Large-scale Diurnal Storage Study

Presentation at DOE ESS Peer Review
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Sentech, Inc., now part of SRA International
Project Objective

• Characterize and assess emerging innovative bulk ES technologies and relevant applications
  – Focus on concepts using pumped storage or compressed air with capacities greater than 100 MW

• Recommend strategy for DOE to hasten the commercialization of these innovative technologies.
• Project Duration:
  – May through December 2010

• Sandia Delegated Representative:
  – Georgianne Huff

• Joint project with KEMA Consulting:
  – Poonum Agrawal, Sentech, Inc., now part of SRA International
  – Rick Fioravanti, KEMA Consulting
  – Paul Gordon, Sentech, Inc., now part of SRA International
  – Larry Markel, Sentech, Inc., now part of SRA International
  – Ali Nourai, KEMA Consulting
  – Nellie Tong, KEMA Consulting
Overview

• Technical Approach
• Application Selection for Bulk Energy Storage
• Application Requirements
• Technologies Reviewed
• Characteristics Reviewed
• Feasibility Assessment Methodology
• Feasibility Assessment Results
• Summary/Conclusions
• Future Tasks
Technical Approach

1. Identify relevant applications and needed requirements for bulk energy storage ✓
2. Characterize novel technologies ✓
3. Assess and screen technological feasibility ✓
4. Analyze gaps and barriers (in process)
5. Recommend needed R&D (in process)
Application Selection

- Evaluated 19 applications
- Applied two criteria to assess suitability
  - Discharge Duration
  - Frequency of Use
- Identified 6 applications appropriate for bulk energy storage
## Application Requirements

<table>
<thead>
<tr>
<th>Applications</th>
<th>Capacity (MW)</th>
<th>Discharge Duration (Hours)</th>
<th>Desirable Minimum Energy Efficiency (%)</th>
<th>Response Time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Electric Energy Time-shift</td>
<td>1</td>
<td>≥500</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Electric Supply Capacity</td>
<td>1</td>
<td>≥500</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Load Following</td>
<td>1</td>
<td>≥500</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Renewable Energy Time Shift</td>
<td>&lt;1</td>
<td>≥500</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Renewable Capacity Firming</td>
<td>&lt;1</td>
<td>≥500</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Wind Generation Grid Integration- Long Duration</td>
<td>&lt;1</td>
<td>≥500</td>
<td>1</td>
<td>6</td>
</tr>
</tbody>
</table>
Novel Technologies Reviewed

**Pumped Storage Hydropower**
1. Aquifer
2. Archimedes’ Screw Storage
3. Below Ground Reservoir
4. In ground storage pipe with piston
5. In-reservoir tube with bubbles
6. Energy Island
7. Ocean Pumped Storage
8. Variable-Speed

**Compressed Air Energy Storage**
1. Adiabatic
2. Diabatic Renewable
3. Near-isothermal
4. Liquid Air Energy Storage
5. Transportable CAES
6. Underwater CAES
7. Other: Adsorption Enhanced
8. Other: Hydrokinetic
9. Other: Vehicle compression
Characteristics Reviewed

Business Characteristics
1. Commercial Status
2. Permitting
3. Siting
4. Capital Cost
5. Annual O&M Cost
6. Calendar Life
7. Construction Lead Time
8. Companies Involved
9. Studies/Project Installations

Grid Characteristics
1. Power
2. Energy
3. Energy Efficiency
4. Ramp Rate or Response Time
5. Other Features
Feasibility Assessment

- Technical Feasibility
- Technical Maturity
- Engineering Feasibility
- Economic Feasibility
- R&D Requirement
Screening Approach

• Assessed each of the technologies by the 5 attributes and scored them on a scale of 1-10
• 4 reviewers
• Averaged scores, discussed and reconciled outliers
• Identified the technologies by development timeframe:
  – Score > 40: Short-term (< 5 years)
  – Score between 25 and 40: Medium-term (between 5 - 10 years)
  – Score < 25: Long-term (> 5 years)
Feasibility Assessment Results - CAES

- Adiabatic
- Adsorption Enhanced
- Diabatic Renewable
- LAES
- Hydrokinetic
- Near-isothermal
- Transportable CAES
- Underwater CAES
- Vehicle compression

- Technical Feasibility Score
- Technical Maturity Score
- Economic feasibility Score
- Engineering feasibility Score
- R&D requirements Score
Feasibility Assessment Results - PSH

- Technical Feasibility Score
- Technical Maturity Score
- Engineering feasibility Score
- Economic feasibility Score
- R&D requirements Score

Aquifer, Archimedes' Screw, Below Ground, Energy Island, In-ground storage pipe, In-reservoir tube w/..., Ocean, Variable-Speed
<table>
<thead>
<tr>
<th></th>
<th>Short-term (&lt; five years)</th>
<th>Mid-Term (5-10 years)</th>
<th>Long-term (&gt;10 years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSH</td>
<td>• Ocean</td>
<td>• Aquifer</td>
<td>• In-reservoir tube with bubbles</td>
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<tr>
<td></td>
<td>• Variable Speed</td>
<td>• Archimedes’ Screw</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>• Below Ground Reservoir</td>
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<td></td>
<td>• Energy Island</td>
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<tr>
<td></td>
<td></td>
<td>• In-ground storage pipe</td>
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<td>CAES</td>
<td>• Near Isothermal</td>
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Based on the preliminary assessment it is recommended that DOE fund R&D, demonstration and incentives for commercialization based on the timeframe for development for each technology.

<table>
<thead>
<tr>
<th>Type of Government Support</th>
<th>Time to Commercialization</th>
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<tr>
<td>R&amp;D funding</td>
<td>Short-term (&lt; five years)</td>
</tr>
<tr>
<td>Funding for Demonstrations</td>
<td>✓</td>
</tr>
<tr>
<td>Incentives for Commercialization</td>
<td>✓</td>
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Future Tasks

• Incorporate feedback from peer review
• Complete gap and barrier assessment
• Develop R&D recommendations
• Complete final report by November 2010
• Present final results to DOE Energy Storage and Wind and Hydropower Programs by December 2010
Contact Information

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