PROJECT NAME: **Pumped Thermal Energy Storage Using Low-Cost Particles and a Fluidized Bed Heat Exchanger for Maximum Power Efficiency (PUMP)**
Last 5 digits of project number: **38480**
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BACKGROUND and OVERVIEW

- Analyze cycle performance of particle pumped thermal energy storage (PTES) system with concentrating solar power (CSP).
- Develop and de-risk a fluidized bed (FB) heat exchanger (HX) for low gas/particle approach temperature.
- Establish a foundational software tool to optimize PTES system performance
- Evaluated and integrated reversible turbomachinery with PTES and CSP and compared its cost/performance with separate charge/discharge turbomachines.

METHODS

- Thermodynamic modeling of PTES and hybrid CSP-PTES to achieve >55% of energy storage efficiency.
- Laboratory demonstration of 10kW$_t$ FB HX prototype.
- Develop Modelon Modelica modules of all heat transfer fluids and components in the particle PTES system.
- Identify PTES/hybrid CSP-PTES system configurations, and size components and incorporate reversible turbomachinery into PTES.

KEY MILESTONES

- Developed PTES-CSP hybridization and modeled the system performance for a path to meet the storage efficiency of >55%.
- Developed product FB HX design and a PTES system configuration with reversible turbomachinery.
- Designed, built, and commissioned a >10kW$_t$ lab-scale counterflow FB HX and PTES system.
- Testing FB HX prototype with 25°C particle inlet temperature and gas inlet temperature up to 300°C targeting 5°C approach temperature.

CONCLUSION

- Enable integration of particle PTES into hybridized CSP-PTES systems.
- Established design guidelines and lessons learned for large-scale FB HX design and development.
- Achieved storage cycle efficiency >55% and cost goals.
- Prove high counterflow FB HX effectiveness (low approach temperature) for particle PTES systems
- Advance PTES designs by integrating reversible turbomachinery and resolve risks in scaling components.

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Fluidized Bed Heat Exchanger for High Temperature Particle Thermal Energy Storage to Integrate into High-Efficiency(>55%) Hybridized Concentrating Solar Power - Pumped Thermal Energy Storage Systems

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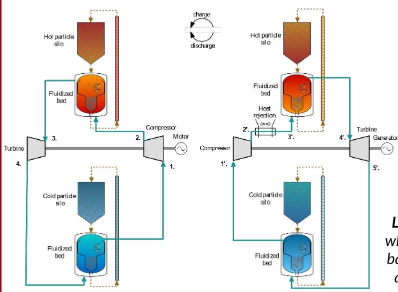
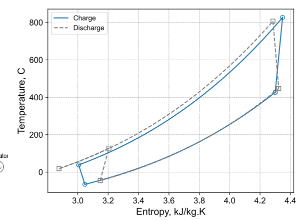
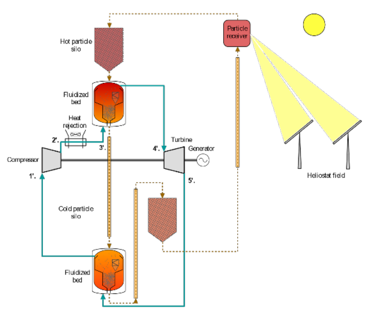
Standalone PTES System

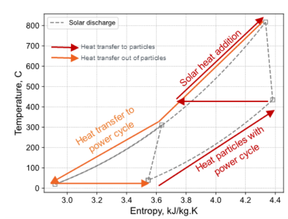




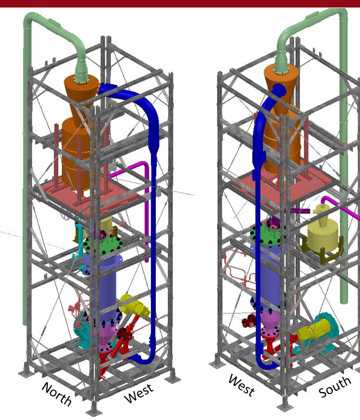
Hybrid CSP-PTES System



Left: Dual mode hybridized CSP-PTES systems whereby the system can operate as PTES or CSP based on solar availability and power needs and achieve low costs and high storage efficiency. ***Above Left:*** PTES with reversible turbomachinery. The hot and cold FB HX and particle storage are independent. ***Above:*** T-s diagram for PTES mode in charge and discharge. ***Below Left:*** CSP mode to provide greater heat recuperation and increase cycle efficiency. ***Below:*** T-s diagram for CSP mode.

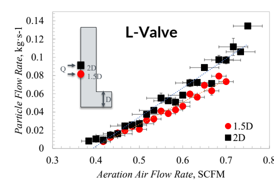


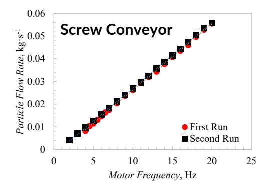
Prototype FB HX Test Station

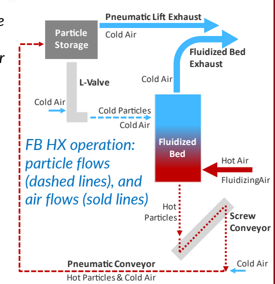


Component	Color
Scale assembly	Mauve
Storage bin and upper cyclone	Orange
Storage bin valve	Pink
FB Main body	Blue
FB Lower cone	Pink
FB Cover	Green
FB First Exhaust	Purple
Fines Storage Bin and Cyclone	Yellow
L-Valve	Cyan
Screw conveyor auger assembly	Red
Screw conveyor motor	Yellow
Pneumatic conveyor ducting	Blue
Pneumatic conveyor blower	Teal
Instrumentation	Rose Mauve
FB Upper Exhaust	Pink
Upper Exhaust	Green

Above Left: *PUMP test structure at NREL ESIF laboratory.* ***Above Right:*** *PUMP test structure CAD to illustrate all components including the FB HX (light blue) and particle conveying technologies used to control FB height and operating parameters: mechanical screw conveyor (red) controls FB particle outflow, L-valve (cyan) controls FB particle inflow, and pneumatic conveyor (dark blue) transports particles in return loop.* ***Below:*** *L-valve and screw conveyor.*







FB HX operation: particle flows (dashed lines), and air flows (sold lines)

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