Supercritical CO$_2$-Based Long-Duration Electrical Energy Storage
Echogen overview

- Founded in 2007
- Mission: To develop and commercialize a better exhaust and waste heat recovery power system using CO$_2$ as the working fluid
sCO$_2$ power cycle commercial activity

- Key partnerships – Siemens (Oil & Gas), GE (Marine)
- First commercial article (EPS100 – 7.5 MWe) designed and built by Echogen, tested at Siemens
- First commercial sale (EPS120 – 9.5 MWe) announced in March 2019 by Siemens to TransCanada
Ongoing Echogen projects

- Leading multiple DOE- and industry-funded projects in:
  - Nuclear – Micro-reactor power plant, others
  - Fossil – 10 MWe indirectly-fired power plant (FE)
  - Solar – thermochemical energy storage (SETO)
  - Energy Storage – (ARPA-E)
  - Thermal power plant integration with ETES (Coal FIRST)
  - Large-scale (100 MWe+) CO₂ compressor technology development (SETO)
ETES (or TEES, or PTES, or Carnot Battery) storage

Heat Pump Cycle

\[ \text{COP} = \frac{Q_h}{E_{chg}} \]

Ideal COP = \(\frac{1}{1 - \frac{T_c}{T_h}}\)

Overall Process

\[ \text{RTE} = \frac{E_{gen}}{E_{chg}} = \text{COP} \times \text{Efficiency} \]

Ideal cycle RTE = \(\text{COP}_{\text{Carnot}} \times \eta_{\text{Carnot}} = 100\%\)

Non-ideal processes result in RTE \(~60\%, \text{ even at modest temperature ratio}\)
Cycles on a PH diagram

HTX heat transfer is supercritical - sensible enthalpy transfer interaction with HTR

LTX is subcritical – condensation and evaporation - ~ constant temperature interaction with LTR
Longer Duration = Lower Capex/kWh = Lower LCOS

Lower Capex => Lower LCOS
ETES lab-scale system

ARPA-E funded project

~200 kWth system, including both charging and generating cycles

Focused on reservoir and heat exchanger development and TEA

Operation and controls development
Capability matrix for discussion

<table>
<thead>
<tr>
<th>Services</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arbitrage</td>
<td>Yes (if economics support)</td>
</tr>
<tr>
<td>RES smoothing</td>
<td>&quot;</td>
</tr>
<tr>
<td>Peak capacity</td>
<td>&quot;</td>
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<tr>
<td>Seasonal storage</td>
<td>No</td>
</tr>
</tbody>
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**Technical requirements**

- Round trip efficiency as high as possible - $ vs RTE trade
- Low thermal loss – Small $T$ to environment
- Modularity and scalability – Yes – 10-100 MWe blocks
- Cycling capacity => small degradation during lifetime – Typical power plant
- Compactness and affordability of storage medium – Very
- Low CAPEX for energy conversion system – Yes at longer durations
- High flexibility during charging phase – TBD
- Compatibility for retrofitting existing plant – Yes
- Compatibility with district heating and cooling – Yes
- Safety and chemical hazard – Excellent
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