Comparison of different energy storage systems for renewable energies on a Caribbean island

Philipp Blechinger\textsuperscript{1,2}, Markus Hlusiak\textsuperscript{1}, Jan Meiss\textsuperscript{1}, Kristina Bognar\textsuperscript{2}, and Christian Breyer\textsuperscript{1}

\textsuperscript{1)} Reiner Lemoine Institut gGmbH, Ostendstraße 25, 12459 Berlin, Germany
\textsuperscript{2)} Technische Universität Berlin, Institut für Energietechnik, Fasanenstraße 89, 10623 Berlin, Germany

DPG Tagung, Arbeitskreis Energie
Berlin, March the 28th 2012
Research approach

Problem
➔ Intermittent nature of renewable energies requires storage
➔ Special conditions on Caribbean islands (hot, only two seasons)

Object
➔ Energy supply system of Petite Martinique

Method
➔ Literature research
➔ HOMER Energy Simulation

Objective
➔ Finding the optimal energy supply and storage system for PM regarding renewable energies
Agenda

- Introduction – Petite Martinique
- Storage technologies
- Results
- Conclusion
Petite Martinique

Sources:
CIA (2011),
Google (2010)
## Petite Martinique

![Petite Martinique](image)

<table>
<thead>
<tr>
<th>Category</th>
<th>Value / Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface area</td>
<td>2.4 km²</td>
</tr>
<tr>
<td>Highest point</td>
<td>230 meter</td>
</tr>
<tr>
<td>Population</td>
<td>Approximately 1,000</td>
</tr>
<tr>
<td>Climate</td>
<td>Subtropical</td>
</tr>
<tr>
<td>Average temperature</td>
<td>25 degree celsius</td>
</tr>
<tr>
<td>Economic sectors</td>
<td>Fishing, boat building, agriculture, tourism</td>
</tr>
</tbody>
</table>

Sources: CIA (2011), Google (2010)
Comparison of different energy storage systems for renewable energies on a Caribbean island

Philipp Blechinger
philipp.blechinger@rl-institut.de

Energy supply system

<table>
<thead>
<tr>
<th>Category</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yearly demand</td>
<td>800 MWh</td>
</tr>
<tr>
<td>Peak demand</td>
<td>152 kW</td>
</tr>
<tr>
<td>Supply system</td>
<td>2 Diesel GenSets (240 kW / 210 kW)</td>
</tr>
</tbody>
</table>

Sources:
LogSheet (2010),
NASA (2010),
Gerlach (2011)
Energy supply system

- No seasonal changes in load profile or solar radiation
- Wind and solar often complementary

Sources: LogSheet (2010), NASA (2010), Gerlach (2011)
Agenda

- Introduction – Petite Martinique
- Storage technologies
- Results
- Conclusion
Comparison of different energy storage systems for renewable energies on a Caribbean island

Philipp Blechinger
philipp.blechinger@rl-institut.de

# Lead-Acid batteries vs vanadium redox flow

<table>
<thead>
<tr>
<th></th>
<th>Lead-Acid</th>
<th>Vanadium redox flow</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages</strong></td>
<td>• Relatively cheap</td>
<td>• Flexible combination of storage power and capacity</td>
</tr>
<tr>
<td></td>
<td>• Mature technology</td>
<td>• Long lifetime</td>
</tr>
<tr>
<td><strong>Disadvantages</strong></td>
<td>• Difficult waste management</td>
<td>• High initial costs</td>
</tr>
<tr>
<td></td>
<td>• Vulnerable to high temperatures</td>
<td>• Maintenance effort for pumps and membranes</td>
</tr>
</tbody>
</table>

Sources:
Toledo (2010), Schiffer (2007),
Sauer (2008), Bopp (2000),
Agenda

- Introduction – Petite Martinique
- Storage technologies
- Results
- Conclusion
Energy supply system simulation: Input

Sources:
- Personal conversation
- Manufacturer / supplier (confidential)

*Energy storage system:*

**L-A Battery:**
- 1kW/6kWh: 1,500 USD
- 1,600 cycles (80% DoD)

**VRF Battery:**
- 1 kW: 2,000 USD plus
- 1 kWh: 1,000 USD
- 14,000 cycles (100% DoD)

**Norwin 225 kW**
- 550,000 USD
- 2,600 USD/kW<sub>p</sub>
- 152 kW peak
- 2.2 MWh/day

1.20 USD/liter
### Optimization of energy supply system: Results

#### Optimized energy supply system
- 1 Wind turbine (225 kW)
- 140 kW<sub>p</sub> photovoltaic
- 100 kW / 600 kWh L/A Battery

<table>
<thead>
<tr>
<th>Name</th>
<th>LCOE</th>
<th>Capex</th>
<th>Diesel consumption</th>
<th>Renewable Fraction</th>
<th>CO&lt;sub&gt;2&lt;/sub&gt;-Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current system</td>
<td>0.53 US-$/kWh</td>
<td>0 USD</td>
<td>335,800 liter/yr</td>
<td>0 %</td>
<td>884,000 kg</td>
</tr>
<tr>
<td>Optimized system</td>
<td>0.29 US-$/kWh</td>
<td>1,100,000 USD</td>
<td>66,700 liter /yr</td>
<td>81 %</td>
<td>176,000 kg</td>
</tr>
</tbody>
</table>

#### Energy storage system
- Storage costs included into levelized cost of energy
- Storing renewable energy is partly more economical than diesel power generation
- **VRF Battery** not competitive at these initial costs
Detailed analysis of storage costs

Levelized cost of storage (LCOS)

\[ LCOS = \frac{\text{capex} \times \text{crf} + \text{opex}}{E_{\text{output}}} \]

capex: Capital expenditures per battery

crf: Capital recovery factor

opex: Annual operation and maintenance expenditures per battery

\[ E_{\text{output}} = \text{Annual battery output (} \eta \times n \times C \times \text{DoD}) \]

C: Installed capacity

n: Annual full cycles (input energy divided by C*DoD)

DoD: Maximum depth of discharge

\[ \eta \]: Roundtrip efficiency

Sources:
Lambert (2006),
Nair (2011)
Comparison of different energy storage systems for renewable energies on a Caribbean island

Philipp Blechinger
philipp.blechinger@rl-institut.de

Sensitivity analysis of storage costs

- Only significant cost reduction of VRF battery can make it competitive
- Reduction of lifecycles of L/A batteries not as crucial as change in initial costs of VRF batteries
Agenda

- Introduction – Petite Martinique
- Storage technologies
- Results
- Conclusion
Conclusion

Energy storage system
• L/A more economical for small Caribbean island than redox flow at the moment
• Flow batteries only advantageous due to environmental reasons

Energy supply system
• Renewable energies combined with storage are already competitive compared to conventional systems on islands
  • Lower levelized cost of energy
  • Less CO2-emissions
• Many other islands with similar conditions
  • Same load profile
  • Excellent renewable resources

=> Enormous market potential!
THANK YOU.


References 2


Comparison of different energy storage systems for renewable energies on a Caribbean island
Philipp Blechinger ► philipp.blechinger@rl-institut.de

Back up

Sources: Tokuda (2000)