Storage Solutions in Developing Countries

A Case Study on the Market Potential for Battery Storage in Tanzania
1. Energy supply in Tanzania
2. Battery storage technologies
3. Fields of application for battery storage
4. Market potential & Outlook
Energy supply in Tanzania

Status Quo in Tanzania

- **Frequent power outages:** 3-10 times per month for 3-5 hours
- Power capacity insufficient to meet a steadily increasing demand
- Unreliable power supply is stated as one out of three largest obstacles for doing business in Tanzania
- Industry suffers production downtimes and needs to backup with expensive diesel power generation

Storage technologies as a cost competitive alternative?
Energy supply in Tanzania

- **Generation**
  - Ca. 1.5 GW installed capacity
  - Electricity mix: Gas and oil (71%), biomass (28%), hydro (1%)

- **Grid**
  - 14% of population grid-connected
  - Grid coverage only in northern, central and coastal regions

- **Demand**
  - Growing by 11.7% p.a.
  - Huge gap between supply and demand leads to frequent power outages
Energy supply in Tanzania

Back-up power supply:

- Diesel generators most commonly used back-up power source (>54% of companies)
- High Diesel prices up to 1.20 Euro/liter

High costs for diesel power generation
30-43 ct/kWh
vs.
National Grid price
3-12 ct/kWh

Analysis of the cost competitiveness of storage technologies for back-up power supply

Figure: Regional diesel cap prices
Source: Own illustration according to EWURA (2015) and Szabo et al. (2011)
Agenda

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Battery storage technologies

### Comparison of technical characteristics of lead-acid and lithium-ion batteries

<table>
<thead>
<tr>
<th>Technical parameter</th>
<th>Lead-acid batteries (VRLA)</th>
<th>Lithium-ion batteries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy density (Wh/kg)</td>
<td>20 – 45</td>
<td>100 – 200</td>
</tr>
<tr>
<td>Power density (W/kg)</td>
<td>100 – 200</td>
<td>200 – 4000</td>
</tr>
<tr>
<td>Lifetime (years)</td>
<td>3 – 10</td>
<td>10 – 15</td>
</tr>
<tr>
<td>Cycles (at 100 % DoD)</td>
<td>200 – 470</td>
<td>3000 - 5000</td>
</tr>
<tr>
<td>Max. depth of discharge</td>
<td>~ 50 %</td>
<td>~ 80 %</td>
</tr>
<tr>
<td>Self-discharge (at 20° C)</td>
<td>&lt; 5 % per month</td>
<td>&lt; 5 % per month</td>
</tr>
<tr>
<td>Roundtrip efficiency</td>
<td>60 – 85 %</td>
<td>90-95 %</td>
</tr>
<tr>
<td>Capital expenditures&lt;sub&gt;2013&lt;/sub&gt; (EUR/kWh)</td>
<td>250 - 500</td>
<td>800 - 1600</td>
</tr>
</tbody>
</table>

- Cost advantage and maturity
- Lighter and longer lifetime
- Applicable for regularly occurring long-lasting outages
- Suitable for frequent outages and weak grid stability

Facilitator: Stefanie Werler | BSW Off-grid Forum | 11.06.2015
Agenda

1. Energy supply in Tanzania
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3. Fields of application for battery storage
4. Market potential & Outlook
Fields of application for battery storage

- **Residential sector:** households, villages
- **Commercial sector:** Service, agriculture, small industries
- **Tourism sector:** grid-connected hotels, small lodges
- **Telecom sector:** grid-connected and off-grid towers
- **Health care and administration:** hospitals and public buildings
Fields of application for battery storage

An excel tool was developed to assess the economic attractiveness of lead-acid and lithium-ion batteries

**Input parameters:**
- Electricity consumption
- Load curve (evening/midday peak)
- Frequency and duration of power outages
- Battery type and profile

**Results:**
- Economic comparison of lead-acid batteries, lithium-ion batteries, and diesel genset
- Project cost debt-financed/equity-financed
- Energy demand curve and power outages
- Sensitivity analysis: diesel fuel price, interest rate, battery CAPEX
Market potential & Outlook

Commercial sector: Service, agriculture, small industries

- Unreliable electricity supply major obstacle for business
- High diesel fuel costs and low interest rates are most favourable for cost-effectiveness of batteries
- Lithium-ion batteries suitable for customers with frequent outages and a weak grid stability,
- Lead-acid batteries can be applied for regularly occurring long-lasting outages

<table>
<thead>
<tr>
<th></th>
<th>Access to finance</th>
<th>Electricity</th>
<th>Tax rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small enterprise (5-19)</td>
<td>42,1</td>
<td>24,3</td>
<td>7,6</td>
</tr>
<tr>
<td>Medium enterprise (20-99)</td>
<td>25,1</td>
<td>24,0</td>
<td>10,7</td>
</tr>
<tr>
<td>Large enterprise (100+)</td>
<td>19,8</td>
<td>45,4</td>
<td>9,3</td>
</tr>
</tbody>
</table>

Figure: Three biggest obstacles for doing business in Tanzania (Number of employees in brackets)
Market potential & Outlook

Commercial sector: Service, agriculture, small industries

- A coffee farm selected as case study
- Stable demand of around **135 kW per hour** due to constant use of energy intensive machinery (water pumping)
- Blackouts occur daily between 5 and 7pm

Conservative assumptions:
- Grid power costs 0.1 EUR/kWh
- Diesel fuel costs 1 EUR/l
- Interest rate of 15 % is applied
- No solar PV capacity installed

![Load profile and power outages for agricultural company case study](source: Own illustration – load profile was made available by OneShore Energy GmbH)
Market potential & Outlook

Commercial sector: Service, agriculture, small industries

- Approx. 9% electricity losses due to power outages
- Necessary storage capacities to compensate blackouts: 456 kWh Li-ion, 238 kWh L/A and 210 kW diesel generator

<table>
<thead>
<tr>
<th>Battery back-up systems</th>
<th>Lead-acid</th>
<th>Lithium-ion</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Installed capacity</strong></td>
<td>455.9</td>
<td>238.4</td>
<td>kWh</td>
</tr>
<tr>
<td><strong>Installed power</strong></td>
<td>152.0</td>
<td>238.4</td>
<td>kW</td>
</tr>
<tr>
<td><strong>Total Investment</strong></td>
<td>159,581.0</td>
<td>238,427.4</td>
<td>EUR</td>
</tr>
<tr>
<td><strong>Annual CAPEX</strong></td>
<td>35,562.6</td>
<td>43,985.3</td>
<td>EUR</td>
</tr>
<tr>
<td><strong>Annual OPEX fix</strong></td>
<td>3,191.6</td>
<td>2,384.3</td>
<td>EUR</td>
</tr>
<tr>
<td><strong>Annual OPEX var.</strong></td>
<td>0.0</td>
<td>0.0</td>
<td>EUR</td>
</tr>
<tr>
<td><strong>Annual charging costs</strong></td>
<td>12,641.9</td>
<td>11,346.2</td>
<td>EUR</td>
</tr>
<tr>
<td><strong>Total annual costs</strong></td>
<td>51,396.2</td>
<td>57,715.7</td>
<td>EUR</td>
</tr>
<tr>
<td><strong>Annuity factor</strong></td>
<td>0.22</td>
<td>0.18</td>
<td></td>
</tr>
<tr>
<td><strong>LCOE battery back-up energy</strong></td>
<td><strong>0.50</strong></td>
<td><strong>0.56</strong></td>
<td>EUR/kWh</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Diesel generator</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Installed capacity</strong></td>
<td>210.0</td>
<td></td>
<td>kW</td>
</tr>
<tr>
<td><strong>Total Investment</strong></td>
<td>63,000.0</td>
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<td>EUR</td>
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<tr>
<td><strong>Annual CAPEX</strong></td>
<td>10,774.1</td>
<td></td>
<td>EUR</td>
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<tr>
<td><strong>Annual OPEX fix</strong></td>
<td>210.0</td>
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<td>EUR</td>
</tr>
<tr>
<td><strong>Annual OPEX var.</strong></td>
<td>5,120.0</td>
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<td>EUR</td>
</tr>
<tr>
<td><strong>Annual fuel costs</strong></td>
<td>40,959.8</td>
<td></td>
<td>EUR</td>
</tr>
<tr>
<td><strong>Total annual costs</strong></td>
<td>57,063.8</td>
<td></td>
<td>EUR</td>
</tr>
<tr>
<td><strong>Annuity factor</strong></td>
<td>0.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>LCOE diesel back-up energy</strong></td>
<td><strong>0.56</strong></td>
<td></td>
<td>EUR/kWh</td>
</tr>
</tbody>
</table>
Market potential & Outlook

Tourism sector: grid-connected hotels, small lodges

- Contribution to Tanzanian GDP: 12,1%
- Average hotels consume between 500 and 1,500 kWh per day
- Almost all hotels have back-up power generation facilities or are solely operating on diesel generators
- Large potential for storage systems

Case study resort – assumptions:
- Daily Consumption 1 MWh
- Grid power costs 0.1 EUR/kWh
- Diesel fuel costs 1.20 EUR/l (remote lodge)
- Interest rate of 8 % is applied (access to international capital market)
- Solar PV system with a peak capacity of 35 kWp
## Market potential & Outlook

### Tourism sector: grid-connected hotels, small lodges

### Battery storage systems vs. Diesel generator

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Lead-acid battery</th>
<th>Lithium-ion battery</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installed capacity</td>
<td>208.5</td>
<td>69.5</td>
<td>kWh</td>
</tr>
<tr>
<td>Installed power</td>
<td>69.5</td>
<td>69.5</td>
<td>kW</td>
</tr>
<tr>
<td>Total Investment</td>
<td>72,991.7</td>
<td>69,515.9</td>
<td>EUR</td>
</tr>
<tr>
<td>Annual CAPEX</td>
<td>16,266.2</td>
<td>12,824.3</td>
<td>EUR</td>
</tr>
<tr>
<td>Annual OPEX fix</td>
<td>1,459.8</td>
<td>695.2</td>
<td>EUR</td>
</tr>
<tr>
<td>Annual OPEX var.</td>
<td>0.0</td>
<td>0.0</td>
<td>EUR</td>
</tr>
<tr>
<td>Annual charging costs</td>
<td>5,950.4</td>
<td>5,340.5</td>
<td>EUR</td>
</tr>
<tr>
<td>Total annual costs</td>
<td>23,676.5</td>
<td>18,860.0</td>
<td>EUR</td>
</tr>
<tr>
<td>Annuity factor</td>
<td>0.22</td>
<td>0.18</td>
<td></td>
</tr>
<tr>
<td>LCOE battery back-up energy</td>
<td><strong>0.42</strong></td>
<td><strong>0.33</strong></td>
<td>EUR/kWh</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Diesel generator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installed capacity</td>
<td>104.3</td>
</tr>
<tr>
<td>Total Investment</td>
<td>31,282.1</td>
</tr>
<tr>
<td>Annual CAPEX</td>
<td>5,349.8</td>
</tr>
<tr>
<td>Annual OPEX fix</td>
<td>104.3</td>
</tr>
<tr>
<td>Annual OPEX var.</td>
<td>2,833.4</td>
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<tr>
<td>Annual fuel costs</td>
<td>23,761.5</td>
</tr>
<tr>
<td>Annual fuel consumed</td>
<td>19,801.3</td>
</tr>
<tr>
<td>Total annual costs</td>
<td>32,049.0</td>
</tr>
<tr>
<td>Annuity factor</td>
<td>0.17</td>
</tr>
<tr>
<td>LCOE diesel back-up energy</td>
<td><strong>0.57</strong></td>
</tr>
</tbody>
</table>
Market potential & Outlook

Telecom sector: grid-connected and off-grid towers

- 4,600 telecom towers in Tanzania with annual growth rate of 19% p.a.
- Two thirds grid-connected and one third off-grid
- The majority of towers face power outages for more than 6 hours per day
- High costs for purchase and transport of diesel

➢ Telecom towers bear a high market potential for batteries due to regular blackouts as well as high costs for energy costs back-up power supply

Figure: Electricity supply costs for on-grid and off-grid operating telecom towers

Source: GSMA (2015c)
Market potential & Outlook

Health care and administration: hospitals and public buildings

- Reliable electricity supply essential for health infrastructure
- **Largely underdeveloped** health system; in remote areas health care is provided by small dispensaries or health centres
- Only **50% of all health facilities** are provided with access to **electricity** and 30% with access to reliable electricity supply (power outages less than 2 hours)

- Back-up energy supply for health care required

Figure: Health care infrastructure in Tanzania
Source: National electrification prospectus (REA 2014)
Market potential & Outlook

- Most attractive: off-grid and weak grid regions
- Tourism sector and commercial sector most promising
- Lithium-ion batteries most suitable for occurrence of highly fluctuating power outages which require quick charging and discharging reactions
- Lead-acid batteries are attractive for longer steady back-up power supply (less cost per kWh storage capacity)
- The combination of battery systems with PVs further reduces back-up power costs
- The most influencing factors on the economic viability of battery systems for on-grid back-up power supply are the applied interest rate and the local diesel price
Market potential & Outlook

How to overcome the hurdles for market entry?
## Market potential & Outlook

### Challenges

#### Technical
- Missing quality standards for battery products
- Technical know-how of local distributors

#### Financial
- Difficult access to local or international financing
- High upfront investments
- Short term price sensitivity of end-customer
- Import taxes on batteries

#### Projects
- Missing pilot projects for new technologies
- High consulting and marketing effort
- Diverse customer structure
- Price sensitivity of customers
- Strong international competition with low cost products

### Approach

#### Technical
- Introduction of standards
- Training of local distributors and electricians

#### Financial
- International financing programs and guarantees
- Micro-financing for small projects
- Education on economic advantages of batteries
- Combination of RE products and batteries to save import taxes

#### Projects
- „Centralized“ project development
- Collaborative pilot projects
Thank you for your attention!

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www.giz.de/projektentwicklungsprogramm