without access to electricity [calculated] (50%)
- Diesel price [worldbank] (20%)

**B: „Political and financial framework“**

- Political stability [worldbank] (15%)
- Corruption index [transparency Int.] (20%)
- Inflation rate [worldbank] (15%)
- Ease of doing business index [worldbank] (50%)
Results of Comparative Country Ranking

exclusion criteria: political instability, travel warning from Ministry of Foreign Affairs, diesel price (≤ 0.25 USD/l)
not considered: electrification rate > 95% and < 200,000 people in rural areas without electricity
target countries: rank 1 to 89
no data

Top 20 of 89
1 Rwanda
2 Zambia
3 South Africa
4 Botswana
5 Namibia
6 Ghana
7 Kenya
8 Uganda
9 Tanzania
10 Peru
11 Ethiopia
12 Papua New Guinea
13 Solomon Island
14 China
15 Bahamas
16 Colombia
17 Malawi
18 Burkina Faso
19 Mongolia
20 Nepal
Levels and Participants of Electrification Projects

Premise Level
- **State**
  - Policy for renewable energies
  - Permissions
  - Investment security
- **Investor, financier**
  - Obtain permissions
  - Find investor

Operational Level
- **Operator**
  - Energy has to be reliable and predictable
- **Customer**
  - Energy
  - Tariff
    - Tariffs must be cost-covering and affordable
- **System integrator**
  - (Can also be operator, investor or state)
    - Comprehensive design with people on-site

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„Which specific electrification scheme is best for a given location?“

Planned joint research project of RLI and ARE:

„Off-Grid Solutions for Global Electrification“
### Information per pixel

<table>
<thead>
<tr>
<th>Resource Assessment</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Local diesel price</td>
<td>EUR/liter</td>
</tr>
<tr>
<td>Solar, wind, hydro</td>
<td>kWh, m/s, m³</td>
</tr>
<tr>
<td>Population</td>
<td>#</td>
</tr>
<tr>
<td>GDP</td>
<td>EUR</td>
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<tr>
<td>etc</td>
<td></td>
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</tbody>
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<table>
<thead>
<tr>
<th>RE Hybrid Electrification options</th>
<th></th>
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<tbody>
<tr>
<td>Diesel only</td>
<td>EUR/kWh</td>
</tr>
<tr>
<td>Hybrid micro grids (LCOE)</td>
<td>EUR/kWh</td>
</tr>
<tr>
<td>(solar, wind, battery, diesel,...)</td>
<td></td>
</tr>
<tr>
<td>Optimized solution: capacities, RE share, diesel consumption</td>
<td>kW, %, liter</td>
</tr>
<tr>
<td>Solar-Home-Systems (LCOE)</td>
<td>EUR/kWh</td>
</tr>
<tr>
<td>Electricity demand</td>
<td>kWh/year</td>
</tr>
<tr>
<td>Distance to grid</td>
<td>km</td>
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<tr>
<td>Nightlights (access to electricity)</td>
<td>yes/no</td>
</tr>
<tr>
<td>etc.</td>
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</tbody>
</table>
Thank you!

And special thanks to the RLI off-grid team

For further questions please contact us:
Paul Bertheau: paul.bertheau@rl-institut.de
requirements

- has to agree to permit tariffs for mini-grids which are mostly higher than in the remaining country
- has to create legal framework

frequent problems/experiences

- legal framework lacks
- complex licensing procedures
- scepticism about renewable energies
- high import duties
- monopoly on energy supply
- financial sector is underdeveloped

requirements

- investor has to take risks
- financier has to be willing, to provide enough capital (for investor)

frequent problems/experiences

- high investment costs at the beginning
- foreign exchange risk
- lack of credit availability
- high transaction costs
- insufficient trust in project development
- lacking security during project period
- local expectations on investment costs and return times
- has to obtain permissions
- has to find investor and financier
- **currently has often firstly to create requirements**

**frequent problems/experiences**

- knowledge lack of local conditions
- projects not adapted to local conditions
- scarce communication with community and integration of local players

- has to meet cultural needs
- has to plan for long-term operation
- has to integrate and train local participants
- has to create a sustainable tariff structure
- has to ensure that responsibilities are clear defined
frequent problems/experiences

- maintenance and responsibility for operation is neglected
- continuos adaption with demand not considered
- poor payment practices of consumers

**cashier**

- must be accepted
- has to earn money

**operator**

- has to ensure maintenance and quality
- has to be addressable and able to react quickly
- has to make provisions and profit

- **customer**
  - households, workshops
  - has to understand the system
  - must be willing to pay

- **technician**
  - must have technical expertise
  - has to earn money

**energy**

- **tariff**
  - tariff must be cost covering and affordable

**payment of tariffs**

- has to earn money

**installation, service, maintenance**