SOUTHERN AFRICA ENERGY PROGRAM (SAEP)
BATTERY STORAGE COST-BENEFIT FOR REGIONAL DISTRIBUTORS – NAMIBIA CASE
AFRICA CESP WORKSHOP PRESENTATION
February 2019
AGENDA

• Introduction to SAEP
• CENORED-SAEP Project Scope and initial assessment
• Cost Benefit Analysis – Battery Storage
• Model Outputs
• Next steps
The USAID Southern Africa Energy Program’s assists in the development of generation, transmission and distribution whilst promoting investment in the energy sector for a brighter, more sustainable future.

5 Years
ACTIVITY DURATION
March 2017 – March 2022

IMPLEMENTED BY
Deloitte, with McKinsey, WorleyParsons, CrossBoundary, and Another Option

TARGET COUNTRIES
Angola, Botswana, Lesotho, Madagascar, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia, Zimbabwe

REGIONAL PARTNERSHIP FOCUS
SADC, SAPP, RERA, SACREEE

Program Funding
The Southern Africa Energy Program is funded by the United States Agency for International Development (USAID), in support of the US Government’s Power Africa Initiative. To date, Power Africa’s more than 130 private and public sector partners have committed more than $52 billion to mobilize and organize international efforts to electrify Africa.

USAID supports Power Africa through programs that bring together technical and legal experts, the private sector, and governments from around the world to work in partnership to increase the number of people with access to power.
SAEP OVERVIEW

OBJECTIVE
Increase investment in electricity supply and access in Southern Africa by strengthening the regional enabling environment and facilitating transactions.

GOALS
1. Generate 3000 MWs
2. Develop 1000 MW transmission capacity
3. Create 3 million new connections

PROGRAM OUTCOMES / TASK AREAS

- **Outcome 1**: Improved Regulation, Planning and Procurement for Energy
- **Outcome 2**: Improved Commercial Viability of Utilities
- **Outcome 3**: Improved Regional Harmonization and Cross-Border Trade
- **Outcome 4**: Scaled Renewable Energy (RE) and Energy Efficiency (EE)
- **Outcome 5**: Increased Human and Institutional Capacity
CENORED OVERVIEW

• NamPower is the national utility responsible for Gx, Tx and energy trading (imports & procurement from large IPPs)
• Distribution – Operated by Regional Electricity Distributors (REDs) or Municipalities
  ❑ A total of 3 REDs and 15 Municipalities
• CENORED is one of the REDs; the other two are ERONGORED and NORED
• CENORED Distributes electricity to the various towns and settlement areas of Central and Northern Namibia
• Covers an area of over 120 000 square kilometres
• Strategic objectives include improving cost efficiency, and increasing embedded RE generating capacity to 20 MW or greater if energy storage proves viable
PROJECT SCOPE
CENORED wanted to evaluate the costs and benefits of using battery storage at six solar PV sites to mitigate the financial risk of increasing bulk tariffs and improve renewable energy integration

Key Considerations:

- Increasing NamPower time-of-use (TOU) tariffs, including fast-growing maximum demand and network access charges
- Significant discrepancies between peak and off-peak NamPower energy charges
- Management of variable renewable energy from solar PV resources
- CENORED is interested in being an off-taker of battery services, rather than owning and operating the facilities

Proposed and Existing Solar PV Sites:

- Site 1 (3.5 MW)
- Site 2 (0.75 MW)
- Site 3 (0.5 MW)
- Site 4 (5 MW)
- Site 5 (1.5 MW)
- Site 6 (5 MW)

Source: NamPower Time of Use Tariff Schedule
The initial analysis focused on energy time-shift and renewables capacity firming, however additional battery storage applications may be worth subsequent consideration.

### RELEVANT BATTERY STORAGE APPLICATIONS

<table>
<thead>
<tr>
<th>Type</th>
<th>Application</th>
<th>Description</th>
<th>Benefits</th>
<th>Relevance &amp; User(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk Storage</td>
<td>Energy Time-Shift</td>
<td>The use of energy storage to purchase or store energy when prices are low and shift that energy to be sold when prices are higher (during peak times)</td>
<td>Cost savings from reduced peak load consumption</td>
<td>Primary driver of analysis (CENORED)</td>
</tr>
<tr>
<td>Renewables Integration</td>
<td>Renewables Capacity Firming</td>
<td>The use of energy storage to firm energy generation of a variable energy resource so that output reaches a specified level at certain times of the day</td>
<td>Increased generation capacity credit and reduced renewable energy curtailment</td>
<td>Primary driver of analysis (CENORED)</td>
</tr>
<tr>
<td>Renewables Integration</td>
<td>Renewables Ramp Rate Control</td>
<td>The use of energy storage to control the ramp rate of a variable energy resource to limit the impact to the grid</td>
<td>Increased grid stability despite renewable energy integration</td>
<td>Dependent on regulatory requirements and total vRE supply levels (CENORED)</td>
</tr>
<tr>
<td>Ancillary Services</td>
<td>Frequency Regulation</td>
<td>The use of energy storage to mitigate load and generation imbalances on the second to minute interval to maintain grid frequency</td>
<td>Near real-time maintenance of system-wide AC frequency</td>
<td>Dependent on existing services (CENORED and/or NamPower)</td>
</tr>
<tr>
<td>Ancillary Services</td>
<td>Voltage Support</td>
<td>The use of energy storage to provide reactive power for voltage support and respond to voltage control signals from the grid</td>
<td>More efficient provision of reactive power</td>
<td>Dependent on existing services (CENORED and/or NamPower)</td>
</tr>
<tr>
<td>Ancillary Services</td>
<td>Spinning/Non-Spinning Reserves</td>
<td>The use of energy storage that is online (spinning) or offline (non-spinning) and can be synchronized to supply generation capacity within 10 mins</td>
<td>Increased supply reliability and adherence to reserve capacity requirements</td>
<td>Dependent on existing reserves and regulatory requirements (NamPower)</td>
</tr>
<tr>
<td>Ancillary Services</td>
<td>Black Start</td>
<td>The use of energy storage to provide power to the grid following a grid-wide blackout</td>
<td>Black start capabilities without constant operation</td>
<td>Multiple black start plants already in production (NamPower)</td>
</tr>
<tr>
<td>Transmission and Distribution (T&amp;D)</td>
<td>T&amp;D Upgrade</td>
<td>The use of energy storage to avoid or defer costly transmission or distribution upgrades</td>
<td>Deferral or elimination of large investments in new T&amp;D equipment</td>
<td>Dependent on load forecasts and infrastructure capacity (NamPower)</td>
</tr>
<tr>
<td>Transmission and Distribution (T&amp;D)</td>
<td>Transmission Congestion Relief</td>
<td>The use of energy storage to provide system capacity during peak times to relieve upstream transmission congestion</td>
<td>Reduction or elimination of congestion-related charges</td>
<td>Dependent on load forecasts and infrastructure capacity (NamPower)</td>
</tr>
</tbody>
</table>

**Legend:**
- Very Low
- Low
- Unknown
- High
- Very High
The analysis considered lithium-ion and flow batteries due to the technologies’ immediate and long-term competitiveness in the region and their applicability to CENORED’s use case.

### Relevant Battery Storage Technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Maturity / Bankability</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Competitiveness in SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced Lead Acid</td>
<td>Mature / Strong</td>
<td>• Mature technology</td>
<td>• Low cycle life</td>
<td>2016 – 2020</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Capital cost relatively low</td>
<td>• Limited DoD</td>
<td>2021-2025</td>
</tr>
<tr>
<td>Sodium Sulfur Battery</td>
<td>Mature / Strong</td>
<td>• Limited cycle life</td>
<td>• High power and energy density</td>
<td>2026-2031</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Requires external heat system</td>
<td>• Longer discharge times than Li-ion</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• High temperature system</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Large daily self-discharge</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lithium-Ion</td>
<td>Commercial / Strong</td>
<td>• High round trip efficiency</td>
<td>• Limited but improving cycle life</td>
<td>2016 – 2020</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Continuing performance improvements and manufacturing cost reductions</td>
<td>• Deep discharge cycles lower lifetime</td>
<td>2021-2025</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• High cycle life, full DoD</td>
<td>• Thermal management in harsh conditions</td>
<td>2026-2031</td>
</tr>
<tr>
<td>Vanadium Flow</td>
<td>Demo / Moderate</td>
<td>• Mature for a flow technology</td>
<td>• Lower round trip efficiency</td>
<td>2016 – 2020</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Vanadium is a SA resource</td>
<td>• Requires mechanical systems</td>
<td>2021-2025</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• High cycle life, full DoD</td>
<td>• High cost of Vanadium</td>
<td>2026-2031</td>
</tr>
<tr>
<td>Zinc Bromine Flow</td>
<td>Demo / Moderate</td>
<td>• High cycle life, full DoD</td>
<td>• Lower round trip efficiency</td>
<td>2016 – 2020</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Less expensive electrolyte than Vanadium</td>
<td>• Requires mechanical systems</td>
<td>2021-2025</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Small daily self-discharge</td>
<td>• Power and energy not fully independent</td>
<td>2026-2031</td>
</tr>
<tr>
<td>Iron-Chromium Flow</td>
<td>Demo / Weak</td>
<td>• Lower round trip efficiency</td>
<td>• Power and energy scale independently</td>
<td>2016 – 2020</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Low energy density</td>
<td>• Small daily self-discharge</td>
<td>2021-2025</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Requires mechanical systems</td>
<td>• High cycle life, full DoD</td>
<td>2026-2031</td>
</tr>
<tr>
<td>Liquid Metal Batteries</td>
<td>R&amp;D / Weak</td>
<td>• Long electrode life</td>
<td>• Liquid layers sensitive to motion</td>
<td>2016 – 2020</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Low cost potential</td>
<td>• High temperature – requires active heating</td>
<td>2021-2025</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Rapid charge/discharge</td>
<td></td>
<td>2026-2031</td>
</tr>
</tbody>
</table>

Source: USTDA South Africa Energy Storage Technology and Market Assessment
COST-BENEFIT ANALYSIS MODEL
MODEL OVERVIEW

The model used relied on tariff, solar PV generation, and CENORED load data to generate a simulated power-flow and tariff paths, as well as illustrative CENORED cost savings and project cash flows.

### Inputs
- NamPower TOU tariff schedule
- Proposed solar PV tariffs
- Proposed solar PV nameplate capacity
- Projected solar PV capacity factor
- CENORED load for each site

### Outputs
- Simulated power-flow
- Simulated tariff paths
- Illustrative lifecycle and annual cost savings for CENORED
- Illustrative project cash flows for an independent developer

### Scenarios
- Solar PV Only
- Battery Storage Only
- Solar PV + Battery Storage

<table>
<thead>
<tr>
<th>Battery Storage Technology</th>
<th>Battery Storage Costs</th>
<th>Tariff Price Path</th>
<th>Load Forecast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithium-Ion NMC, Flow Vanadium</td>
<td>Low, Average, High</td>
<td>Unlikely, Likely, Very Likely</td>
<td>Unlikely, Likely, Very Likely</td>
</tr>
</tbody>
</table>
The simulated power-flow shows the exchange of energy between CENORED, NamPower, the solar PV plant, the battery storage system, and the load on a Week Day, Saturday, or Sunday.

**Model Outputs: Simulated Power-Flow**

- Battery charging in the early morning using NamPower off-peak energy
- Battery discharging during morning and evening peak time periods
- Solar PV power replacing NamPower peak energy during morning peak
- Battery storing solar PV power for use during evening peak once the morning peak period is over
- CENORED using NamPower bulk energy to service load
The simulated tariff paths show the relative price per kWh of the NamPower TOU tariffs, solar PV tariffs, and battery storage tariffs.

MODEL OUTPUTS: SIMULATED TARIFF PATHS

- **NamPower energy charges** shown by season (low, high) and TOU (off-peak, standard, peak)
- **Battery storage tariffs** set at a multiple of solar PV tariff
- **Solar PV tariff** based on proposed / existing rates for the selected site
MODEL OUTPUTS: ILLUSTRATIVE CENORED COST SAVINGS

The illustrative CENORED cost savings show the potential savings that could be achieved from the selected scenario relative to business as usual.
MODEL OUTPUTS: ILLUSTRATIVE PROJECT CASH FLOWS
The illustrative project cash flows demonstrate the potential return on investment for an independent project developer.

![Graph showing project cash flows](image-url)

- **Initial capital investment**, including system, EPC, and land costs
- **Annual after tax cash flows**
- **Cumulative cash flow**
The model is not designed to fully optimize the following variables, therefore further analysis on these areas will be required prior to a final decision on battery storage deployment.

### Variable Considerations and Limitations

<table>
<thead>
<tr>
<th>Variable</th>
<th>Current Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery storage sizing (i.e., power and energy profiles)</td>
<td>The battery systems’ energy capacity is sized according to solar PV plant nameplate power capacity; the systems’ power capacity is based on 0.25 charge rate (4-hour duration at full discharge)</td>
</tr>
<tr>
<td>Battery storage tariffs</td>
<td>Battery storage tariffs are set at a multiple of the site’s solar PV tariffs. A range of tariffs were modelled to test the impact on project return (developer perspective) and energy savings (utility perspective)</td>
</tr>
<tr>
<td>Battery storage dispatch schedule</td>
<td>The battery storage systems’ dispatch schedule is programmed to store NamPower bulk energy for use during morning peak hours on week days only, and to store afternoon solar PV output for use during the evening peak hours on week days and weekends</td>
</tr>
<tr>
<td>Additional battery storage services</td>
<td>The model is not configured to identify potential savings and cash flows from additional battery storage services</td>
</tr>
</tbody>
</table>
THE NEXT PHASE OF THE WORK WILL FOCUS ON RESOLVING MODEL LIMITATIONS

Potential Way Forward

Conduct deep dive into specific sites focused on:

- Tariff pricing and structuring
- Storage system power and energy profiles
- Storage system degradation

SAEP is currently working with CENORED to scope the next phase of the work which will enable the CENORED executive to make investment decisions