Supercritical CO_2-Based Long-Duration Electrical Energy Storage Technical Overview

Summary

- Long duration (>4-6 hours) energy storage is becoming increasingly important
- Echogen is introducing an “Electro Thermal Energy Storage” (ETES) system based on its ground-breaking development of commercial supercritical CO2 power cycles
- ETES stores electrical energy as thermal energy, and recovers back to electrical energy
- Materials are low-cost, safe, and environmentally-benign
- ETES does not require lakes on mountains or giant holes in the ground to install
- Economics for long-duration storage at utility scale (10+ MWe) are excellent
- Echogen is looking for partners for a commercial-scale demonstration plant

ECHOGEN power systems

WHAT IS THE NEED?

Long-Duration Storage

The Case for Long-Duration Storage (LDS)

- Increasing penetration of renewables requires LDS
- LDS can allow base load plants to avoid maneuvering
- Grid management by local application of LDS (non-wires alternatives)
- LDS increases ability to participate in capacity market

- Significant support at US Federal level
  - ARPA-E DAYS program ($36M)
  - Administration budget request for $158M (Advanced Energy Storage Initiative)
  - Bipartisan bill for $300M to support utility-scale, long-duration storage demonstrations (Better Energy Storage Technology Act)

ECHOGEN power systems

WHAT IS ETES?

Electro Thermal Energy Storage

ETES in a Nutshell (Simplified View)

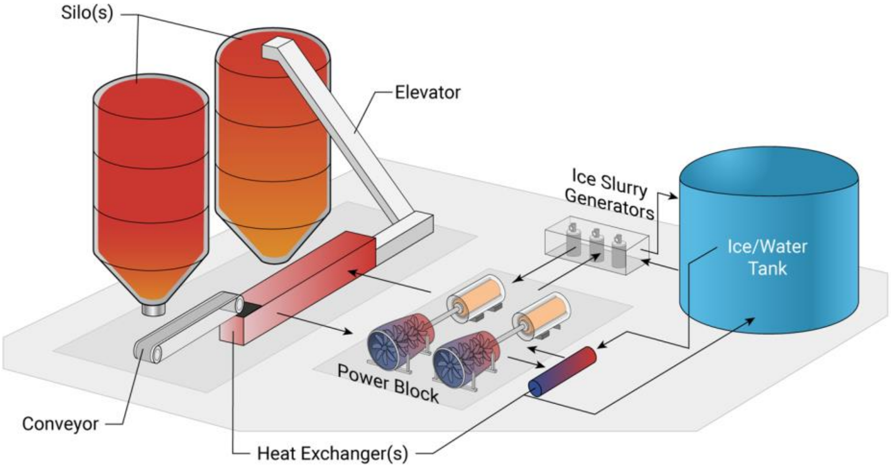
Thermodynamic cycles transform energy between electricity and heat

Charging cycle

- Heat pump cycle
- Uses electrical power to move heat from a cold reservoir to a hot reservoir
- Creates stored energy as both "heat" and "cold"

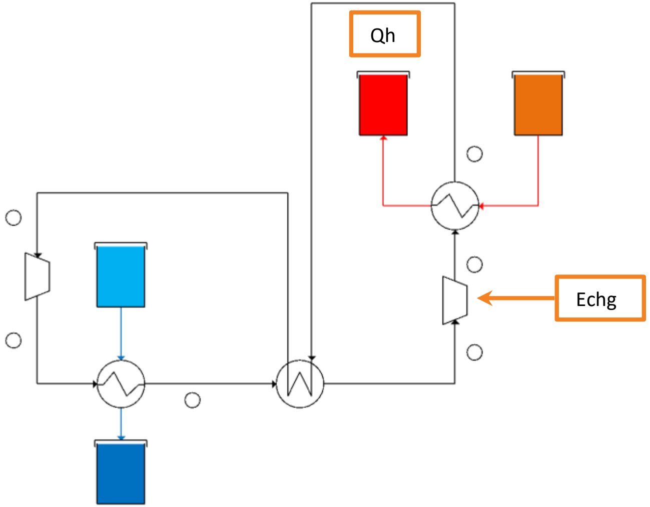
Generating cycle

- Heat engine cycle
- Uses heat stored in hot reservoir to generate electrical power
- "Cold" energy improves performance of heat engine



ECHOGEN power systems

ETES for Thermo Geeks

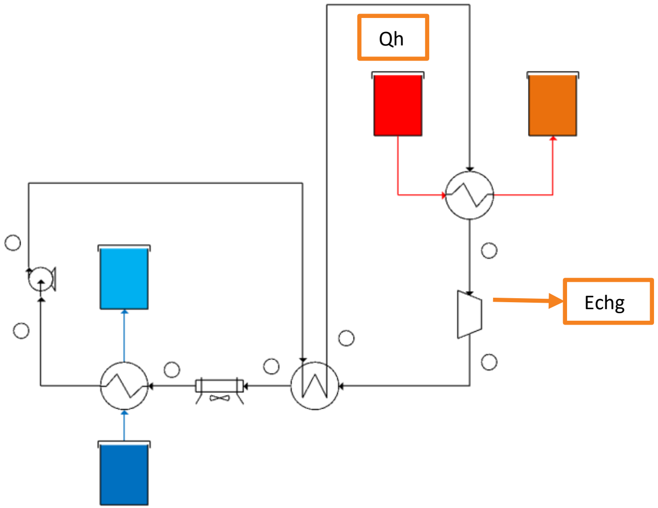


Heat Pump Cycle
COP = Qh/Echg

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

Overall Process
RTE = Egen/Echg
= COP x Efficiency

Ideal RTE = 100%



Power Cycle
Efficiency = Egen/Qh

Ideal efficiency = 1-Tc/Th

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

ECHOGEN

Experts in CO_2 Power Equipment and Systems

Who Are We?

- Founded in 2007
- Mission: To develop and commercialize a better exhaust and waste heat recovery power system using CO_2 as the working fluid


THE GLOBAL JOURNAL OF ENERGY EQUIPMENT
Turbomachinery INTERNATIONAL
SEPTEMBER/OCTOBER 2012 • VOLUME 53 NUMBER 5 • $7.50
www.turbomachinerymag.com
SPECIAL REPORT
SUPERCRITICAL CO_2 THE NEXT BIG STEP?
MATCHING TURBINES & COMPRESSORS
CENTRIFUGAL COMPRESSOR PERFORMANCE
WASTE HEAT RECOVERY
COAL REVIVAL

What Have We Accomplished?

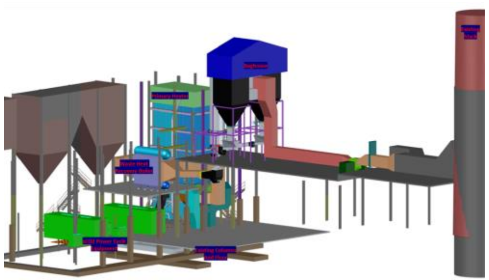
- Key partnerships – Siemens (Oil & Gas), GE (Marine)
- First commercial article (EPS100 – 7.5 MWe) designed and built by Echogen, tested at Siemens
- First commercial sale
- (EPS120 – 9.5 MWe)
- announced in March
- 2019 to TransCanada

TransCanada SIEMENS

ECHOGEN power systems

Where Are We Heading Next?

- Leading multiple DOE- and industry-funded projects in:
  - Nuclear – Micro-reactor power plant, others
  - Fossil – 10 MWe indirectly-fired power plant (pre-FEED)



  - Solar – thermochemical energy storage
  - Electro Thermal Energy Storage – ARPA-E DAYS program
  - Thermal power plant integration with ETES

ECHOGEN power systems

WHY USE CO_2 FOR ETES?

High Efficiency, Low Cost, Safe Materials

Working Fluid and Reservoir Choices…

Main Metrics Are:

- Efficiency
- Cost
- Safety

Remember Three Things…

- Round-trip efficiency is not a strong function of the reservoir temperatures
- Two main types of reservoirs—phase-change and “sensible”
- “Glide-matching” is vital

ECHOGEN power systems

If RTE Isn’t a Strong Function of ΔT…

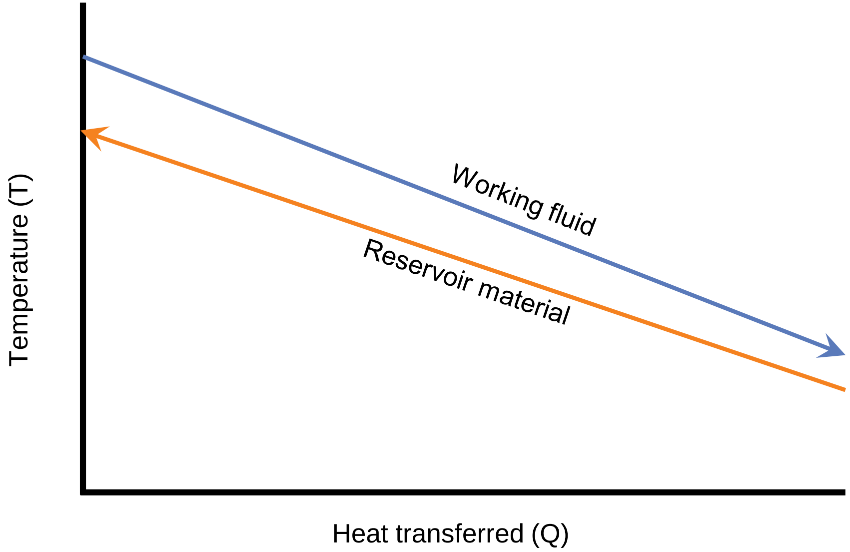
… then we can choose the reservoir temperatures to suit the working fluid (and vice versa)

Since efficiency is only modestly driven by ΔT, then cost and safety become the main drivers in selecting reservoirs

ECHOGEN power systems

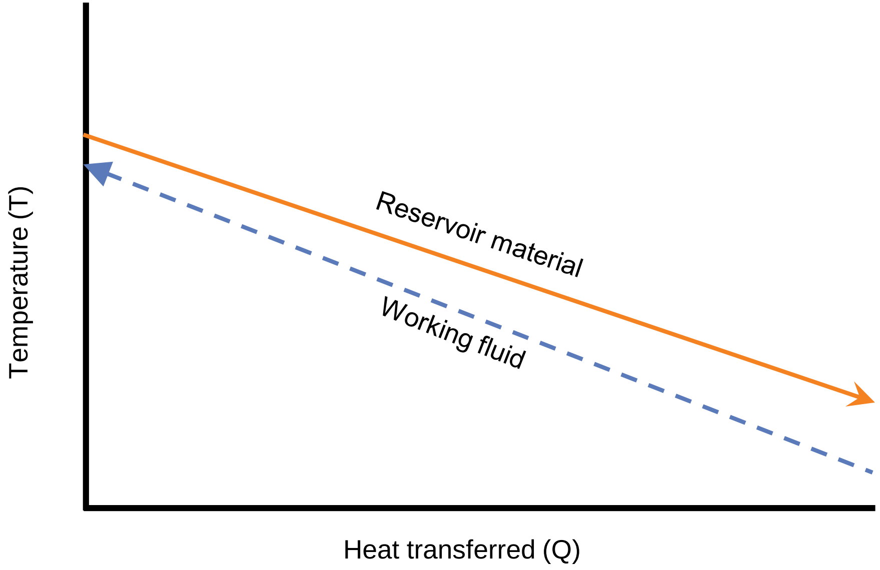
Reservoir Type and “Glide Matching”

Charging process – hot working fluid heats up cold reservoir



Reservoir Type and “Glide Matching”

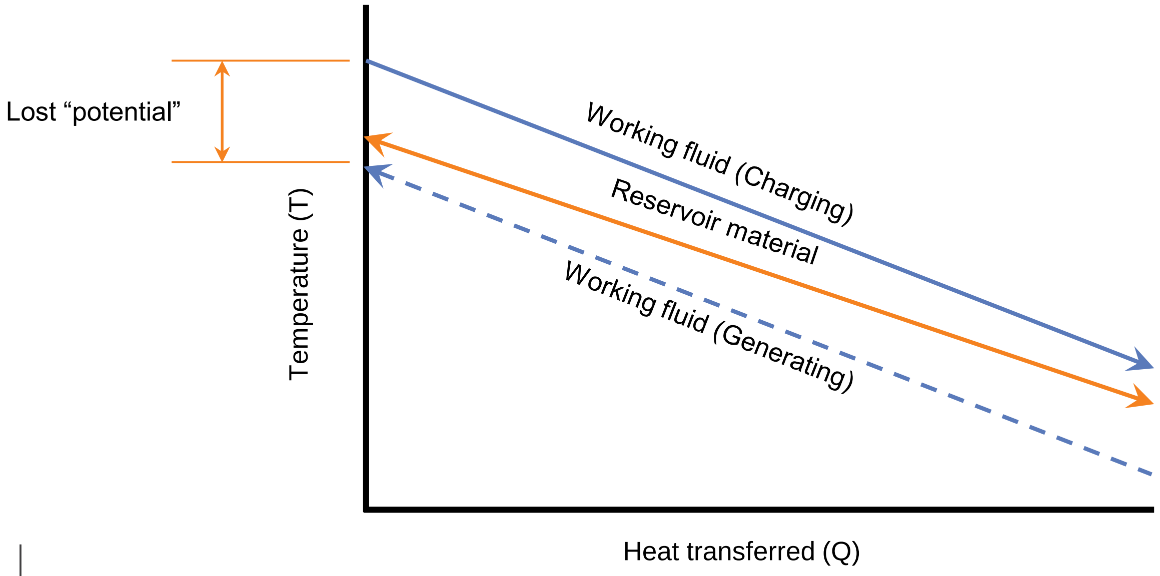
Generating process – reservoir material heats up working fluid



ECHOGEN power systems

Reservoir Type and "Glide Matching"

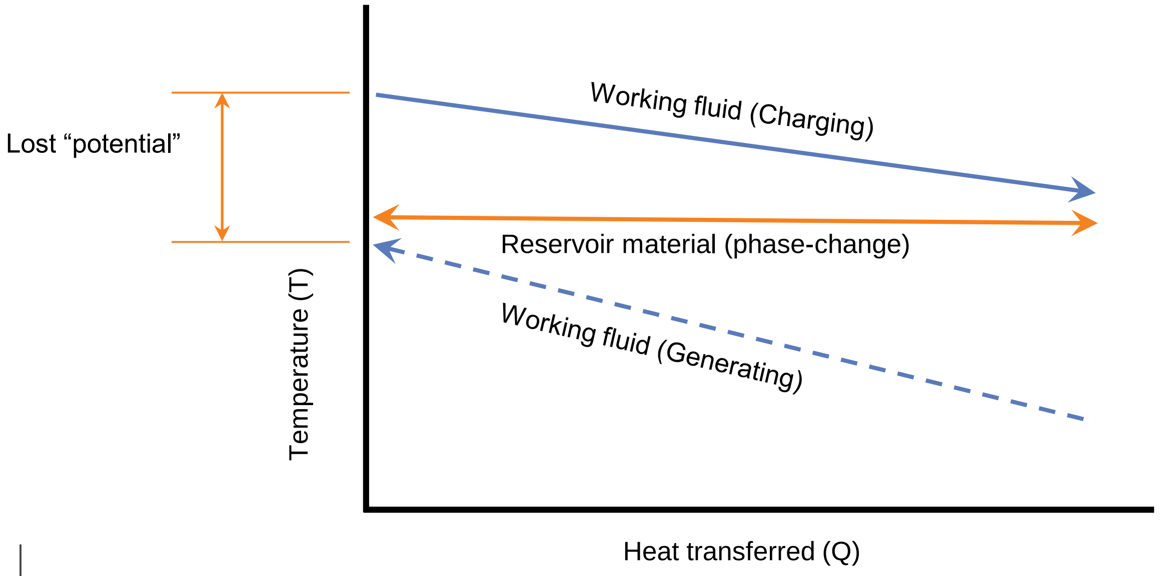
Glide match defines the lost thermodynamic "potential" (exergy for the nerds among us) in the round-trip process



ECHOGEN power systems

Reservoir Type and “Glide Matching”

An example of bad glide-matching… sensible fluid with a phase-change reservoir



ECHOGEN power systems

CO_2 Cooling and Heating Processes

- The low-temperature processes are condensation and evaporation (constant-temperature phase changes)
- So we pair them with another phase change process:

- Conversely, the high-temperature processes are sensible (temperature increases as heat is added)
- So we pair them with another sensible enthalpy material:

ECHOGEN power systems

The Material(s) World

- By selecting a moderate temperature range, we avoid costly materials of construction for containment and piping:
  - LTR: -10 to -2°C (14 to 28°F) – no cryogenic materials
  - HTR: 300-350°C (572 to 662°F) – no nickel-based alloys

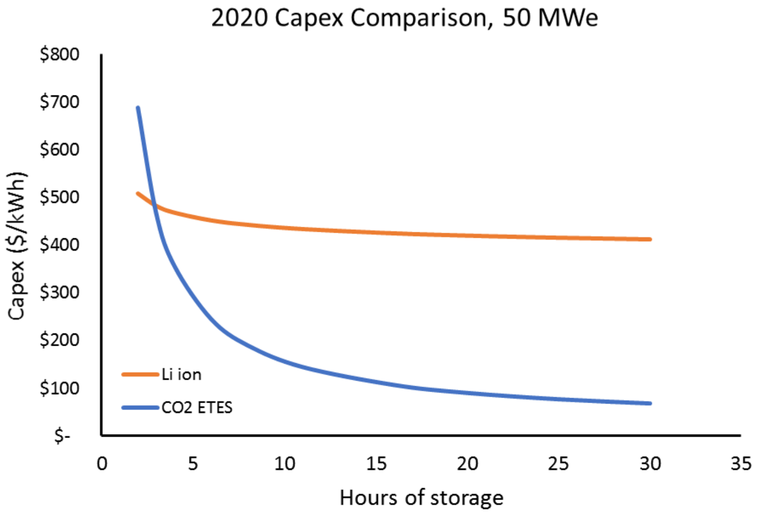
- Storage materials are low-cost and safe:
  - Water + 10% PG: $12/kWhe (water/salt < $1/kWhe)
  - Sand: < $1/kWhe
  - Containment (tanks & silos): $12/kWe

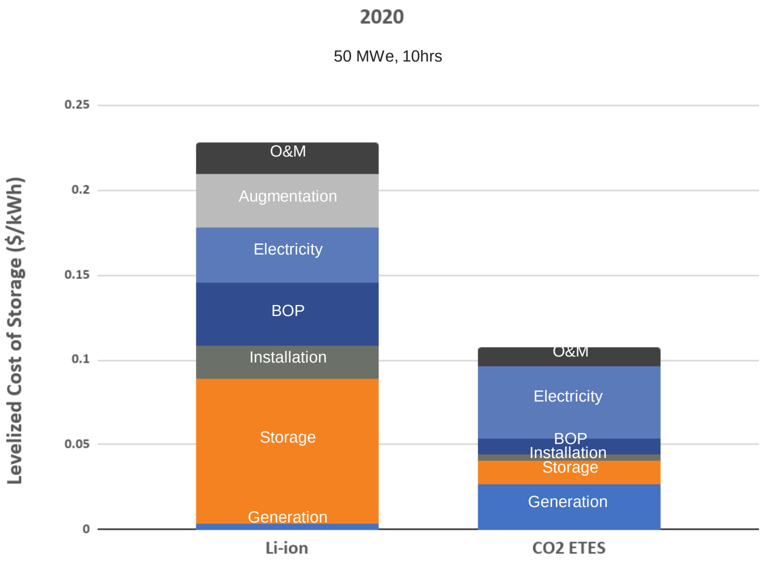
- Reservoirs are not pressurized
  - No need for large pressure vessel containers

- CO_2 itself is low-cost, non-flammable and non-corrosive

ECHOGEN power systems

Longer Duration = Lower Capex/kWh





Lower Capex => Lower LCOS

ECHOGEN power systems

What Does CO_2 ETES Offer?

- Low capex and LCOS for long duration applications
- Safe, low-cost, low-impact storage and construction materials
- A native AC-AC storage solution (no power electronics)
- Conventional generation equipment
- Compact plant footprint free from geographical restrictions
- Significant development risk reduction from existing CO2 power cycle work

ECHOGEN power systems

Where Do We Go From Here?

- Lab-scale system operational (~200 kWth) by end of 2019
- Demonstration plant (10 MWe, 8 hours) design underway
- Generation cycle uses EPS100 design and hardware
- Charging cycle – only new component is charging compressor (commercial product)
- Grid-connected, fully-functional electrical storage system
- Actively seeking partnerships and funding to build and test system
- Targeting late 2020/early 2021 for commissioning and operations
- Successful demonstration will lead to 3-5X scale-ups

ECHOGEN power systems

EES Team has Done it Before

Schedule, cost, and performance projections are based upon demonstrated experience with comparable systems

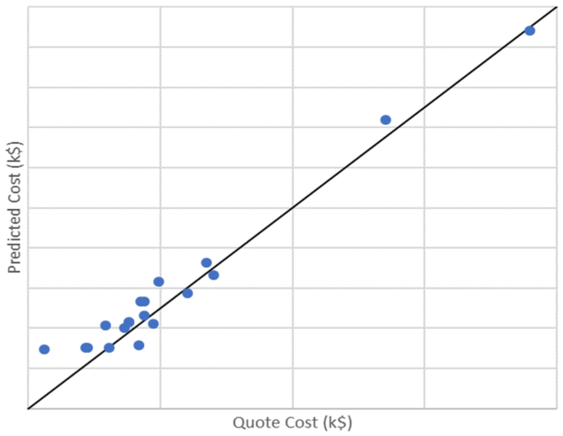
- Team has over 10 years designing, building and testing comparable systems for most of the proposed solution
  - Built and operated the largest sCO_2 power systems in the world

- Echogen has devoted hundreds of manhours towards building and validating component cost models

- Previous EPS100 experience on cost, timing, and performance

  - Turbo-machinery first article + NRE within 2.3% of $2.2M budget
  - Total skid cost within 0.15% of $8.2M budget
  - Process skid ship date within +1 day of target
  - Power skid ship date within +6 weeks of target

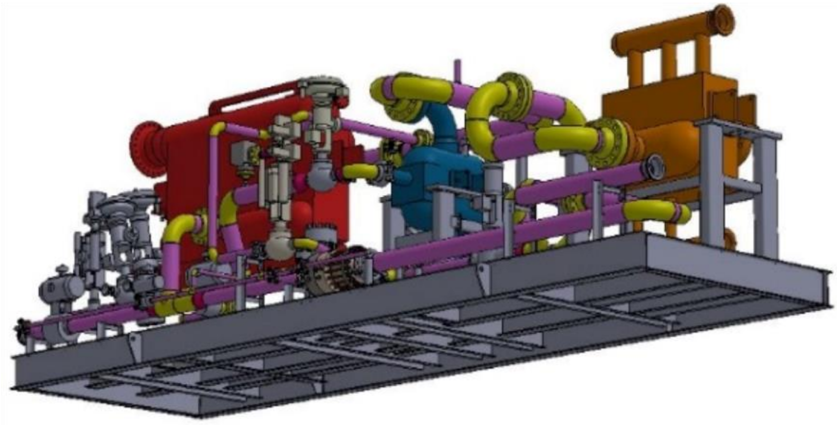
PCHE model cost vs quote



ECHOGEN power systems

EES Team has Done it Before

From concept...



… to reality, on time, on budget

ECHOGEN
power systems

Summary For Those Who Called in Late

- Long duration (>4-6 hours) energy storage is becoming increasingly important
- Echogen is introducing an "Electro Thermal Energy Storage" (ETES) system based on its ground-breaking development of commercial supercritical CO_2 power cycles
    - ETES stores electrical energy as thermal energy, and recovers back to electrical energy
    - Materials are low-cost, safe, and environmentally-benign
    - ETES does not require lakes on mountains or giant holes in the ground to install
    - Economics for long-duration storage at utility scale (10+ MWe) are excellent
- Echogen is looking for partners for a commercial-scale demonstration plant

ECHOGEN power systems

Contact: Tim Held, Ph.D. (CTO) theld@echogen.com