Technologies to enable cost-effective long duration energy storage

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Components of energy storage

Power Block

Energy Unit

Energy Unit
Components of energy storage: Energy
Energy storage medium cost and specific energy

<table>
<thead>
<tr>
<th>Medium</th>
<th>Specific Energy (kWh/kg)</th>
<th>Specific Cost ($/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rocks, $\Delta T=100s$ of °C</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Fire bricks, $\Delta T=800$°C</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>NH$_3$ (l)</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>H$_2$</td>
<td>100 $/kWh$</td>
<td>100 $/kWh$</td>
</tr>
<tr>
<td>Solar salt, $\Delta T=300$°C</td>
<td>100</td>
<td>100 $/kWh$</td>
</tr>
<tr>
<td>LiCoO$_2$</td>
<td>100</td>
<td>100 $/kWh$</td>
</tr>
<tr>
<td>V$_2$O$_5$</td>
<td>100</td>
<td>100 $/kWh$</td>
</tr>
<tr>
<td>LAES (77K)</td>
<td>100</td>
<td>100 $/kWh$</td>
</tr>
<tr>
<td>H$_2$O$_2$, h=300 meters</td>
<td>100</td>
<td>100 $/kWh$</td>
</tr>
<tr>
<td>Air, P=200 bar</td>
<td>100</td>
<td>100 $/kWh$</td>
</tr>
</tbody>
</table>

*Materials characteristics only.*
Considerations for containerization

Container Costs ($/kWh)

- Carbon Steel Tank
- Stainless Steel Tank
- Calcium Aluminate Tank

Energy Density (kWh/L)

Container + Storage Media Cost ($/kWh)

- Carbon Steel Tank
- Stainless Steel Tank
- Calcium Aluminate Tank

Sensible thermal media

T_h (K)

600 800 1000 1200 1400 1600

0 20 40 60 80 100 120
New energy scaling paradigms for long duration
New energy scaling paradigm: variable cycle life

“Universal” Power Block

Storage tank for daily cycling

Storage tanks for beyond daily cycling

Cycles over 20 y

Control valve

$\$/kWh Storage Medium
New energy scaling paradigm: variable energy density

Power Block

Storage tank for daily cycling

Storage tanks for beyond daily cycling

- Fully dissolved reactants, 15 Wh/L
- Concentrated reactants, >100 Wh/L

Container + Media Cost ($/kWh)

Separation/concentration process

Cost ($/kWh)
Components of energy storage: Power
Power block options at various scales and below $1/W

*Values are for $/kW_{thermal}
Low round trip efficiency limits the budget for capital costs

Charge price = 2.5 ¢/kWh; Discharge price = 7.5 ¢/kWh
Low round trip efficiency limits the budget for capital costs

Charge price = 2.5 c/kWh; Discharge price = 7.5 c/kWh
A fundamental shift in cost-performance tradeoff

Conventional Storage Design Space

Long-Duration Storage Design Space

Cost

Low
High

Performance

Low
High

(RTE, cycle life, material purity, etc.)
Thank you

- Long-duration storage is an area of active program development

- We would like your feedback and ideas to enable cost-effective long-duration energy storage
  - We’re particularly interested in innovative approaches that can:
    1. Dramatically reduce energy-related costs
    2. Fundamentally shift the cost/performance scaling of today’s state-of-the-art systems

- ARPA-E workshop on long duration storage (held Dec. 7-8, 2017)
  - www.arpa-e.energy.gov/?q=workshop/long-duration-stationary-energy-storage

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