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Project POLAR
Long Duration Energy Storage in the Arctic North

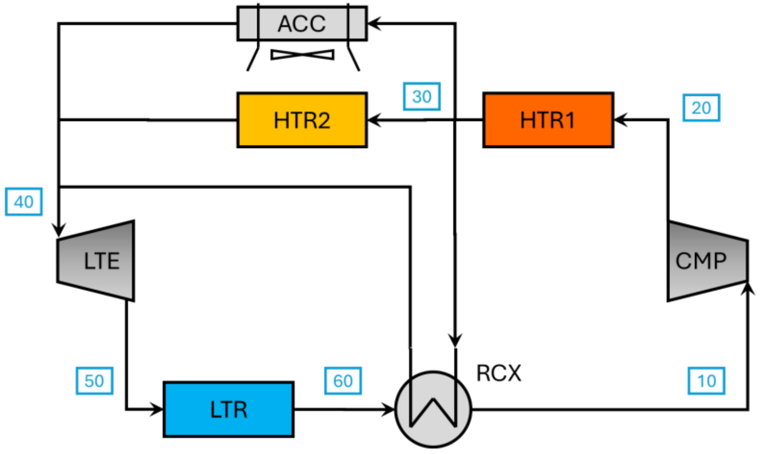
Timothy J. Held, Chief Technology Officer
Special guest appearance by Justin Raade, EPRI

ECHOGEN energy storage

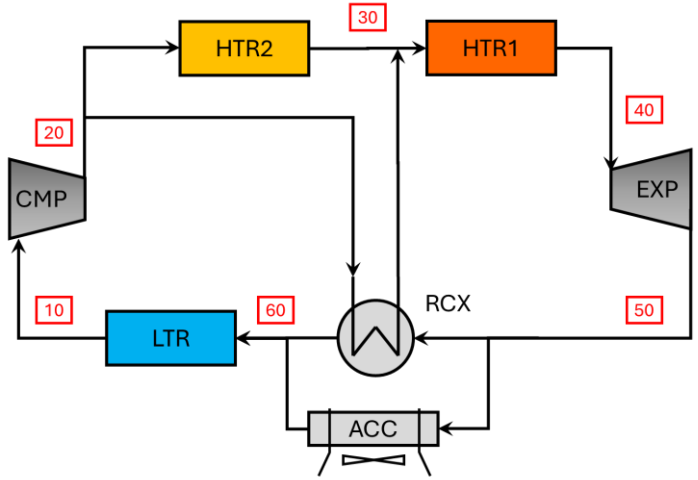
Pumped Thermal Energy Storage (PTES)
Low-cost, safe and environmentally-responsible electrical energy storage anywhere

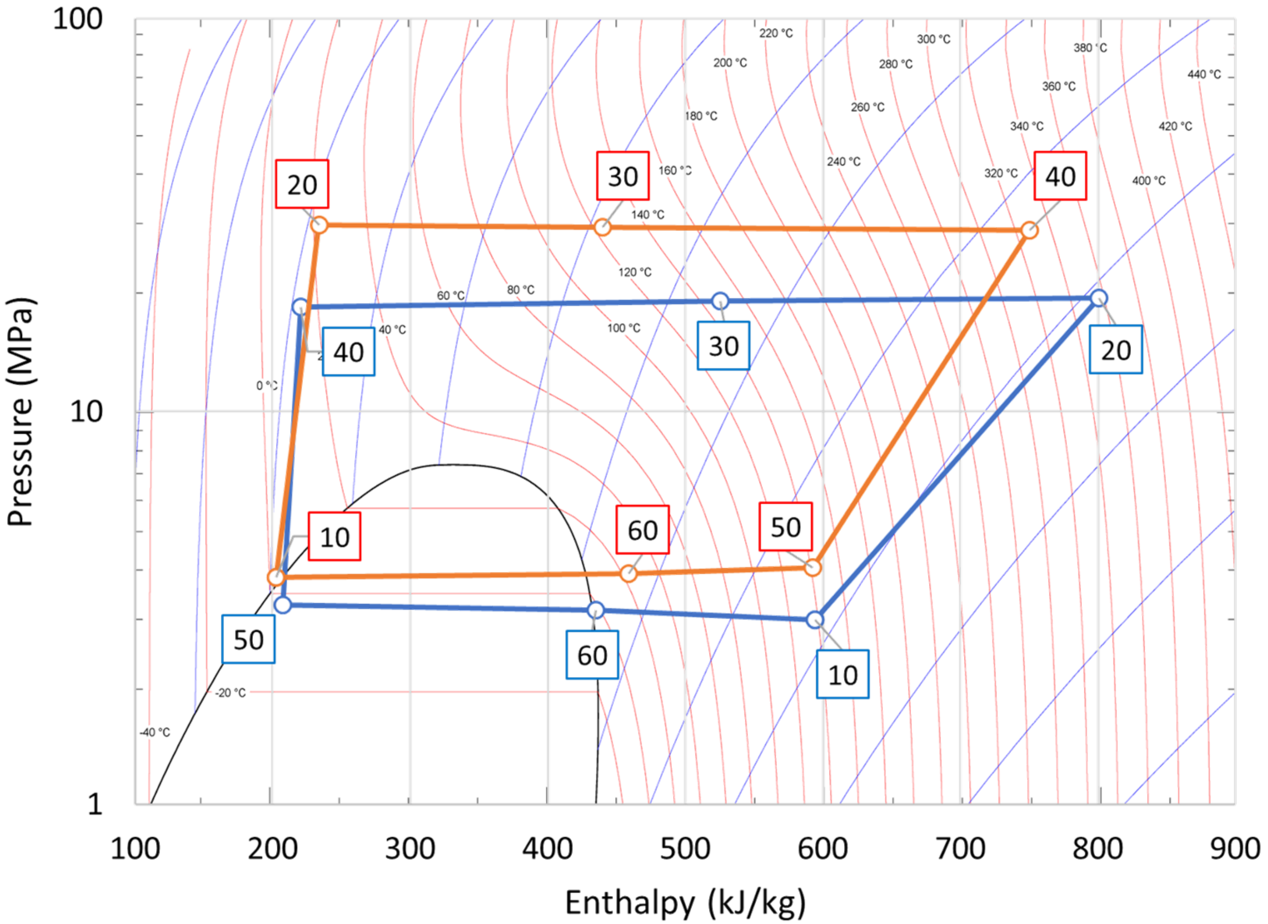
Pumped Thermal Energy Storage basics

Charging



Generating





Proven Technology

Balancing innovation with proven components to deliver a reliable system

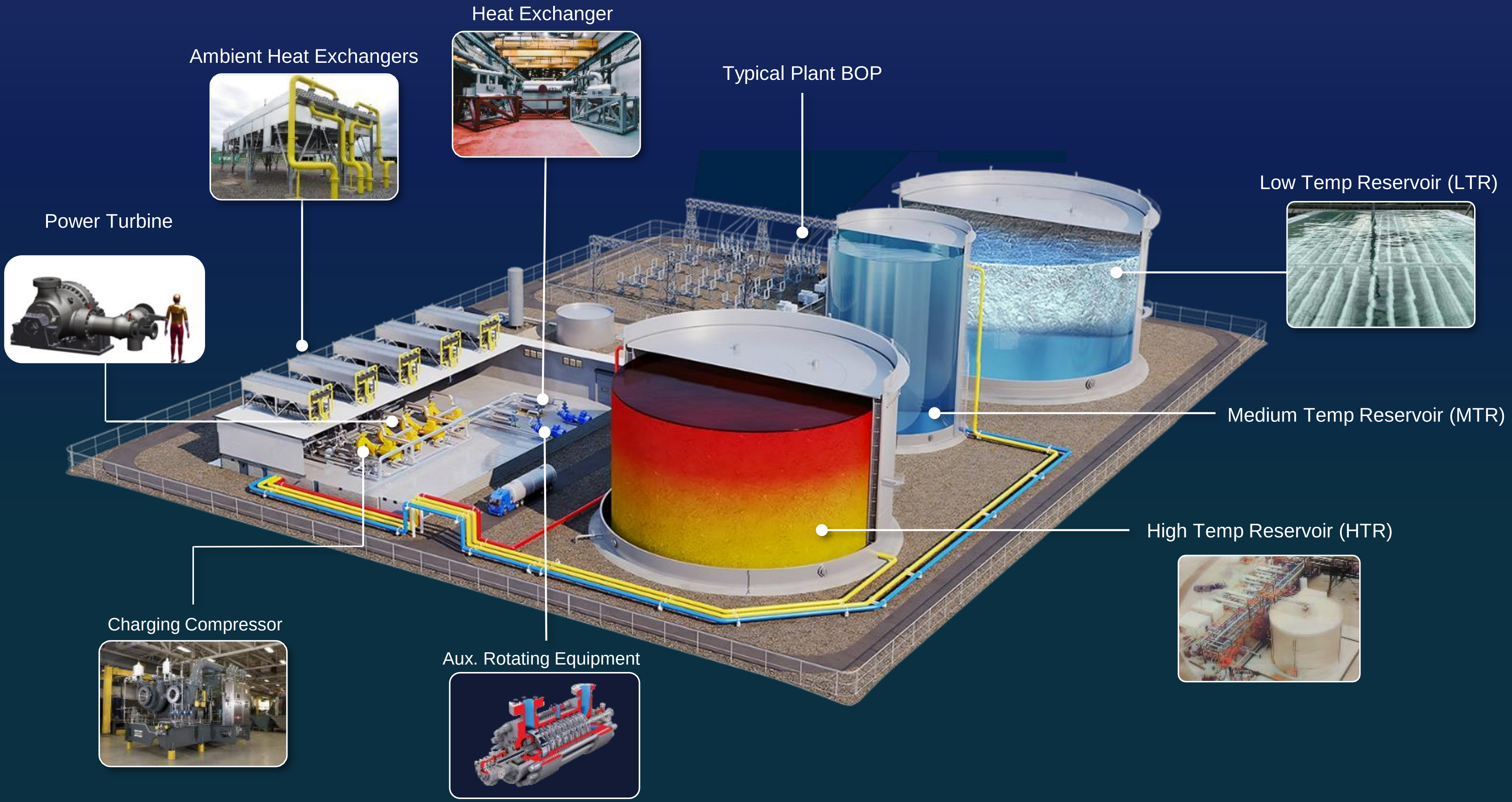
Systems

Generation

The EPS100 is a commercially available generating system with over 330 hours of operation

Heat Pump

Large pilot scale system used to validate models

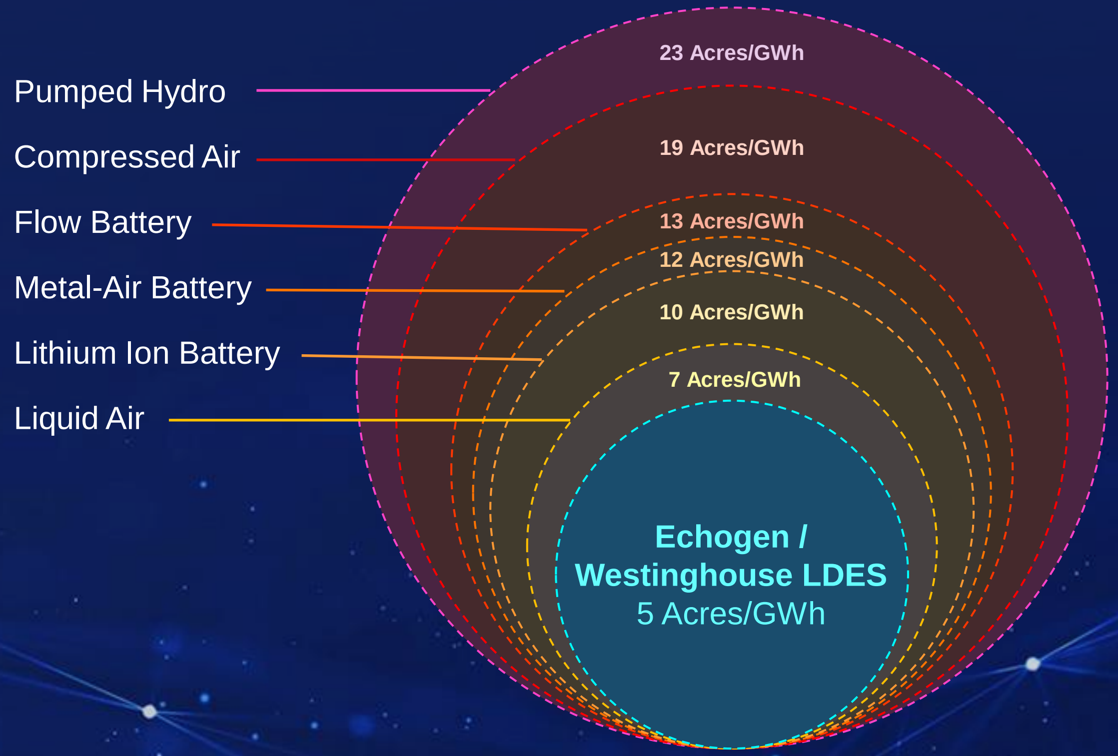


Siting & Sustainability

One of the most compact LDES footprints at ~5 acres for GWh+

Storage Technology Comparison

OVERALL FOOTPRINTS



Sustainability

- No topographical or geologic dependencies
- Can be built anywhere with a fully domestic supply chain
- Non-toxic, non-hazardous materials, low chemical, fire and safety risks
- Low carbon footprint, fully recyclable end of life
- Established & Existing Supply Chain

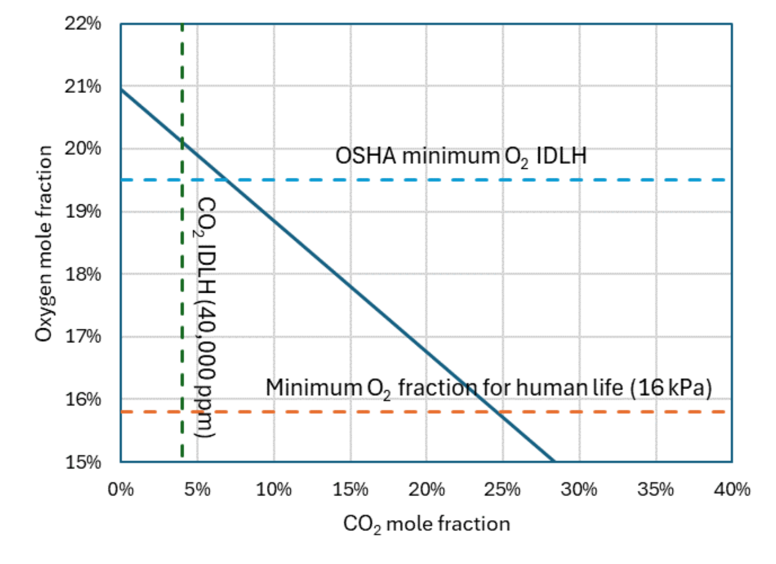
Safety

CO_2 Safety Concerns

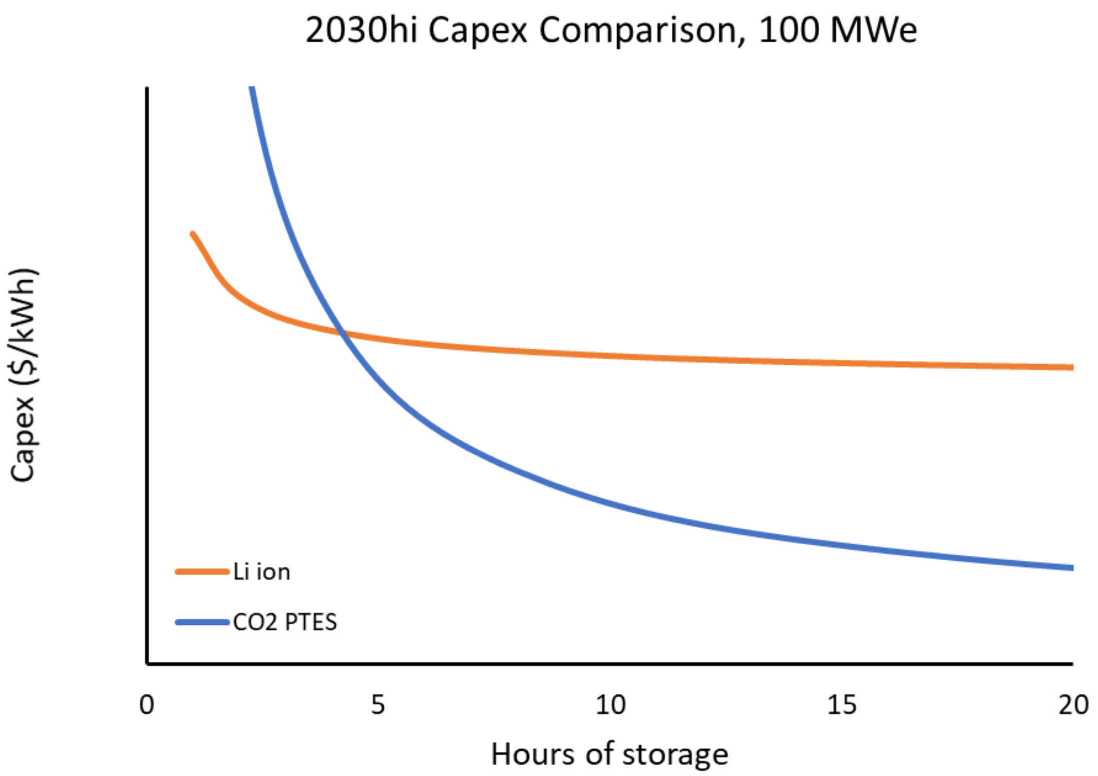
- CO_2 has both asphyxiant and physiological/medical effects
- Vented CO_2 can be heavier than air and can form dispersed solid phase (dry ice "snow")

PTES Safety Strategies and Features for CO_2 Systems

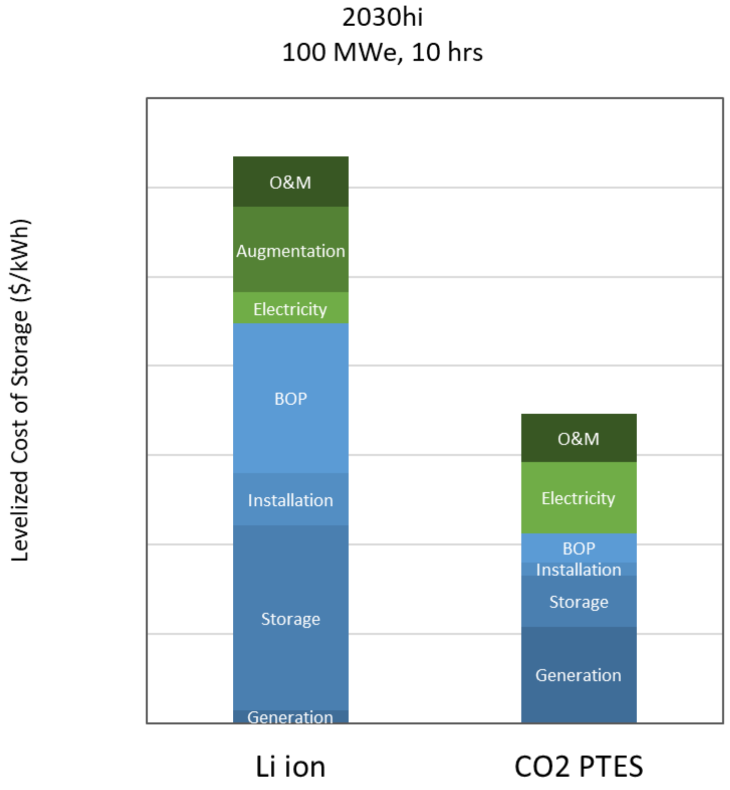
- Limit CO_2 inventory (0.5 mt/MWh, with path to < 0.1)
- Confine working fluid to process piping systems designed to ASME B31.1, BPV Section VIII, etc. standards
- Use well-established NIOSH standards for CO_2 exposure and monitor on-site (low-cost instrumentation)
- Use specialized design tools for vent system and dispersion modeling (e.g. DNV Phast™)
- Maintain majority of CO_2 inventory at saturated liquid state – vented mass is limited due to dry ice "flashing"
- Successfully completed HAZOP review for 10 MW CO_2 powerplant on urban college campus



Longer Duration = Lower Capex/kWh = Lower LCOS



Low reservoir cost / kWh



Lower Capex, no augmentation costs => Lower LCOS

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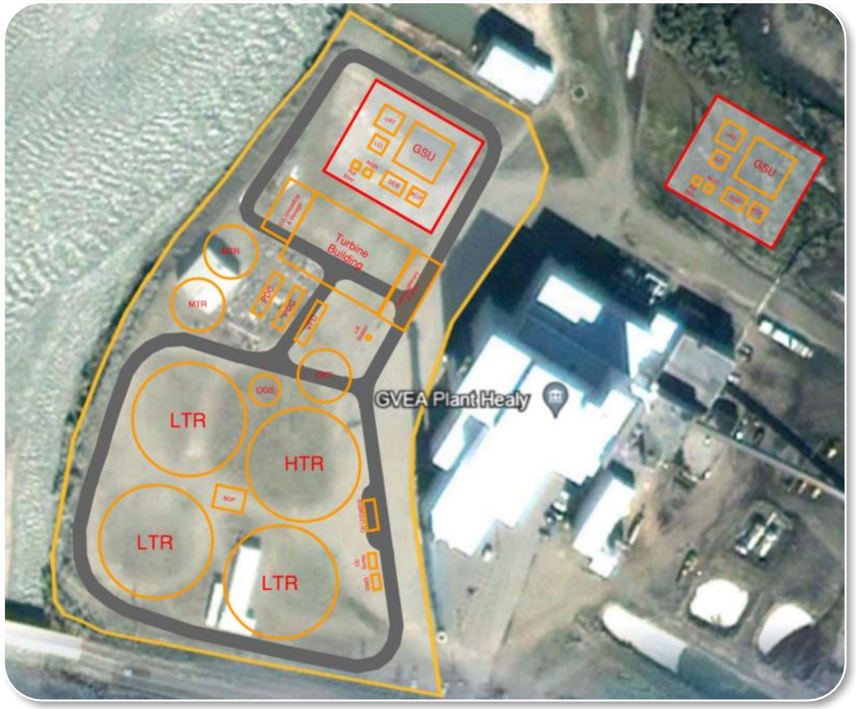
Project overview



- Prime contractor: Westinghouse
- 50MW, 24-hour (1.2 GWh) long-duration energy storage on a 5-6 acre site adjacent to existing power plant
- Extreme climate in central Alaska – Ambient temperature ranges from -50°C to 30°C
- Challenging construction and operational environment
- Use case – diesel-fired peaker utilization reduction
- Highly variable “opportunistic” charging rate
- Reduces transmission limitations & fossil fuel costs
- Air quality and electricity pricing benefits to community

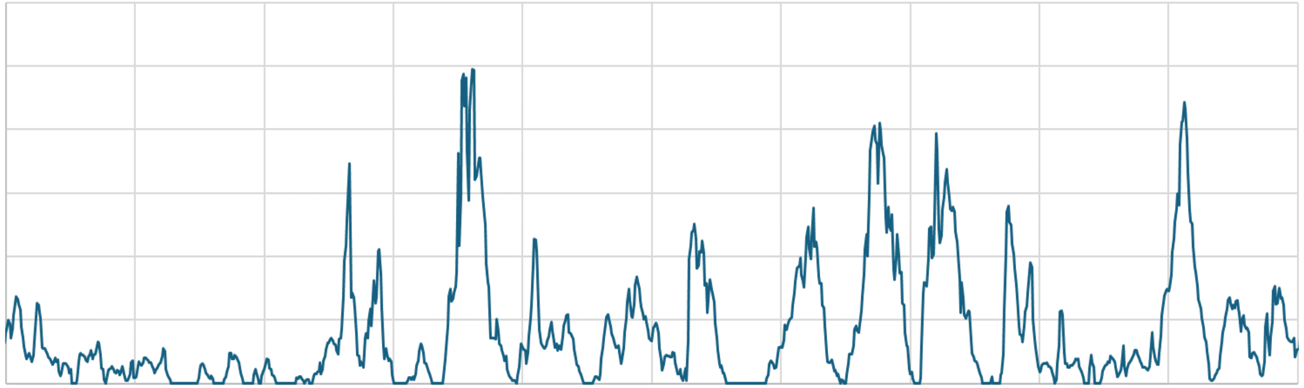
Submission to DOE	Award Date	Contract Signed	Phase 1 Feed Study	Design Completed	Construction Started	COD
March 2023	Sept. 2023	July 2024	July 2024	Q4 2025	Q1 2026	Q1 2029

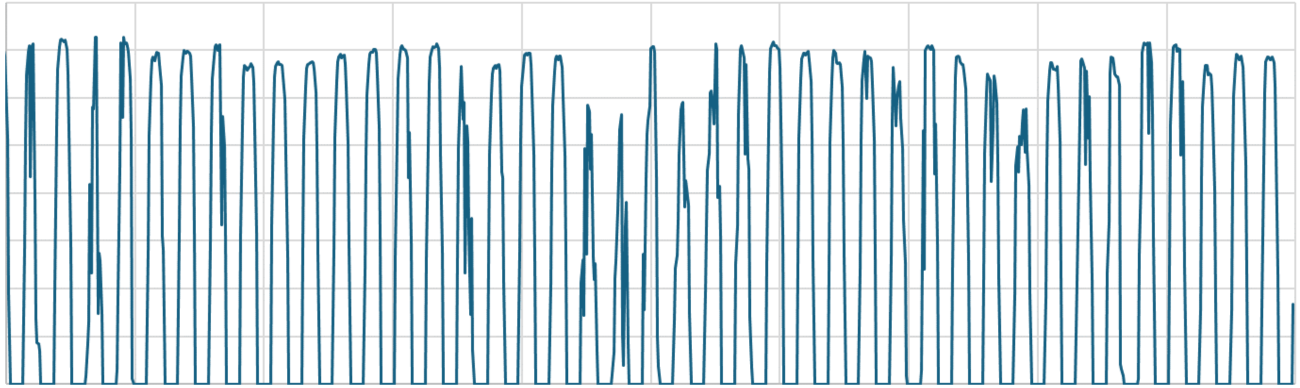
EPRI ELECTRIC POWER RESEARCH INSTITUTE · Shell · ECHOGEN · GVEA · ASRC ENERGY SERVICES a subsidiary of Arctic Slope Regional Corporation

PTES Use Case Flexibility

- Decoupled charge/generate equipment and storage capacity = wide application range
  - Wind applications – Highly variable charging rate, long storage duration needed
  - Solar applications – High charging rate, medium duration needed

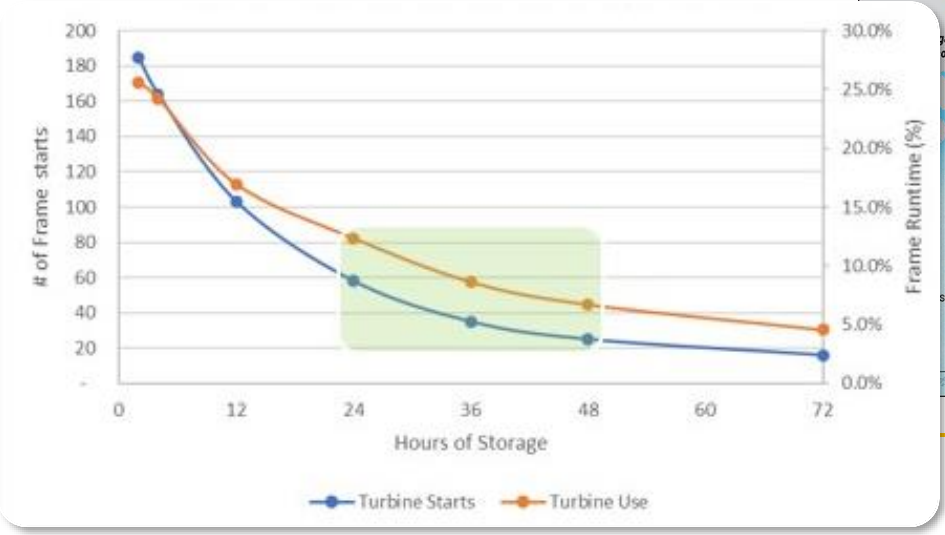
Example generation rate vs time, 1000 hours

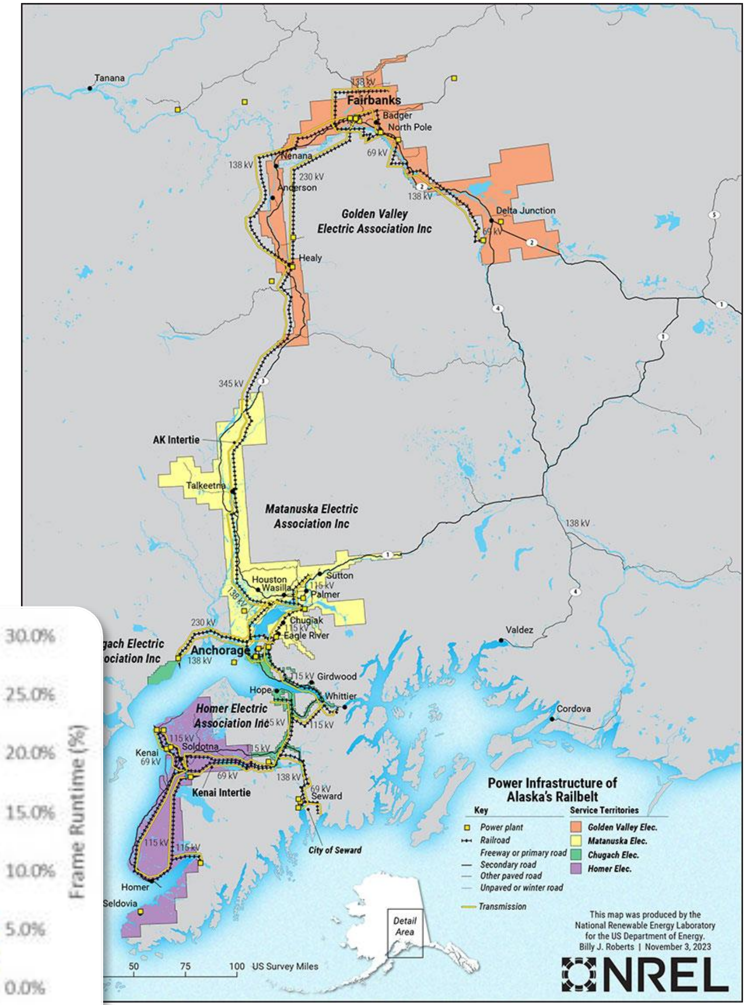




GVEA use case

- Current generation assets (~300 MW)
  - Coal – (Healy, 88 MW)
  - Simple cycle frame gas turbines, ULSD/Naphtha (Fairbanks 38 MW, North Pole 120+60 MW)
  - Wind (Eva Creek, 24.6 MW, 33% CF)
  - Hydro (Bradley Lake, 15 MW)
  - Purchased power from Interties – no longer available
- Low-cost energy to be used to charge PTES, avoid frame gas turbine usage during generation shortfall
- Electricity price, air quality advantages
- High premium on charge and generation rate flexibility





Project status

- FEED study on track for EOY completion
- Preliminary P&IDs, equipment specs transmitted to potential suppliers, quotes received from most
- No component show-stoppers
- Steady-state and quasi-steady-state modeling near completion –
  - Design point
  - Turndown
  - Ambient temperature
  - Reservoir capacity imbalance recovery
  - Reservoir temperature variation
- Transient model and control simulation underway

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Technology Transfer with an Industry Advisory Group for the POLAR project

Justin Raade, EPRI

PTES Roadmap

PTES Design & Technical Modeling

2017 – 2024

- Concept developed and key cycle IP position created
- Detailed steady-state and initial transient models developed and validated against EPS100 data
- Techno-economic design optimization tools created and utilized
- Component and system cost models developed
- Pre-FEED studies completed with Southern Company, EPRI and Advisian Worley

Small Scale Testing

2017 – 2026

- 100 kW_{th} CO_2 test loop
- Integrated heat pump, thermal reservoir, heat engine operations
- Operation and controls methodology development and optimization
- Repeatable cyclic operations demonstrated
- Large-scale axial compressor design validated through testing

Large-scale Testing and Grid Modeling

2024– 2026

- FEED studies at initial commercial deployment sites initiated
- Grid modeling studies conducted with EPRI, commercial developers
- Large scale HTR demonstration
- Full scale modular ice-on-coil thermal reservoir demonstration

Initial Commercial Projects

2026 – 2029

- Won highly-competitive $50M DOE Energy Storage Grand Challenge award for a first commercial project
- Two > 1 GWh projects ongoing
  - 50 MW 24-hr system in AK
  - 100 MW 10-hr system in NY
- Two additional projects expected to COD by 2029

PTES Mass Deployment

2030+

Other Pipeline Growth Opportunities

First European PTES Project

Last week Vodohospodárska Výstavba (VVB) announced the first European commercial scale PTES project using Echogen technology, to be installed in Slovakia

- Echogen is working in partnership with Westinghouse and Vodohospodárska Výstavba (VVB)
- GWh scale project supporting hydroelectric power generation
- Planned to be operational by 2030
- Leveraging local workforce and suppliers

Future Pipeline – Other notable projects in development over the next 12 months

- Planning to kick-off a 3rd GWh scale project in late 2025
  - Site is a retired fossil power plant in New York State
- Projects in early development include the UK, Baltics, Canada, and others

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