Energy Storage Index
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Abstract
Peak energy production from sustainable sources rarely coincides with peak consumption. If sustainable power is to replace fossil fuels, energy storage is required to maintain power during off-peak production hours. Energy producers lack a guide for selecting the ideal energy storage system for their need. The objective was to create a rubric with multiple comparison points to assist in deciding which form of energy storage is most appropriate.

Objective
Create a rubric to grade energy storage systems based on sustainability.

Process
1. Develop list of comparison points to rank the technologies
2. Research different technologies
3. Develop rubric using the comparison points
4. Evaluate eight technologies with rubric

Analysis

Supercapacitor
Supercapacitors are an efficient and compact energy storage system, which stores energy in an electric field. Supercapacitors require little maintenance and have an outstanding lifecycle. A downside to this technology is the risk that one can explode if shorted or destroyed.

Compressed Air (CAES)
Compressed air is stored underground to help connected turbines can run at maximum efficiency during peak hours of consumption. CAES only works in areas with large underground caverns or porous rock formations. The use of caverns rather than tanks greatly reduces the cost of this system. The low cost enables this technology to be useful on a very large scale.

Flywheel
Modern flywheel systems store energy by spinning large masses up to 50,000 RPM. This is a hazard if it becomes fractured. Magnets and a vacuum remove almost all friction. Most systems are small enough to be portable.

Hydrogen Fuel Cell
Hydrogen fuel cell systems hydrolyze water, which later recombines to create electricity. Varying size allows for mobility. There is a high risk concerning hydrogen’s combustibility and environmental impact if not properly contained. Fuel cells have a limited number of cycles.

Thermal (Ice)
Ice works by chilling water at night, and circulating it during the day. Ice cooling can require putting new pipes in walls, and requires similar maintenance to water pipes, plus a pump and chiller. There is a risk of pipes bursting and flooding a basement, however this is still a low-risk technology.

Battery
The most significant advantage of batteries is their potential for mobility. In addition, lithium ion batteries can achieve over 99% efficiency making them the most energy efficient technology evaluated. A limitation is the finite number of times a battery can be cycled and the lack of maintainability.

Pumped Hydro (PHES)
Water is pumped uphill to be stored as gravitational potential energy. This closed system requires only occasional turbine maintenance. Large reservoirs can easily be created, boosting power output. This system is not mobile and is constrained to hilly areas

Pumped Heat
Pumped heat works by creating a difference of 660⁰ C in two tanks of argon, and has no geographic restraints. It is highly scalable with the energy storage capabilities of individual units ranging from household use to power plant use. Pumped heat uses no toxic chemicals and experiences comparable energy efficiency to CAES and PHES.

Results

<table>
<thead>
<tr>
<th>Energy Efficiency</th>
<th>Energy Density ( kWh/lb)</th>
<th>Charge Time</th>
<th>Discharge Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supercap CAES</td>
<td>90%</td>
<td>50</td>
<td>10h</td>
</tr>
<tr>
<td>Flywheel</td>
<td>95%</td>
<td>50</td>
<td>10h</td>
</tr>
<tr>
<td>Fuel Cell</td>
<td>50%</td>
<td>10h</td>
<td>20h</td>
</tr>
<tr>
<td>Ice</td>
<td>80%</td>
<td>10h</td>
<td>20h</td>
</tr>
<tr>
<td>Li Ion</td>
<td>60%</td>
<td>10h</td>
<td>10h</td>
</tr>
<tr>
<td>PBSO1</td>
<td>50%</td>
<td>10h</td>
<td>10h</td>
</tr>
<tr>
<td>Na S</td>
<td>90%</td>
<td>10h</td>
<td>10h</td>
</tr>
<tr>
<td>PHES Heat</td>
<td>80%</td>
<td>10h</td>
<td>10h</td>
</tr>
</tbody>
</table>

Best | Worst

Conclusion
The rubric developed by the team combines the objective points and subjective evaluative parameters in an easy to read format. The heat map is simple to understand since the darkest, or highest rated technologies stand out the most.