Energy Transportation and Storage of the Future

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SwRI is an Applied Research & Development Company

• Founded in 1947, based in San Antonio, Texas
• 501 (c)(3) nonprofit corporation
  • Internal Research
  • New Laboratories
• ~$600M Annual revenue from contract work for industry and government clients
• Over 2,600 employees
• 1,200-acre facility; 2.3 million square feet of laboratories & offices
• Flexible IP policy
• Machinery Department: 70 employees, 5 labs with turbomachinery trains up to 14 MW
Large-Scale Long-Duration Energy Storage is Needed to Enable Deep Renewable Penetration

- Variability, demand mismatch of wind and solar
- Studies show that storage on the order of \(~1x\) daily energy production may be needed\(^1\)
- Storage at renewable plant or baseload plant absorbs ramps/transients
- The storage need for a large city ranges from \(~25\) GWh (4 hours storage in Phoenix) - \(840\) GWh (daily consumption in Tokyo)

Why Not Batteries?

- Batteries offer low $/MW but high $/MWh for significant durations above 2-6 hours
  - Energy and power both scale by adding cells
- Other concerns:
  - Rare-earth material sourcing (lithium, cobalt)^2
  - Degradation^3
  - No viable recycling option^4
  - Thermal management/runaway^5
- Other technologies offer promise of decoupling power with low-cost energy storage
New Long-Duration Energy Storage Technologies are Needed

New Long-Duration Energy Storage Technologies are Needed

- New systems will need:
  - Lower cost than pumped hydro or batteries
  - Higher round-trip efficiency and fewer carbon emissions than gas-fired CAES
  - Longer duration than flywheels
  - Non-specific geology (no mountains or salt caverns)

- Many new system options are based on thermodynamic cycles:
  - Pumped heat energy storage (PHES)
  - Adiabatic or hydrogen-fired CAES
  - Liquid air energy storage (LAES)
  - Thermochemical
    - Hydrogen-based
    - Synthetic natural gas
    - Closed sulfur cycle
Development Needs for Energy Storage: Machinery

- Most new thermodynamic systems are closed or semi-closed cycles requiring:
  - Very high machinery efficiency over a variety of scales (radial→axial)
  - Low leakage/makeup requirements; consider hermetic machinery
  - High pressures, densities, possibly temperatures
  - PHES: High-temp compressor; single machinery train for charge/discharge mode

- Integration of compression, expansion, and heat exchange functionality into machinery to improve cost and performance

- Hydrogen combustion, compression
  - Emissions, stability/range
  - High tip speeds or many stages

- Fast ramping and wide operating range
Development Needs for Energy Storage: Systems

- Control & operation experience of closed or semi-closed cycles
  - Inventory control for turndown; ambient conditions
  - Leakage management / recovery
  - Trip & settle-out scenarios
  - Charge/discharge mode system balancing
- Detailed plant design & cost optimization
- Integration/optimization with numerous generators and applications
  - Coal, Gas, Nuclear, Concentrating Solar, Waste Heat, Combined Heat & Power, Geothermal
  - Existing Brayton/Rankine cycles, advanced power cycles
  - Storage for time-shifting CCS
Current SwRI R&D – Pumped Thermal Energy Storage Demo

• Project funded by DOE/ARPA-E; Partnered with Malta, Inc.
• Advance PHES from concept to a kW-scale system demonstration in 27 months
  • Focus on system operation and integration
  • Evaluate control strategies for system startup, shutdown, and mode change
  • Gather performance data to verify system model (10 MWe, 10 hrs at rated power)
Questions?

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References


