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Electric-to-Electric Moving Particle Thermal Energy Storage (PARTICLE)

Sandia National Laboratories

TMCES Workshop 2024

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OUTLINE

Project Summary

- Technology Overview
- Scope/Objectives Schedule & Budget
- Test Facility & Project Team

Benefits

- Economic and Environmental

Technical Analysis

- Power cycle
- Particle loop
- Grid connection

Conclusion

Project Summary

Technology Overview

Scope/Objectives Schedule & Budget

Test Facility & Project Team

Project Summary

Moving Particle Thermal Energy Storage (MPTES)

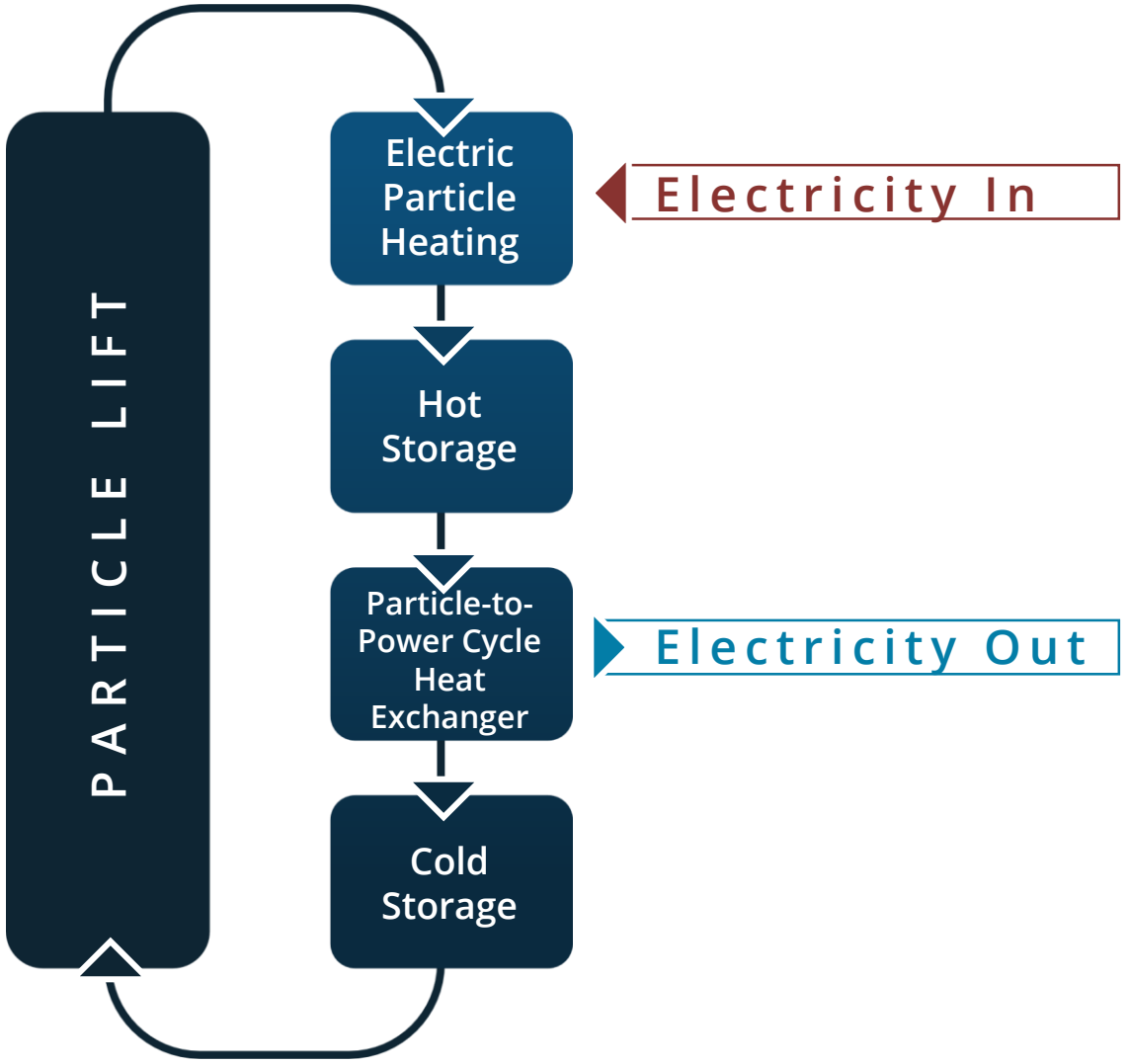
- Thermal energy storage as sensible heat
- Low cost storage media (sand or other particles)
- High temperature ≥ 600 °C storage

Energy in: Electric particle heating (η_h=98%)

Energy out: Power cycle (η_t= 30-60%)

Commercial system round-tip-efficiency (RTE) = ~48%

Technology Overview



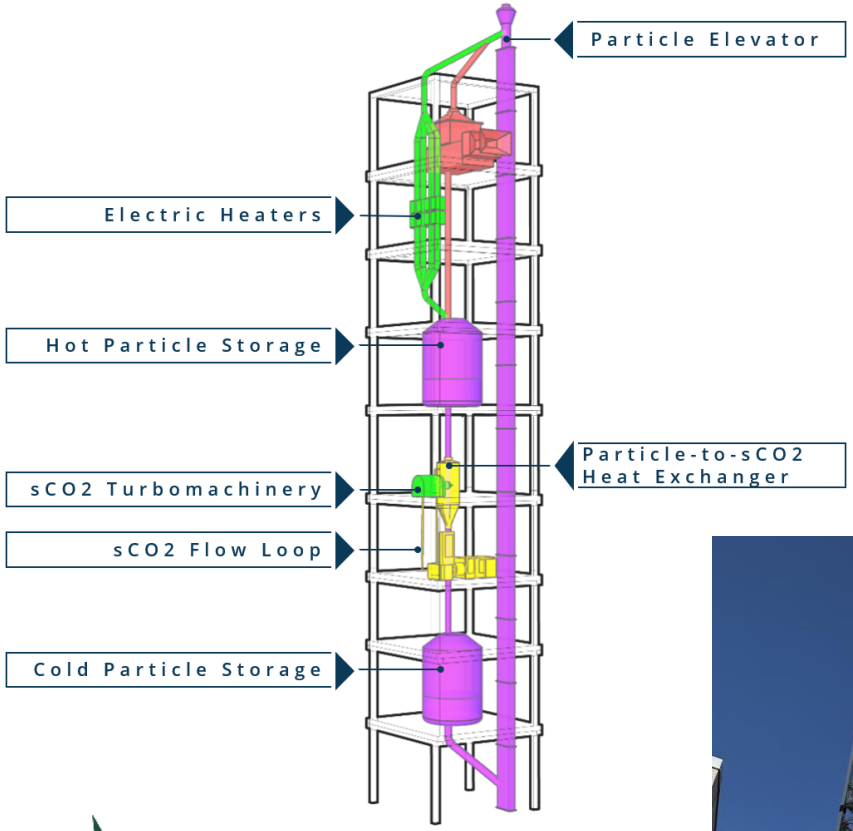
Project Summary

Scope/Objectives

- Demonstrate 100 kW_e x 10+ hr MPTES
  - sCO2 Power Cycle
  - Gen3 Particle Pilot Plant Test Facility
- Assess key performance indicators for multiple charge, hold, discharge scenarios
- Work with leading edge industry members
- Overcome low TRL technology barrier
- De-risk investment for 5-10 year deployment

Timeline:

- 3.5 year project
- Completion December 2027



PEREGRINE TURBINE TECHNOLOGIES

ECHOGEN power systems

CHUGACH

Project Team

- **Sandia National Laboratories (FFRDC)**
  - National Solar Thermal Test Facility (NSTTF)
  - Brayton Laboratory

- **Peregrine Turbine Technologies**
  (sCO2 system and component manufacturer)

- **Echogen Power Systems**
  (TES and energy system developer)

- **Chugach Electric Association, Inc.**
  (Power Utility)

Benefits

Economic

Environmental

Benefits

Economic

Objective: Determine installed cost and LCOS to compare to other LDES technologies

Assessment Case:

- 100 MWe x 10 hours (1 GWh_e) scale
- Silica-sand storage media
- 30 year operational period

Total installed cost = storage system + power block + additional

Competitive LCOS

Item	Installed Cost per Capacity	Units
Storage System	7.48	$/kWh$_t$
Power Block	1157.70	$/kW$_e$
PARTICLE System CAPEX	**158.89**	**$/kWh$_e$**

Parameter	Base	A	B	C
Storage duration [hrs]	10	10	10	50
Purchase Price of Electricity [$/kWh$_e$]	0.03	0.01	0.03	0.03
Round-trip efficiency	48	48	60	48
Annual # of cycles	268	268	312	54
PARTICLE LCOS [$/kWh$_e$]	**0.12**	**0.08**	**0.10**	**0.17**
Lithium-ion[1]	**0.17-0.23**			
TES (generalized)[1]	**0.16-0.19**			
PSH[1]	**0.11-0.12**			

[1] https://www.pnnl.gov/lcos-estimates

Benefits

Environmental

Objective: Quantify CO2 equivalent emissions

- Cradle-to-Grave
- System materials simplified:
- System boundary around storage system

Smaller carbon footprint than well established battery competitors

Sand sourcing less carbon intensive than Lithium

CO2 Emissions [metric-ton]

Item	Material	Cradle-to-Gate	Gate-to-Grave	Cradle-to-Grave
Storage	Sand	3,729	9,434	13,163
	Steel	248	56	304
	Concrete	48,720	720	49,440
	Insulation	1,135	5	1,140
Particle Transport	Steel	4,983	1,073	6,056
	Insulation	604	2	606
Power Block	Steel	166	83	249
	Inconel	1	0.2	2
	CO_2	0.0	0.4	0.4
Construction			14,000	
PARTICLE Total		59,586	25,374	**84,960**
Lithium-ion Total		82,500	173,040	255,540

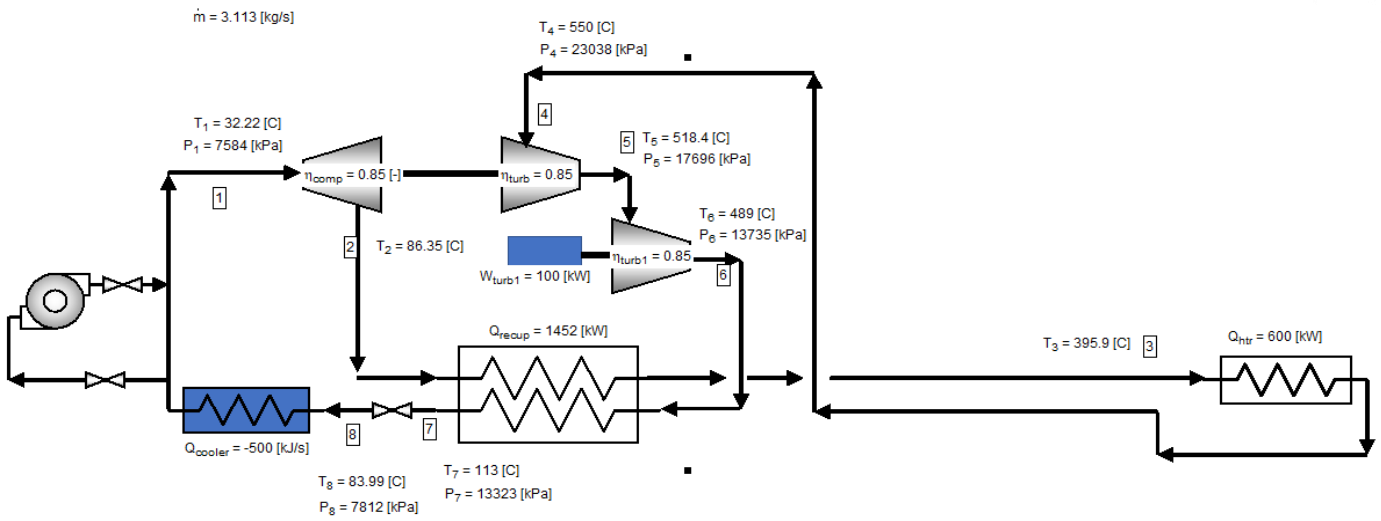
Technical Analysis

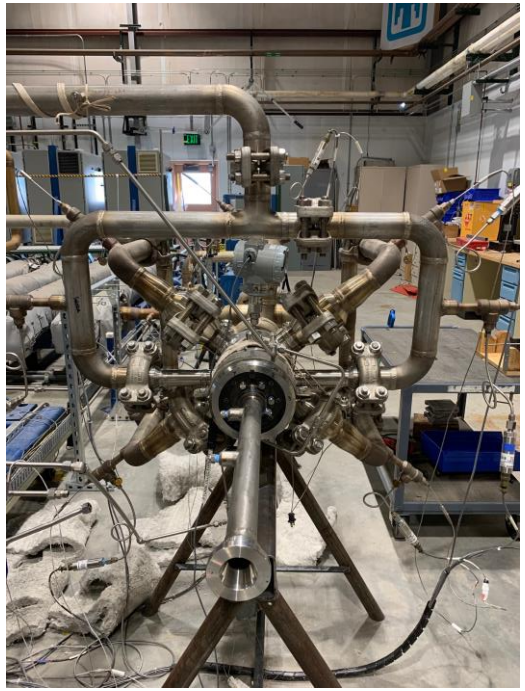
Power Cycle
Particle Loop Requirements
Grid Connection

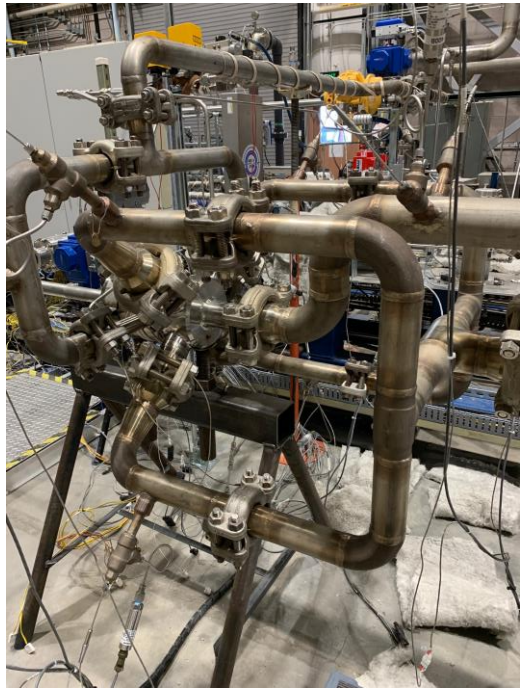
Technical Analysis

Power Cycle

- **Utilize G3P3 sCO2 flow loop and Brayton Lab turbocompressor**
- **Peregrine Turbine Technologies (PTT) 350 kW_e turbogenerator**
- **100 kW_e power rating achievable:**
  - Turbine inlet temperature = 550 °C
  - Pressure ratio = 3.296
  - $m_{dot,sCO2}$ = 3.113 kg/s
  - Heat input = 600 kW_t
  - PTT predicted 127 kW output
- **Material Requirement: SS316**



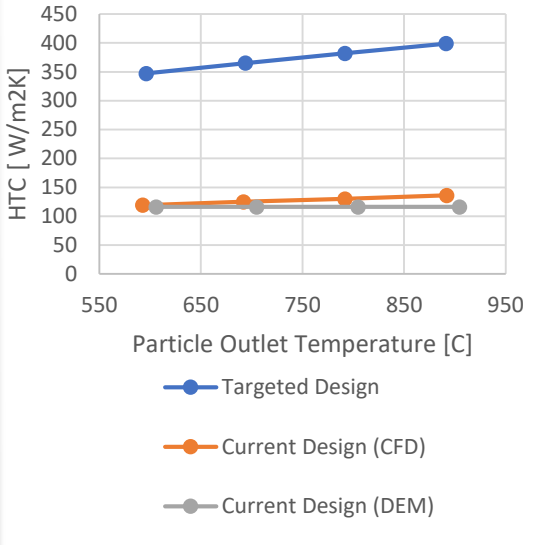


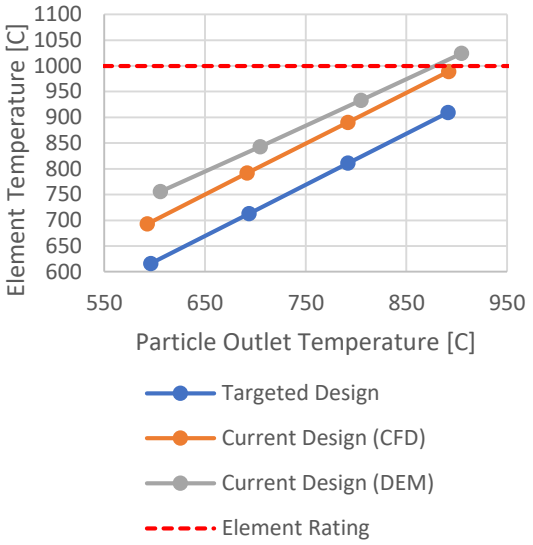


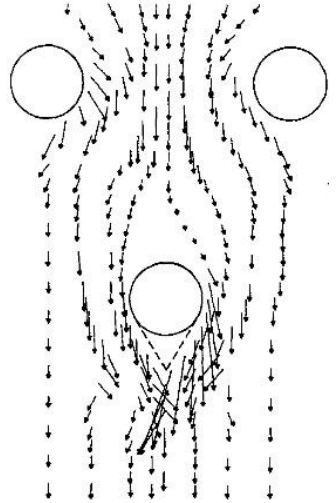
Technical Analysis

Particle Loop Requirements

- **Electric particle heating**
  - Off-the-shelf heater cartridges
  - Improved “target design”
  - ~875 C heating within rating
- **PHX and Particle Storage**
  - 600 kW (100+kW)
  - 550 C outlet required (100+kW)
  - 725 C particles @ 3 kg/s = 11.4 hrs discharge duration

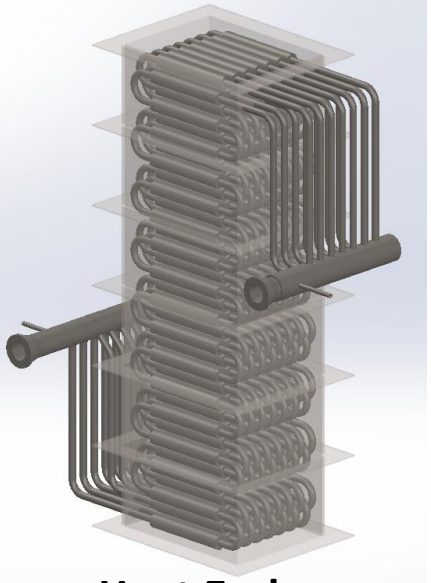




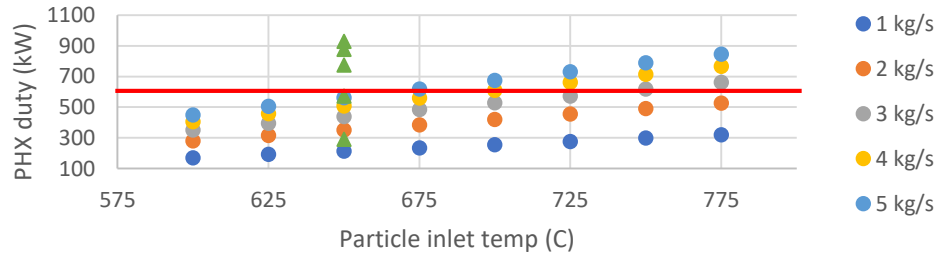


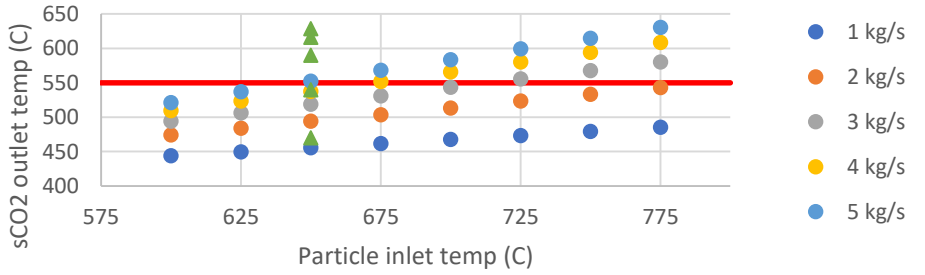
*Collaboration with UL: Bikram Bhatia & Julio Izquierdo

Particle Heater



Heat Exchanger

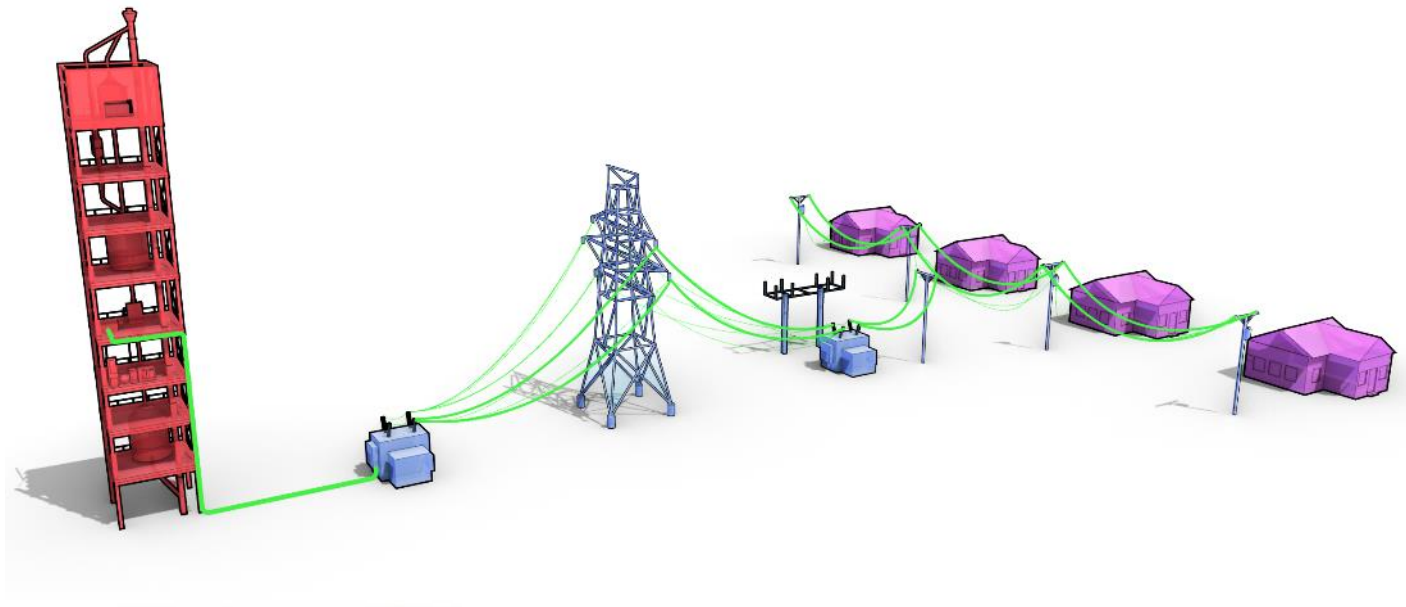


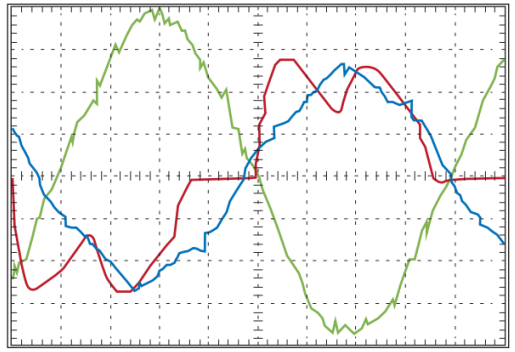


Technical Analysis

Power Generation

- **sCO2 Power Cycle → Grid Power**
- **Permanent magnet machine (Power electronics)**
- **Key Metrics:**
  - Power output consistency
  - System ramp rates
  - Round trip efficiency
  - Operational strategy





Voltage
Current with harmonic filter
Current with mains filter

Conclusion

Conclusion

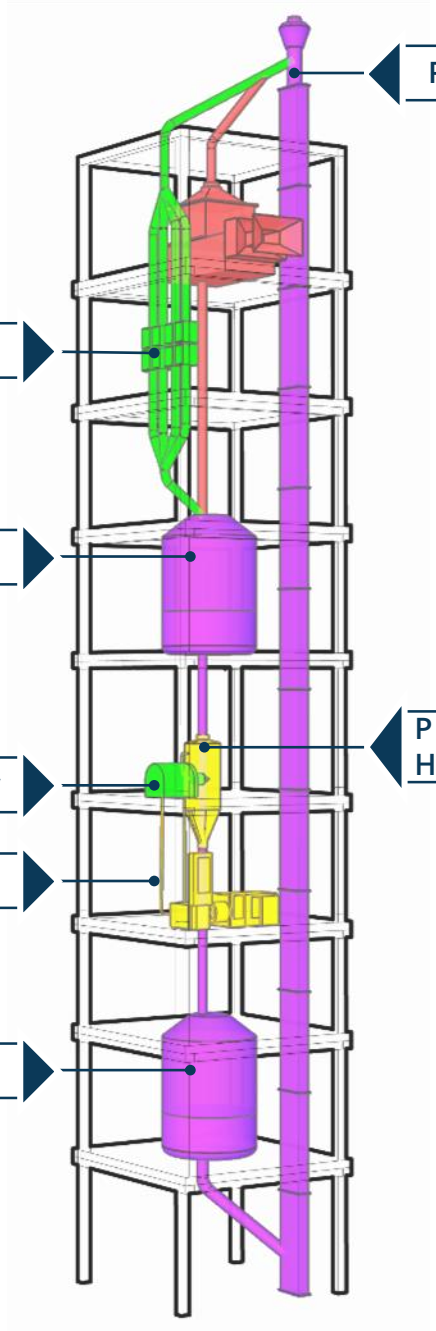
Moving Particle Thermal Energy Storage (PARTICLE)

- 100 kW x 10+ hour demonstration
- Competitive LCOS
- Low carbon footprint

Promising system design results

Serious commercial partnerships

De-risk investment & advance TRL for 5-10 year commercial deployment



QUESTIONS

“Sandia National Laboratories is leading the development and commercialization of moving particle concentrating solar thermal technology at the National Solar Thermal Test Facility. This technology has the potential to deliver cost-effective, large-scale long duration energy storage, contributing to higher renewable energy deployment as well as improved energy resilience.” – Andy McIlroy, Associate Labs Director

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