Cryogenic Energy Storage (CES)

Focusing on Liquid Air Energy Storage (LAES)

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CES pilot plant integrated with SSE Slough biomass plant

CES pilot plant integrated with University of Birmingham CHP plant

CES commercial demonstration plant integrated with Viridor Biogas Power Plant

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The Principle

- **Energy storage** – liquefaction of air using off-peak/renewable electricity with liquid air as the major energy storage medium;
- **Energy release** – vaporization of liquid air using ambient / renewable / waste heat gives 700 times expansion to drive turbine producing electricity.

- **Materials flow** – Air in, air out;
- **Energy flow** – Electricity in, electricity, heat and cold out;
- **Storage methods** – Liquid air (major), heat and cold (ancillary) with the heat from compression and cold from waste cold recovery.
The most advanced cryogenic energy storage technology: already commercially demonstrated, and currently in the deployment stage after some 15 years of development.
Large scale applications - e.g. to partially replace pumped hydro
Small scale applications – e.g. distributed energy systems and backup power
Fast response applications – e.g. frequency regulation if run on spin-gen mode
The pilot plant testing results (1)

Plant start and stop

Quick start and stop processes
Quick response - ~2.5min

Frequency control - Secondary frequency control and possibly primary frequency control if running on the Spin Gen mode.
High efficiency in the utilisation of low grade renewable and waste heat

Utilization of renewable and low grade waste heat – an increase of 1°C gives an increase in power generation efficiency by 0.45%, this cannot be achieved by any other storage technologies.
The Space requirements

- **20MW/80WWh**
  - Compressor house
  - Air cleaner
  - Cold box and cold expanders
  - Liquid air storage
  - Cryo pumps
  - Containerised power turbine and generator (2 x 10MW)
  - Heat exchanger containers
  - Hot water storage
  - Electrical intake and switch-house

- **200MW/1.2GWh**
  - High grade cold storage
  - Cryo pumps
  - Evaporators
  - 2 x 7,000 tonne liquid air tanks
  - 4 x 2,500 tpd liquefiers

**Space requirement estimations** -

- 200MW/1.2GWh plant ~16000m²
- 20MW/80MWh plant ~1600m²
- 5MW/15MWh commercial demonstration plant ~1000m²
- 350kW/2.5MWh system ~600m²
An increase in the scale leads to a significant cost reduction; for a given scale, the 10th unit only costs 1/3 of the first unit.
The economic analyses (2)

LCOE for different ES technologies
(5 hr duration systems at rated power capacity)

LCOE = \frac{\text{sum of costs over lifetime}}{\text{sum of electricity produced over lifetime}} = \frac{\sum_{t=1}^{n} I_t + M_t + F_t}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}
The economic analyses (3)

350kW/2.5MWh

5MW/15MWh
Comparison with other major large scale energy storage technologies (1)

**Compressed Air Energy Storage**

Large scale compressed air energy storage requires large caverns and suitable geological locations;

**Pumped Hydro**

Pumped hydro requires a mountain and two lakes at different elevations and specific geological locations;
Comparison with other major large scale energy storage technologies (2)

<table>
<thead>
<tr>
<th>Storage method</th>
<th>Energy density Wh/L</th>
<th>Life span yrs</th>
<th>Round trip efficiency %</th>
<th>Capital cost USD/kW</th>
<th>LCOE cost USD/kWh*</th>
<th>Storage time</th>
<th>Geological conditions</th>
<th>Technology maturity</th>
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</thead>
<tbody>
<tr>
<td>Pumped Hydro</td>
<td>0.5-1.5</td>
<td>40-60</td>
<td>60-80</td>
<td>600-2000</td>
<td>0.05-0.1</td>
<td>Hours – Months</td>
<td>Strict requirements</td>
<td>Mature</td>
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<tr>
<td>Compressed Air</td>
<td>3-6 (30-300bar)</td>
<td>20-40</td>
<td>40-50</td>
<td>600-1300</td>
<td>0.08-0.15</td>
<td>Hours - Months</td>
<td>Strict requirement</td>
<td>Developed</td>
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<td>60-70</td>
<td>2000-3000</td>
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<td>No requirement</td>
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<tr>
<td>Liquid air</td>
<td>60-120 (No pressure effect)</td>
<td>30-40</td>
<td>40-70</td>
<td>650-2000</td>
<td>0.05-0.15</td>
<td>Hours - Months</td>
<td>No requirement</td>
<td>Nearly Developed</td>
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<td>60-100</td>
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# LCOE of Technologies:  Lio-Ion~$1.4/kWh; NaS~$0.2/kWh; Lead Acid~$0.6/kWh; Flow Battery~$0.4/kWh
Summary of the LAES technology

The LAES technology has a great potential -

- Technology maturity;
- Easiness of technology implementation;
- Space requirements;
- Geological locations;
- Costs.