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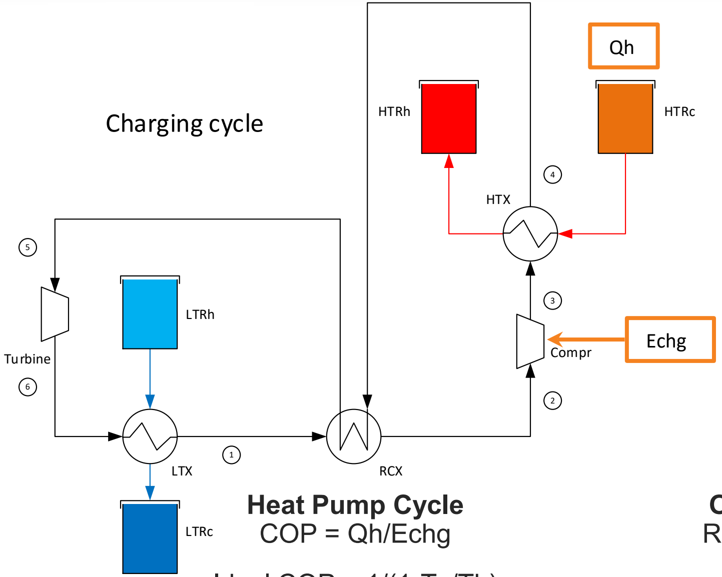
power systems

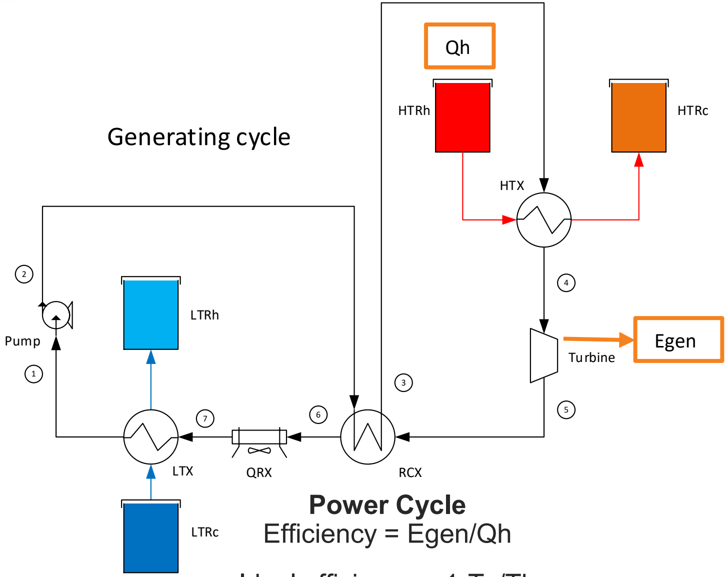
Supercritical CO_2-Based Long-Duration Electrical Energy Storage

Echogen Power Systems background

- Founded in 2007
- Mission: To develop and commercialize a better exhaust and waste heat recovery power system using CO_2 as the working fluid
- First company to deliver a commercial sCO_2 power cycle
- Developing a CO_2-based PTES/ETES system

Pumped Thermal Energy Storage basics





Heat Pump Cycle
COP = Qh/Echg

Ideal COP = 1/(1-Tc/Th)

Overall Process
RTE = Egen/Echg

= COP x Efficiency

Power Cycle
Efficiency = Egen/Qh

Ideal efficiency = 1-Tc/Th

Ideal cycle RTE = COP_{Carnot} x η_{Carnot} = 100%

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

ARPA-E DAYS Program – ETES lab-scale system

LTR

Charge compressor

Gen pump

HTR

ISG

Recuperator

~200 kWth system, including both charging and generating cycles

Initial build

- 2-tank heat transfer fluid HTR
- Ice slurry LTR

Commissioning complete

Initial round of testing complete

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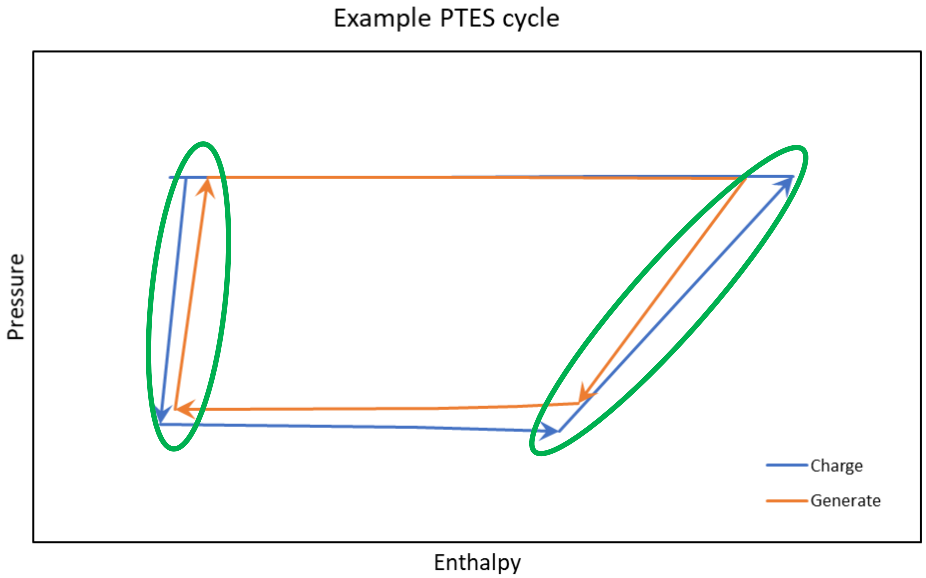
Key performance criteria



- Turbomachinery performance
- Approach temperatures
- Pressure drops

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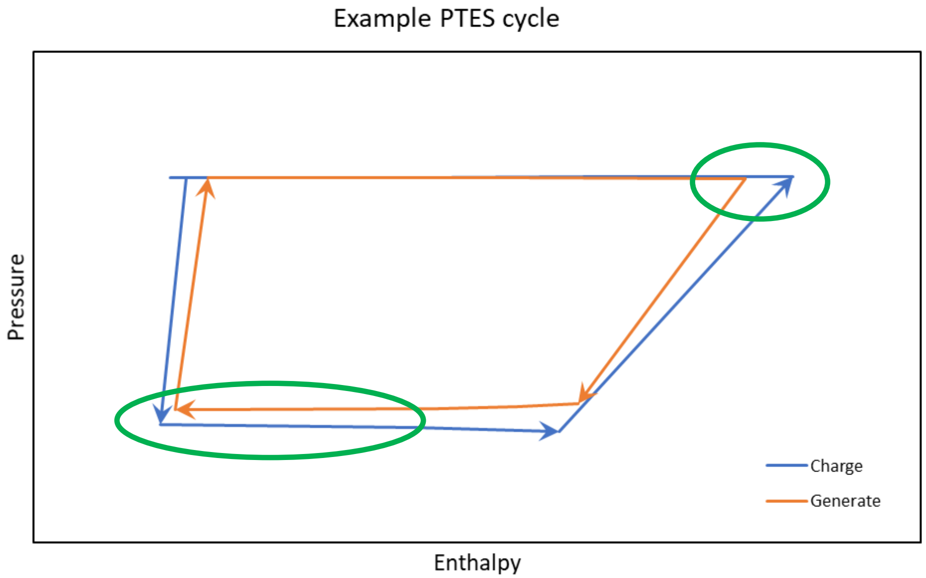
Key performance criteria



- Turbomachinery performance
- Approach temperatures
- Pressure drops

$$\Delta RTE = \frac{T_c}{T_h - T_c} \frac{\Delta T_{apr,h}}{T_h}$$

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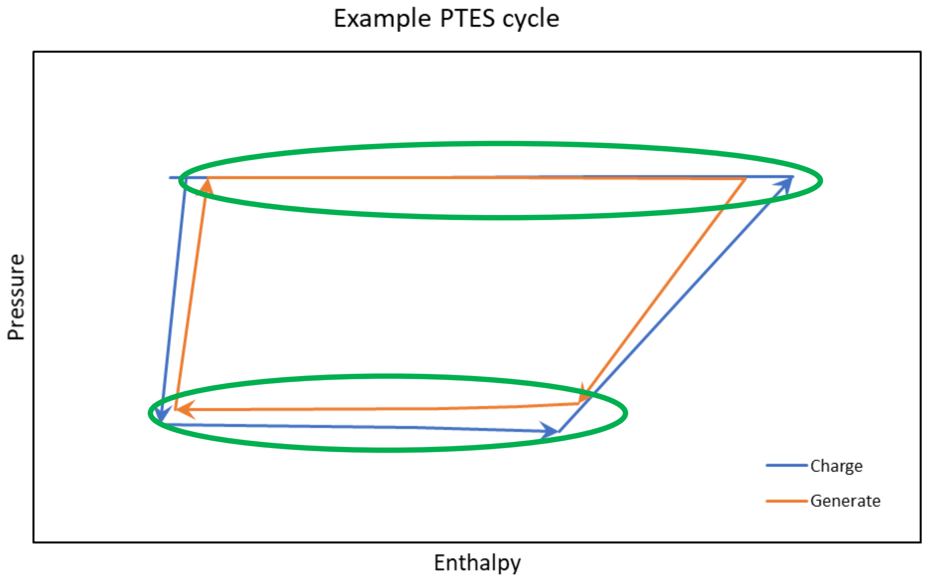
Key performance criteria



- Turbomachinery performance
- Approach temperatures
- Pressure drops

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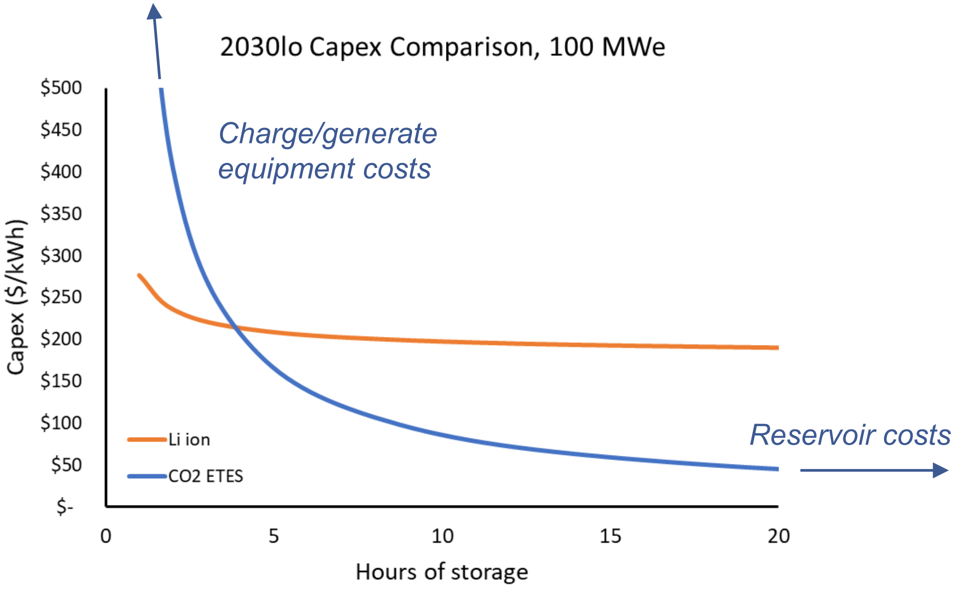
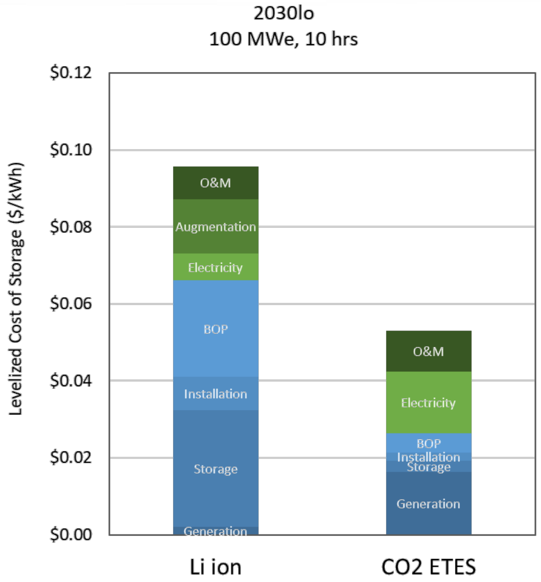
Same song, different verse

- Cycle performance boils down to:
  - Turbomachinery performance
  - Heat exchanger characteristics – UA and ΔP
  - Cycle design – Impacts ΔT_{apr}
- System cost depends on:
  - Heat exchanger characteristics – UA and $\Delta P = f(\$)$
  - Cycle design
  - Reservoir materials and containment structures

Economics dominate use cases





Lower Capex, no augmentation costs => Lower LCOS

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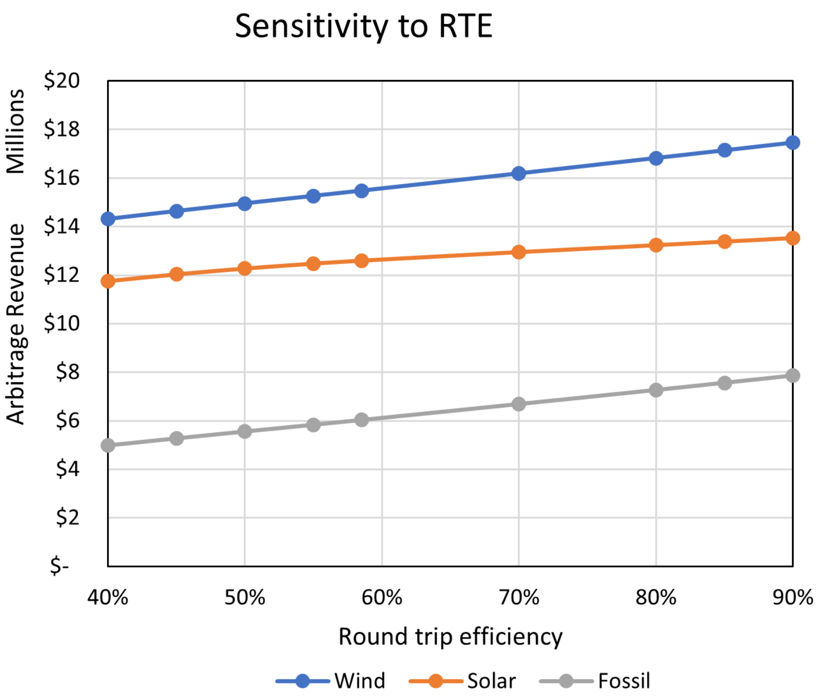
Key issue – determining / modeling customer value



- Model developed in StorageVET (EPRI tool) for several use cases, based on short-term forecasts of localized marginal pricing
- Key result is relative insensitivity of arbitrage revenue to RTE
  - Not necessarily a general result, depends heavily on local pricing and renewable penetration assumptions
- Non-arbitrage revenue key to acceptable IRR, but forecasting is difficult
- DOE help with economic modeling and pricing assumptions would be welcome!

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Closing thoughts

- Performance is important, but costs (capital and operating) matter more
- Low reservoir cost/kWh key to enabling marketability of long-duration energy storage
- Heat exchanger cost/UA is the strongest lever on trading cost vs performance for the charging/generating equipment
- Defining markets, available revenue streams, and electricity price forecasting are critical to both design and marketing of PTES systems

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