CO₂-Based Pumped-Thermal Energy Storage
Technical Overview & Status
Acknowledgments and disclaimers

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PTES in a nutshell

**Electrically-driven heat pump**

**Charging cycle**
- Heat Pump Cycle
  - COP = \( \frac{Q_h}{Echg} \)
  - Ideal COP = \( \frac{1}{1-T_c/Th} \)

**Generating cycle**
- RTE = \( \frac{Egen}{Echg} \)
  - Power Cycle Efficiency = \( \frac{Egen}{Qh} \)
  - Ideal efficiency = \( 1-T_c/Th \)

**Overall Process**
- RTE = \( \frac{Egen}{Echg} \) = COP x Efficiency

**Ideal cycle RTE = COP_{Carnot} x \eta_{Carnot} = 100\%**

Non-ideal processes result in RTE ~60\%, even at modest temperature ratio

**Electric generation heat engine**

**Generating cycle**
- Electric generation
  - Pump
  - Turbine
  - \( Qh \)

**Power Cycle Efficiency = \( \frac{Egen}{Qh} \) **
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
ARPA-E DAYS Program – PTES lab system

~200 kW\textsubscript{th} system, including both charging and generating cycles

Operating for ~ 6 months, repeated charge/generate cycles

Basic cycle and thermal reservoir experience and data

Operation and control methodology development and optimization
Lab-system configuration – Charge cycle
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Lab-system configuration – Charge cycle
Lab-system configuration – Generate cycle
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Work in progress & next steps

- HTR – Sand-based reservoir installation
- HTX – Fluidized bed heat exchanger
- IOC – Ice-on-coil LTR
- Axial compressor (100+ MW)
- 25 MW / 8-hour system preliminary design
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