ENERGY STORAGE:
Top 5 Mistakes

Daniel Crotzer
Who We Are

• Neutral and Unbiased
• Technology Agnostic
• Industry Insight
• Unmatched Experience
• Robust Technical & Financial Analysis
• End-to-End Services

What We Do

Energy Storage Feasibility Studies
Design & Analysis (ESS / S+S / W+S / Microgrid)
Technology & Market Analysis
RFP Drafting, Management and Evaluation
Independent Engineering & Power Systems Analysis
Financial Model Development
Project Optimization
Education
5 BIGGEST MISTAKES

1. Improper Sizing
2. Underestimating OPEX
3. Miscalculating Degradation
4. Contract Negotiations
5. Inadequate EMS
SIZING - DUTY CYCLE

5 Biggest Mistakes - Sizing

5 Biggest Mistakes - Sizing

SIZING - PROCUREMENT

BESS IRR vs CAPEX

CAPEX

IRR

## SIZING - ANALYSIS

<table>
<thead>
<tr>
<th>Model</th>
<th>Cost (USD)</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base model (no optimization)</td>
<td>$60 M</td>
<td></td>
</tr>
<tr>
<td>70 MW / 130 MWh</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Battery algorithm optimization</td>
<td>$58.5 M</td>
<td>$1.5 M</td>
</tr>
<tr>
<td>70 MW / 125 MWh</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manual dispatch (wind forecast)</td>
<td>$40.5 M</td>
<td>$19.5 M</td>
</tr>
<tr>
<td>45 MW / 90 MWh</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Battery OPEX

<table>
<thead>
<tr>
<th>Expense</th>
<th>Cost</th>
<th>Escalation</th>
<th>Value</th>
<th>Accounting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insurance</td>
<td>$241,769</td>
<td></td>
<td>0.2%</td>
<td></td>
</tr>
<tr>
<td>Monitoring &amp; Maintenance</td>
<td>$1,087,960</td>
<td></td>
<td>0.90%</td>
<td></td>
</tr>
<tr>
<td><strong>Total annual battery cost</strong></td>
<td><strong>$1,329,728</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Retail price of electricity ($/MWh)

**70**

### Other OPEX

<table>
<thead>
<tr>
<th>Expense</th>
<th>Cost</th>
<th>Escalation</th>
<th>Value</th>
<th>Accounting</th>
</tr>
</thead>
<tbody>
<tr>
<td>BESS QSE cost</td>
<td>$18,174</td>
<td>1.0%</td>
<td>BESS</td>
<td></td>
</tr>
<tr>
<td>Aux load</td>
<td>$342,113</td>
<td>2%</td>
<td>BESS</td>
<td></td>
</tr>
<tr>
<td>Other cost</td>
<td>$0</td>
<td>2%</td>
<td>BESS</td>
<td></td>
</tr>
<tr>
<td>Storage Land Lease</td>
<td>$302,211</td>
<td>2%</td>
<td>0.25%</td>
<td>BESS</td>
</tr>
<tr>
<td>Property Tax</td>
<td>$4,547,844</td>
<td>2%</td>
<td>1%</td>
<td>BESS</td>
</tr>
</tbody>
</table>

### Aux load calculation

- **Enclosure area (sqft)**: 90,000
- **Cooling cost**: $90,000
- **Empty enclosure cooling cost**: $90,000
- **Charge mileage**: 130,784,177
- **Discharge mileage**: 114,401,447
- **Heating loss factor**: 100%
- **HVAC efficiency (effective)**: 200%
- **BESS cooling cost**: $252,113
# OPEX - MAINTENANCE

<table>
<thead>
<tr>
<th>Action</th>
<th>System</th>
<th>Component</th>
<th>Description</th>
<th>Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspect</td>
<td>DC Block</td>
<td>AC Electrical</td>
<td>Conduit Runs, Penetrations, Circuit Breaker</td>
<td>Annually</td>
</tr>
<tr>
<td>Inspect</td>
<td>DC Block</td>
<td>Battery Racks</td>
<td>Confirm modules are securely attached and inspect modules for signs of wear, discoloration of contacts</td>
<td>Annually</td>
</tr>
<tr>
<td>Inspect</td>
<td>DC Block</td>
<td>Battery Racks</td>
<td>Inspect racking system for defects including rust, corrosion, sagging, and missing or broken clips or bolts</td>
<td>Annually</td>
</tr>
<tr>
<td>Inspect</td>
<td>DC Block</td>
<td>Battery Racks</td>
<td>Inspect and test fans, replace as necessary</td>
<td>Annually</td>
</tr>
<tr>
<td>Inspect</td>
<td>DC Block</td>
<td>Battery Racks</td>
<td>Racking torque check and inspection</td>
<td>Annually</td>
</tr>
<tr>
<td>Inspect</td>
<td>DC Block</td>
<td>Battery Racks</td>
<td>Ensure module wiring is secure, not hanging loose and exposed to potential damage, bent to unapproved radius, or stretched across sharp or abrasive surfaces. Check for aging &amp; corrosion.</td>
<td>Annually</td>
</tr>
<tr>
<td>Inspect</td>
<td>DC Block</td>
<td>DC Bus</td>
<td>Observe DC bus terminal connections and inspect for arcing, dust, discoloration</td>
<td>Annually</td>
</tr>
<tr>
<td>Inspect</td>
<td>DC Block</td>
<td>DC String Box</td>
<td>DC contactors and fuses for signs of arcing, dust or discoloration</td>
<td>Annually</td>
</tr>
<tr>
<td>Inspect</td>
<td>DC Block</td>
<td>DC Wiring</td>
<td>Verify condition of DC conduits and connections, inspect for proper support, bushings, and expansion joints, where needed.</td>
<td>Annually</td>
</tr>
<tr>
<td>Inspect</td>
<td>DC Block</td>
<td>Main DC Disconnect Switch</td>
<td>Verify condition of DC disconnect(s). Open and look for signs of corrosion or damage. Check to make sure cabinet penetrations are properly sealed and there is no evidence of water ingress. Check torque marks on field terminations.</td>
<td>TBD</td>
</tr>
<tr>
<td>Test</td>
<td>DC Block</td>
<td>Safety Systems</td>
<td>Emergency Power Off Operation</td>
<td>Every 6 months</td>
</tr>
<tr>
<td>Inspect</td>
<td>DC Block</td>
<td>String DC Disconnect Switch</td>
<td>Check proper position of DC disconnect switches</td>
<td>Every 6 months</td>
</tr>
<tr>
<td>Inspect</td>
<td>DC Block</td>
<td>String DC Disconnect Switch</td>
<td>Verify condition of DC disconnect(s). Open and look for signs of corrosion or damage. Check to make sure cabinet penetrations are properly sealed and there is no evidence of water ingress. Check torque marks on field terminations.</td>
<td>Every 6 months</td>
</tr>
<tr>
<td>Review</td>
<td>DC Block</td>
<td>Battery and Enclosure temperature data trends</td>
<td></td>
<td>Monthly</td>
</tr>
<tr>
<td>Test</td>
<td>DC Block</td>
<td>Ground Fault Detection</td>
<td></td>
<td>Annually</td>
</tr>
<tr>
<td>Replace</td>
<td>DC Block</td>
<td>Control Power Supplies</td>
<td></td>
<td>10 Years</td>
</tr>
<tr>
<td>Inspect/Replace</td>
<td>DC Block HVAC</td>
<td>Wall-mount HVAC units</td>
<td>Air filters</td>
<td>Every 6 months</td>
</tr>
<tr>
<td>Inspect/Clean</td>
<td>DC Block HVAC</td>
<td>Wall-mount HVAC units</td>
<td>Evaporator, condenser, cabinet, drains,</td>
<td>Every 6 months</td>
</tr>
<tr>
<td>Inspect</td>
<td>DC Block HVAC</td>
<td>Wall-mount HVAC units</td>
<td>Coolant system for damage or leaks</td>
<td>Every 6 months</td>
</tr>
<tr>
<td>Test</td>
<td>Spares Shed</td>
<td>Battery Modules</td>
<td>Check state of charge and conditions within spares shed</td>
<td>Every 6 months</td>
</tr>
<tr>
<td>Test</td>
<td>Inverter</td>
<td>Emergency Power Off (EPO) Operation</td>
<td></td>
<td>Annually</td>
</tr>
<tr>
<td>Inspect</td>
<td>Inverter</td>
<td>Main Disconnect Circuit Breakers</td>
<td></td>
<td>Annually</td>
</tr>
<tr>
<td>Inspect</td>
<td>Inverter</td>
<td>Enclosure for leaks / damage / corrosion</td>
<td></td>
<td>Annually</td>
</tr>
<tr>
<td>Inspect</td>
<td>Inverter</td>
<td>AC / DC Connections</td>
<td></td>
<td>Annually</td>
</tr>
<tr>
<td>Test</td>
<td>Inverter</td>
<td>GFI Duplex Receptacles</td>
<td></td>
<td>6 months</td>
</tr>
<tr>
<td>Replace</td>
<td>Inverter</td>
<td>Control Power Supplies</td>
<td></td>
<td>10 Years</td>
</tr>
<tr>
<td>Replace</td>
<td>Inverter</td>
<td>Internal Fans</td>
<td></td>
<td>10 Years</td>
</tr>
</tbody>
</table>
Thermal Management System

- Based on the application, the integrator will develop a thermal management strategy to maximize the life of the battery and provide safe operation of the battery system.
- HVAC is sized and integrated specific to the BESS operating conditions and environmental considerations.
- Enclosure temperature is regulated to 23°C +/- 5°C during operation of the system.
- Battery capacity degrades more rapidly when it is operated outside of this temperature range, resulting in a tradeoff between operating temperature and cycle life.
5 Biggest Mistakes - Degradation

Miscalculating Degradation

Degradation

Years: 0 to 25

Energy Capacity: 60.0% to 120.0%

- Cycle
- Calendar
- Original Capacity
- System Capacity
- Useable Capacity
5 Biggest Mistakes - Degradation

Miscalculating Degradation

- Cycle
- Calendar
- Original Capacity
- System Capacity
- Useable Capacity
CONTRACT TERMS

1. Warranties
2. Performance Guarantees
3. Liquidated Damages
4. Scope of Work & Testing
5. Defaults
Get a Custom Warranty
...it could save you
$MILLIONS!!!
CONTRACT - PERFORMANCE GUARANTEE

Uptime (%) = \[\frac{(\text{Hours per month}) - (\text{Scheduled maintenance}) - (\text{Unscheduled maintenance})}{(\text{Hours per month}) - (\text{Scheduled maintenance})}\]

A high uptime guarantee is an important aspect of a project. Lower uptime guarantees could result in lower revenue. The following example shows the effect on revenue for two scenarios:

<table>
<thead>
<tr>
<th></th>
<th>Project 1</th>
<th>Project 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uptime Guarantee</td>
<td>100%</td>
<td>95%</td>
</tr>
<tr>
<td>Estimated Lifetime Revenue</td>
<td>$14,000,000</td>
<td>$14,000,000</td>
</tr>
<tr>
<td>Opportunity Cost Calculation</td>
<td>$14,000,000 * (100% - 100%)</td>
<td>$14,000,000 * (100% - 95%)</td>
</tr>
<tr>
<td>Lost Revenue</td>
<td>$0</td>
<td>$700,000</td>
</tr>
</tbody>
</table>
1. Delay
2. Guaranteed COD
3. Performance
   1. Availability/Uptime
   2. Duty Cycle
4. Capacity
   1. Power
   2. Energy
5. RTE
5 Biggest Mistakes – Contract Negotiations

CONTRACT – SOW and Testing

1. Integrator vs EPC vs Equipment scope
2. Dispatch Control
3. Site Acceptance Test
4. Commissioning
5. Annual Testing
5 Biggest Mistakes – Contract Negotiations

CONTRACT – DEFAULTS

1. Guaranteed COD
2. Availability/Uptime
3. Capacity
4. RTE
5. Insurance
EMS

Site Controller
• Manage deployments
• Optimize revenue
• Monitor, control, diagnostics and safety
• Should come with configurable parameters and various algorithms, control rules, SCADA, data/event logging, data visualization and human machine interface (HMI)
• 2-way communication and coordination

5 Biggest Mistakes – EMS
EMS – KEY FEATURES

1. Remote Operability
2. Real-Time Visualization
3. Historian
4. Accessibility (Web, SCADA, API)
5. Safety
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