Session for Reliability and Flexibility

The importance of Long Duration Energy Storage when triplicating renewables.

Focusing on 2 LDES use cases

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Investments in renewables must be met by investments in storage and grid capacity for reliability and flexibility in the grid.

Long Duration Energy storage is key for the solutions to the growth of RE deployment and decarbonization of the grid but are yet to be significantly deployed in most countries.

Renewable energy investments have risen dramatically but less than 1% of energy transition investment goes to storage.

Increased energy storage means access to renewables at all times of the day.

To reach NetZero by 2030 we need 4 Twh of Long Duration Energy Storage.

Investments in renewables must be met by investments in storage and grid capacity for reliability and flexibility in the grid.
### LDES storage technologies

#### Key LDES storage types and parameters

<table>
<thead>
<tr>
<th>Energy storage form</th>
<th>Technology</th>
<th>Market readiness</th>
<th>Max deployment size, MW</th>
<th>Max nominal duration, Hours</th>
<th>Average RTE $^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical</td>
<td>Novel pumped hydro (PSH)</td>
<td>Commercial</td>
<td>10–100</td>
<td>0–15</td>
<td>50–80</td>
</tr>
<tr>
<td></td>
<td>Gravity-based</td>
<td>Pilot</td>
<td>20–1,000</td>
<td>0–15</td>
<td>70–90</td>
</tr>
<tr>
<td></td>
<td>Compressed air (CAES)</td>
<td>Commercial</td>
<td>200–500</td>
<td>6–24</td>
<td>40–70</td>
</tr>
<tr>
<td></td>
<td>Liquid air (LAES)</td>
<td>Pilot (commercial announced)</td>
<td>50–100</td>
<td>10–25</td>
<td>40–70</td>
</tr>
<tr>
<td></td>
<td>Liquid CO$_2$</td>
<td>Pilot</td>
<td>10–500</td>
<td>4–24</td>
<td>70–80</td>
</tr>
<tr>
<td>Thermal</td>
<td>Sensible heat (eg, molten salts, rock material, concrete)</td>
<td>R&amp;D/pilot</td>
<td>10–500</td>
<td>200</td>
<td>55–90</td>
</tr>
<tr>
<td></td>
<td>Latent heat (eg, aluminum alloy)</td>
<td>Commercial</td>
<td>10–100</td>
<td>25–100</td>
<td>20–50</td>
</tr>
<tr>
<td></td>
<td>Thermochemical heat (eg, zeolites, silica gel)</td>
<td>R&amp;D</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Chemical</td>
<td>Power-to-gas-(incl. hydrogen, syngas)-to-power</td>
<td>Pilot (commercial announced)</td>
<td>10–100</td>
<td>500–1,000</td>
<td>40–70</td>
</tr>
<tr>
<td>Electrochemical</td>
<td>Aqueous electrolyte flow batteries</td>
<td>Pilot/commercial</td>
<td>10–100</td>
<td>25–100</td>
<td>50–80</td>
</tr>
<tr>
<td></td>
<td>Metal anode batteries</td>
<td>R&amp;D/pilot</td>
<td>10–100</td>
<td>50–200</td>
<td>40–70</td>
</tr>
<tr>
<td></td>
<td>Hybrid flow battery, with liquid electrolyte and metal anode</td>
<td>Commercial</td>
<td>&gt;100</td>
<td>25–50</td>
<td>55–75</td>
</tr>
</tbody>
</table>

1. Power-to-power only. RTEs of systems discharging other forms of energies such as heat can be significantly higher.

90–95% of Commercial installed LDES capacity of today is Pumped Hydro.

Looking closer at two cases and technologies.

Source: LDES Council/McKinsey report.
Case study: Industrial heat decarbonization with Molten salt

The world’s largest energy demand is for heat, primarily sourced from fossil fuels, which account for 40% of global carbon emissions.

System is Plug-and-Play, no EPC needed. Heatcube is prefabricated and delivered to the facility for easy assemble.

Low footprint and high energy density. Minimal space and can easily be installed at existing process plants.

System can charge and discharge simultaneously for allowing of maximum benefit from the electricity market.

Round-trip efficiency (RTE) is above 93%
Case study: Industrial heat decarbonization with Molten salt

HeatCube will take on one of the roles of replacing coal in district heating, using renewable electricity powered heating and reduce carbon footprint.

In addition to its role in replacing coal, Heatcube will present Aalborg Forsyning with the opportunity to utilize the system within the flexibility market, leveraging the rapid charging reactions time.

Heatcube will assume an active role in the flexible reserve market, thereby maximizing the value of the installation and benefits for the City of Aalborg. Now certified as a Flexibility asset by TSO.

Norbis Park Heatcube facts and figures

- 18 MWh storage capacity
- 150 t Yara molten salt
- up to 2000* t annual CO2 reduction
- 4 MW discharge capacity
- 5 MW charge capacity
- 275 houses powered annually
Case study: Grid capacity Liquid CO2 battery

- Closed thermodynamic transformation
- Manipulation of CO2 between its gaseous and liquid phase
- CO2 warms up, evaporates, and expands, turning a turbine to generate electricity
- Energy storage sweet spot between 8/24 hours
- Zero CO2 emissions into the atmosphere during the entire process
- No cryogenic temperatures and high costs that are typically associated with compressed air energy storage
- Massive reduction of costs by storing the CO2 at ambient temperature in its liquid phase
- Patented technology that uses only water, steel, and CO2
- All components are readily available worldwide from multiple Tier 1 suppliers

Efficient
Round-trip efficiency (75%+) AC-AC and MV-MV

Cost-Effective
Highly competitive CAPEX and OPEX

Flexible
CO2 Batteries can be constructed anywhere in the world

Proven
MW-scale plant already operational and grid-connected

Durable
No degradation of capacity or performance over 30+ years

Reliable
Off-the-shelf components made of eco-friendly materials

Independent
No dependence on rare metals such as lithium
Case study: Ottana, Sardinia, Italy
20MW/200MWh, Energy grid supply 10 hours

- Commercial project operational end of 2024
- CAPEX approximately 50 MEuros. Funded by EIB and Breakthrough Energy.

Services

- Time-shifting: Chose the best time to regulate the flow of energy.
- Physical inertia: minimize in less than 1 second the variation of the grid frequency as a consequence of a mismatch between generation (supply) and load (demand).
- Frequency Containment Reserve (Primary Reserve): Restore the balance between generation and demand within 30 seconds.
- Automatic Frequency Restoration: Replace FCR gradually after 30 min in condition persists.
- Manual Frequency Restoration Reserve (Tertiary reserve): Restore the grid frequency by supporting or partially substituting aFRR after 12.5 Minutes.
- Voltage Regulation: Restore the nominal grid voltage by varying the reactive power of the machine.
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Renewable Energy Solution:
Energy storage

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