Sandia National Laboratories

Long Duration Solar Thermal Energy Storage





Dr. Margaret Gordon, Manager NSTTF & Concentrating Solar Technologies

DOE Office of Electricity Energy Storage Program Annual Meeting and Peer Review

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U.S. DEPARTMENT OF ENERGY
NNSA National Nuclear Security Administration

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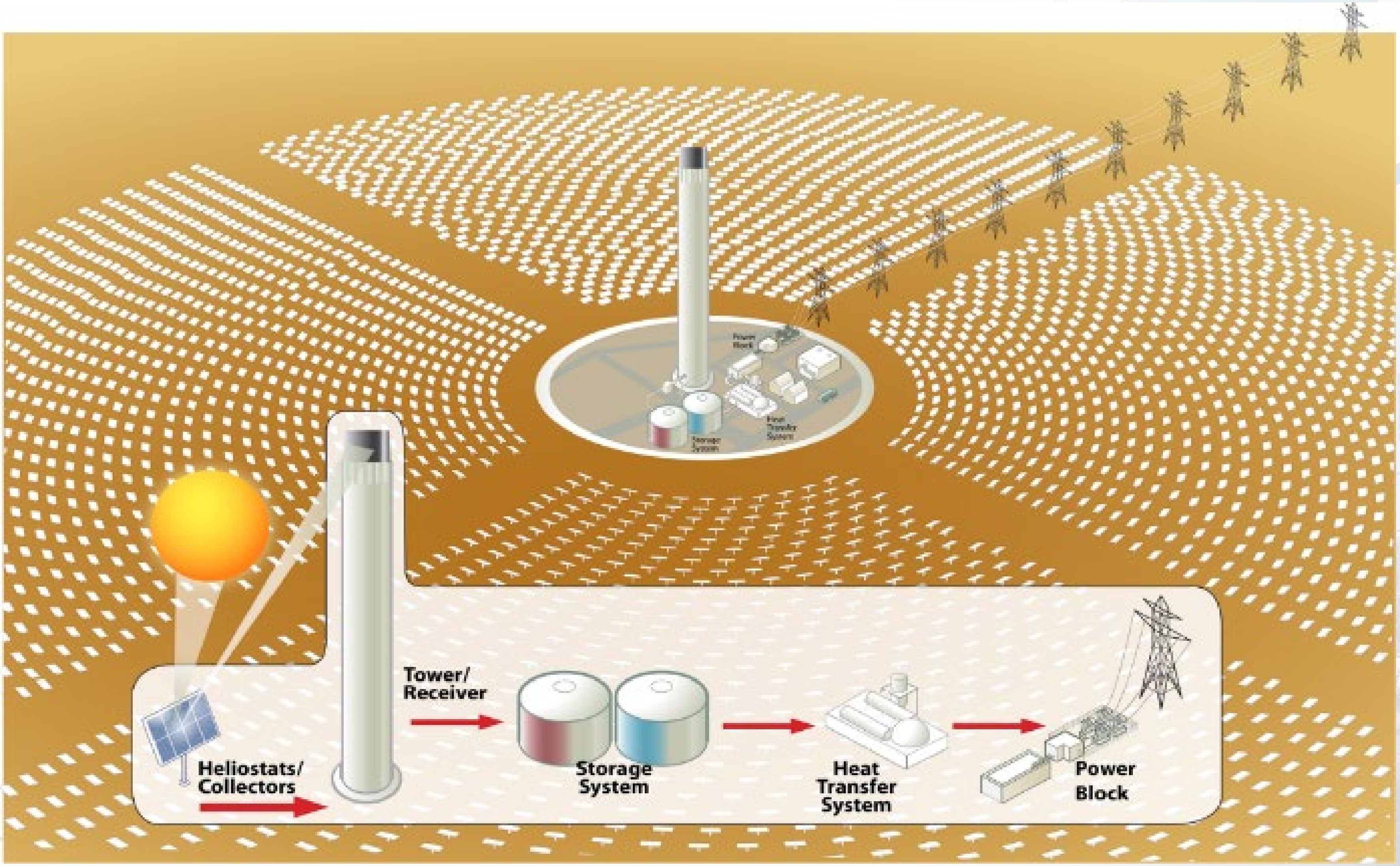
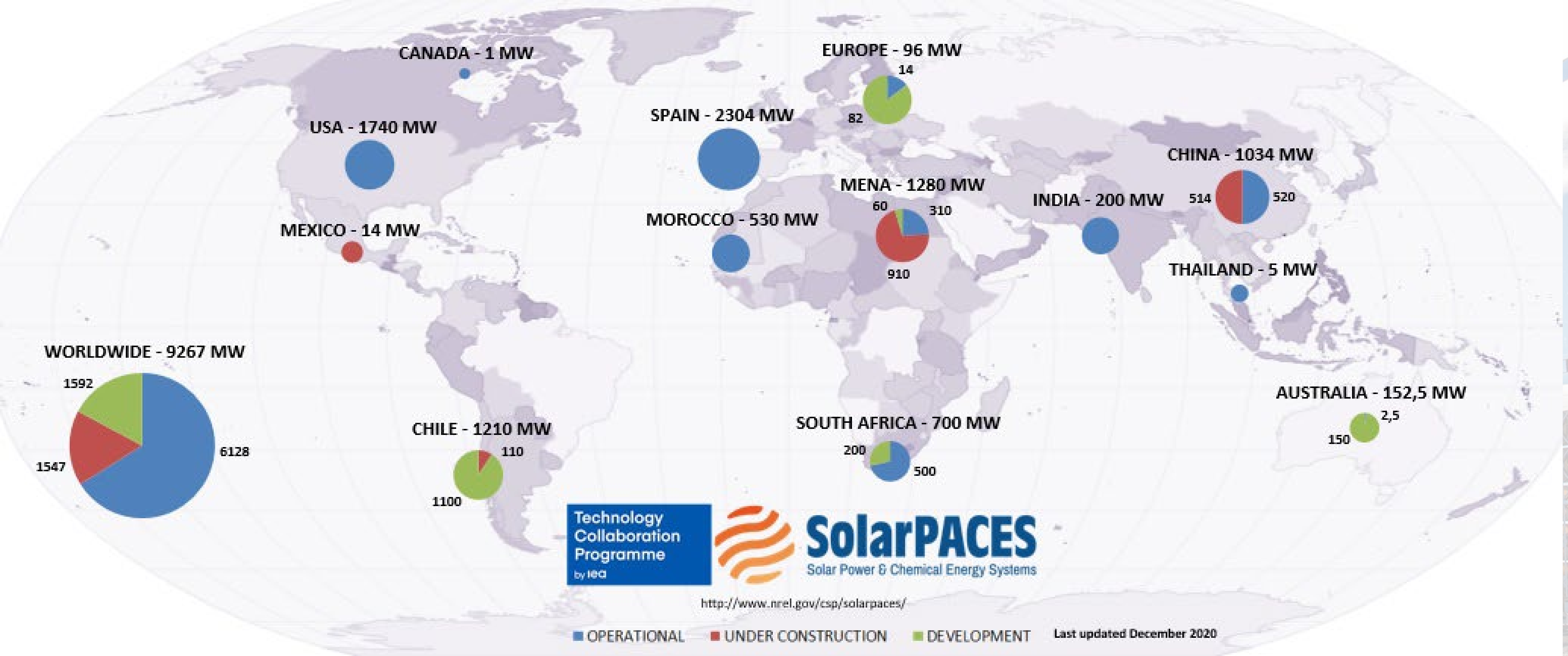
Agenda

1. Concentrating Solar Overview
2. CST value in Thermal Energy Storage
3. Sandia's Solar Thermal Energy Storage work
   1. G3P3
   2. Cyclic thermal storage test stand
   3. THERMS
   4. PTES
4. Challenges and Connections

Concentrating Solar Thermal Energy



CSP around the world



China's CSP + TES investments

- 8 Operational CSP plants with average thermal energy storage capacity of 10+ hours
- 22+ projects upcoming in China
- Hybrid PV + CSP + Storage
  - 900 MW PV ***PLUS***
  - 100-150 MW CSP ***PLUS***
  - 8-12 hours of TES

Jinta 100 MW Molten Salt

Dunhuang 100 MW Molten Salt,

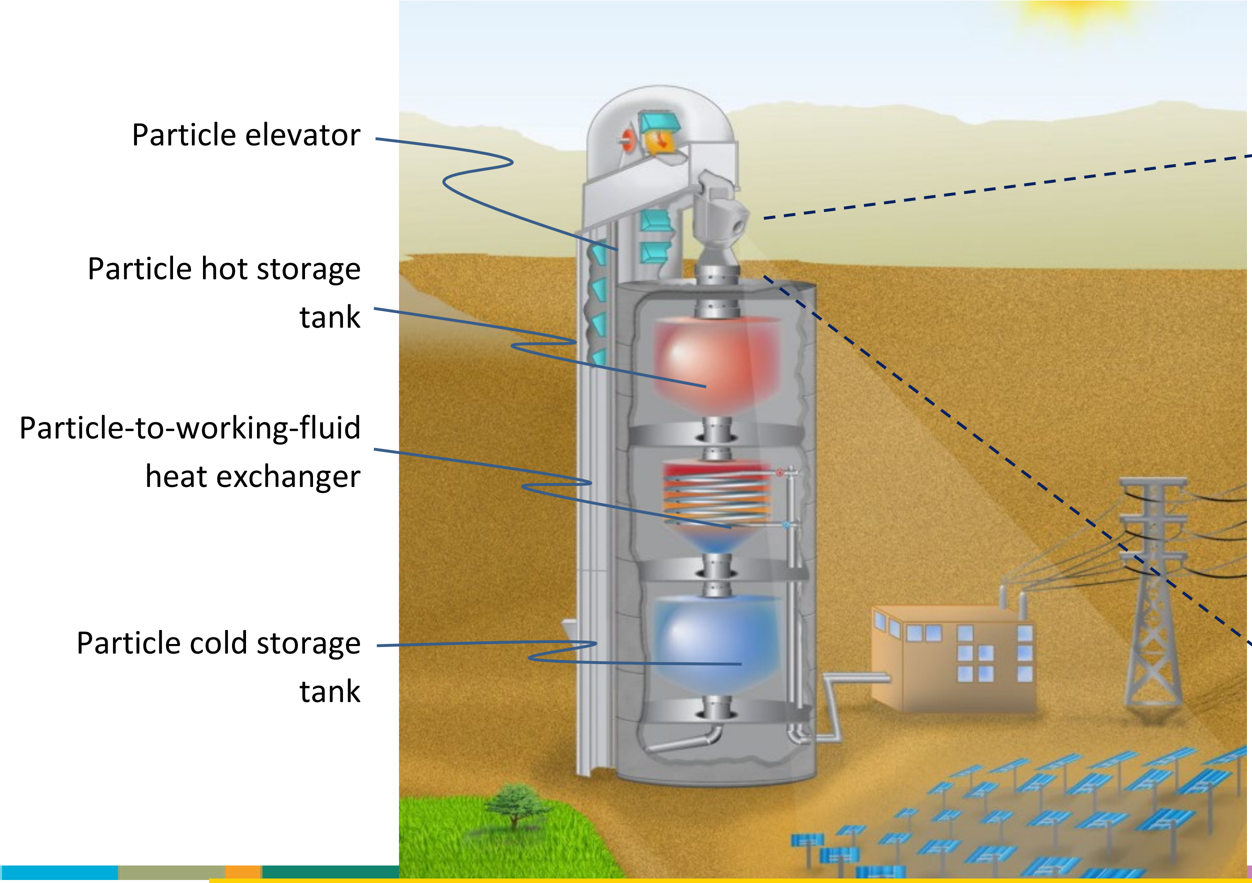
LuNeng Haixi 50MW Molten Salt

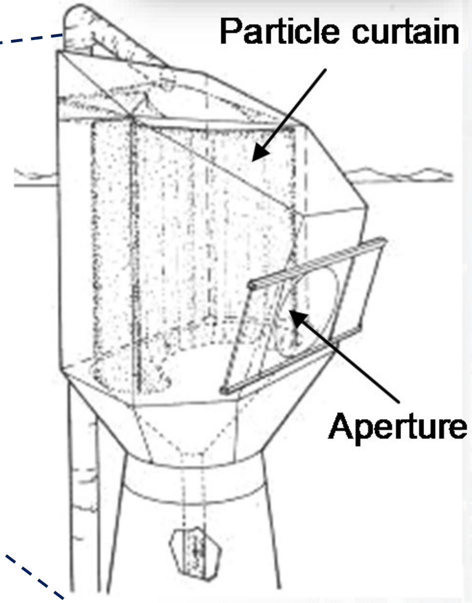
Current Sandia Work in TES

Gen 3 Particle Pilot Plant

High-Temperature Particle-Based CSP

PI: Cliff Ho





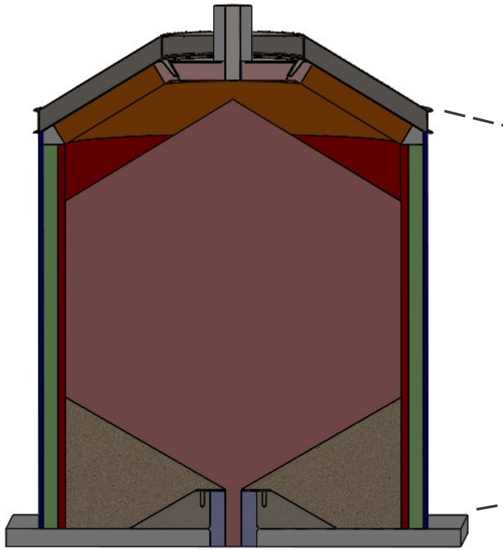
Falling particle receiver

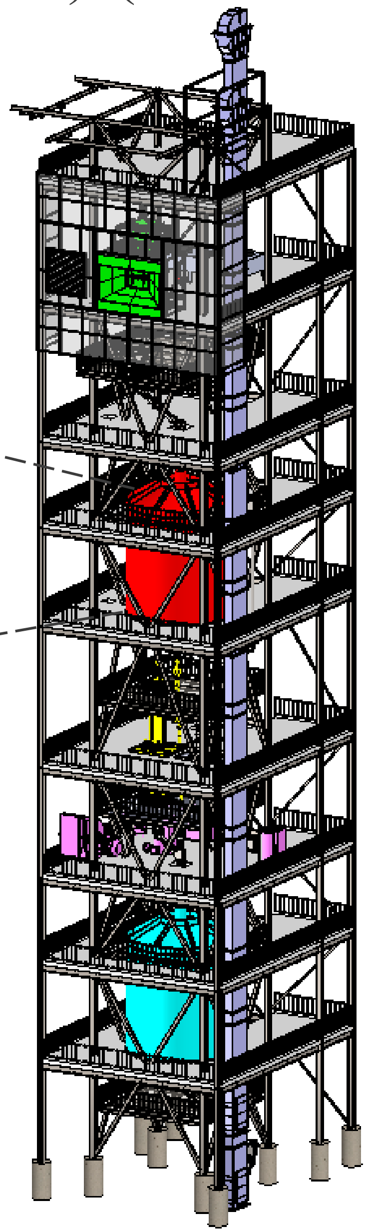
National Solar Thermal Test Facility
Sandia National Laboratories

Particle-based CSP enables next-generation power cycles (supercritical CO_2 Brayton cycle); no freezing

1. Gen3 Particle Pilot Plant (G3P3-USA) (PI: Jeremy Sment)

High-Temperature Particle Storage Bin
(Allied Mineral Products, Matrix PDM, Sandia)





K. Albrecht, SNL

Gen 3 Particle Pilot Plant

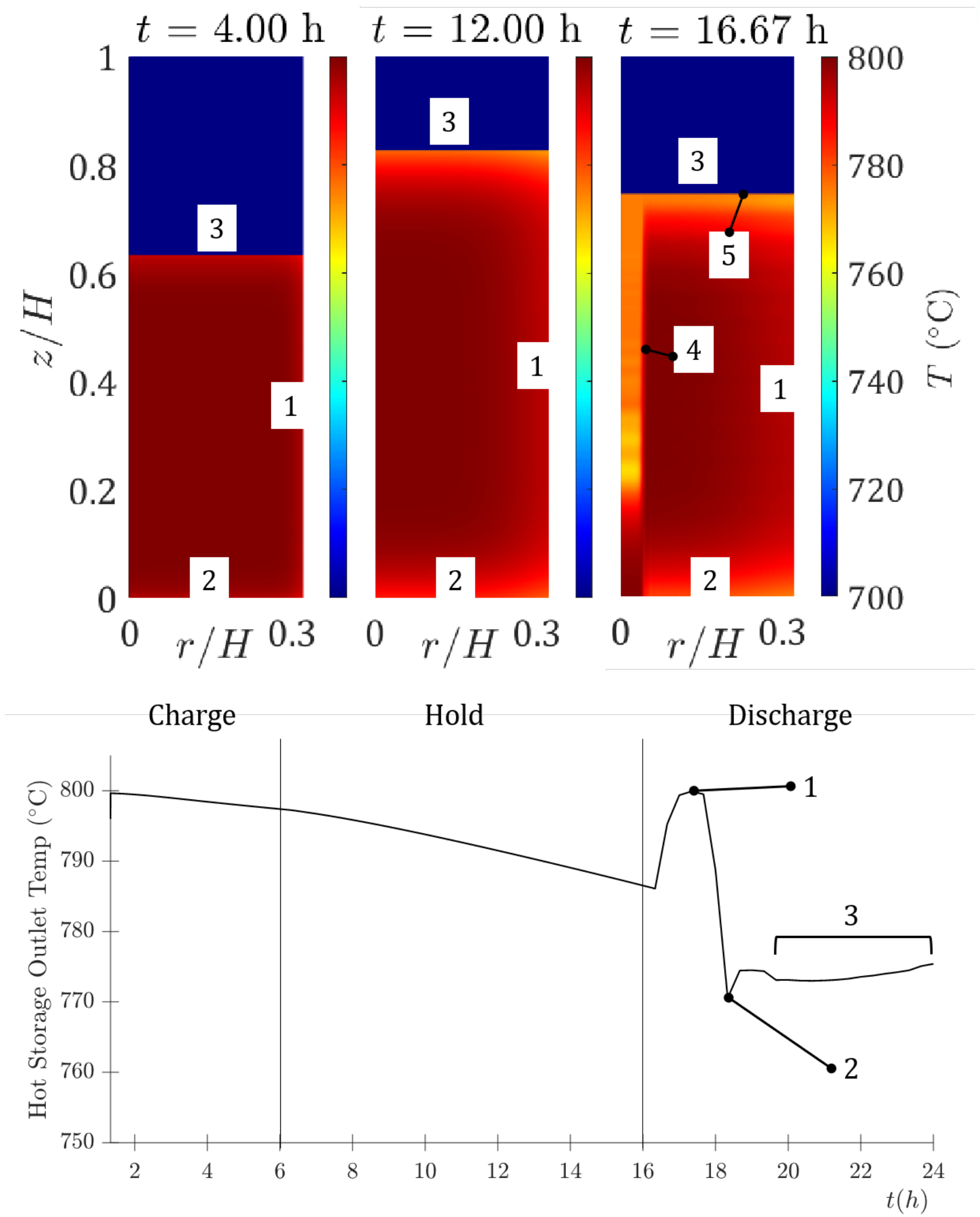
- ~1 – 2 MW_t receiver
- 6 MWh_t storage
- 1 MW_t particle-to-sCO_2 heat exchanger
- ~300 – 400 micron ceramic particles (CARBO HSP 40/70)

Heat Kernel Model for G3P3

Plewe et al 2020, 2021 couples the charge-hold-discharge operational modes using a semi-analytical method based on Heat Kernel theory.

The validation of this model requires a test apparatus with:

- Three capable operational modes: charge, hold, discharge
- Heated by flowing particles to correctly characterize thermal transport by funnel flow
- No less than three cycles to characterize the cyclic steady state effects from the thermal capacitance in the wall layers.
- Adjustable inlet and outlet mass flow rates and temperatures to validate the robustness of the model to predict the timing of the characteristic funnel flow outlet temperature profile



2. Cyclic Thermal Storage Test Stand (PI Jeremy Sment)

- Test stand capable of heating ≤750 kg particles to ≤900° C in an electric furnace.
- Slide gates control the flow of heated particles into a storage bin instrumented with thermocouples and strain gauges.
- The particles then flow into a bucket lift for recirculation

charging bin with heat transfer tubes

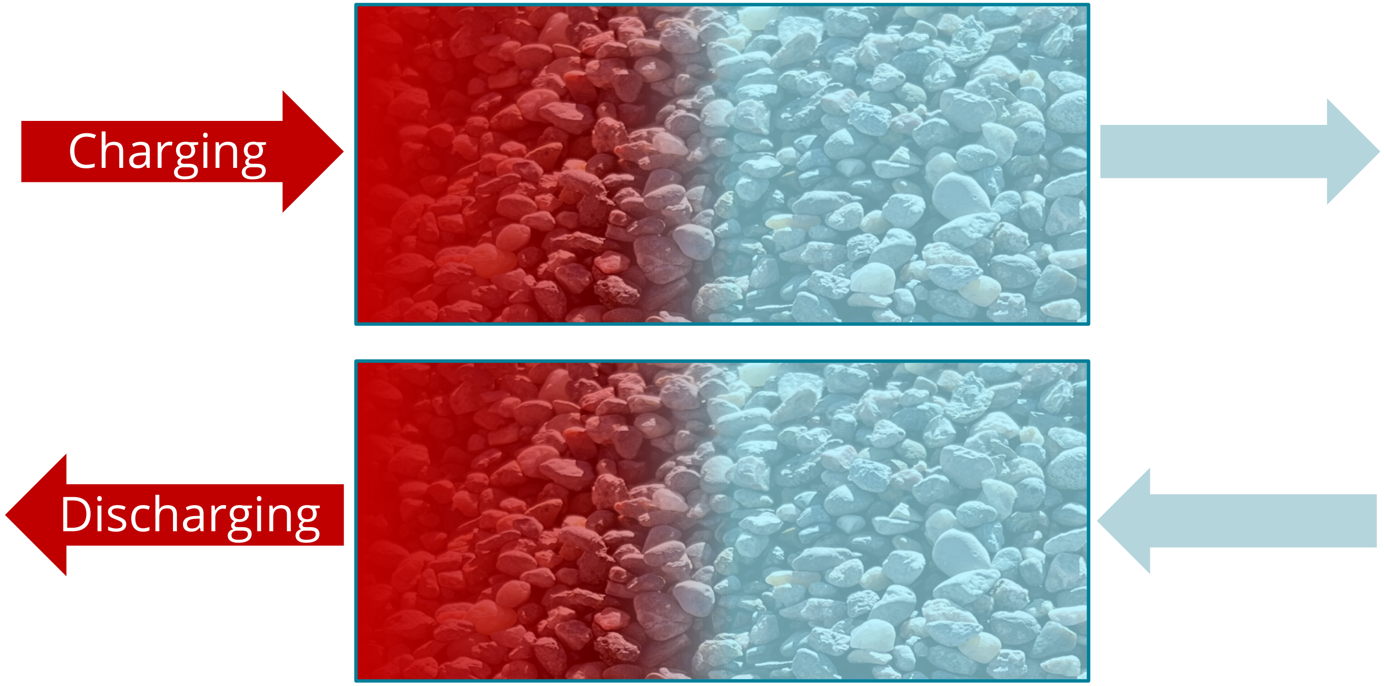
charging bin in furnace

bucket lift and stand

test storage bin

Packed Bed Thermal Energy Storage

- Utilizes a stationary bed of rocks for sensible heat storage
  - Typically metamorphic or basaltic
- Air is the heat transfer fluid
  - Laminar flow within the packed bed reduces parasitic pumping power
- Thermal storage can be used for process heat, HVAC, or grid storage
  - Grid power is used to heat air → air heats rocks → rocks store energy → rocks heat air → air powers turbine
- Energy can be stored for weeks to months
- Siemens Gamesa Electric Thermal Energy Storage and the Ait Baha CSP Pilot Plant have demonstrated electricity generation:

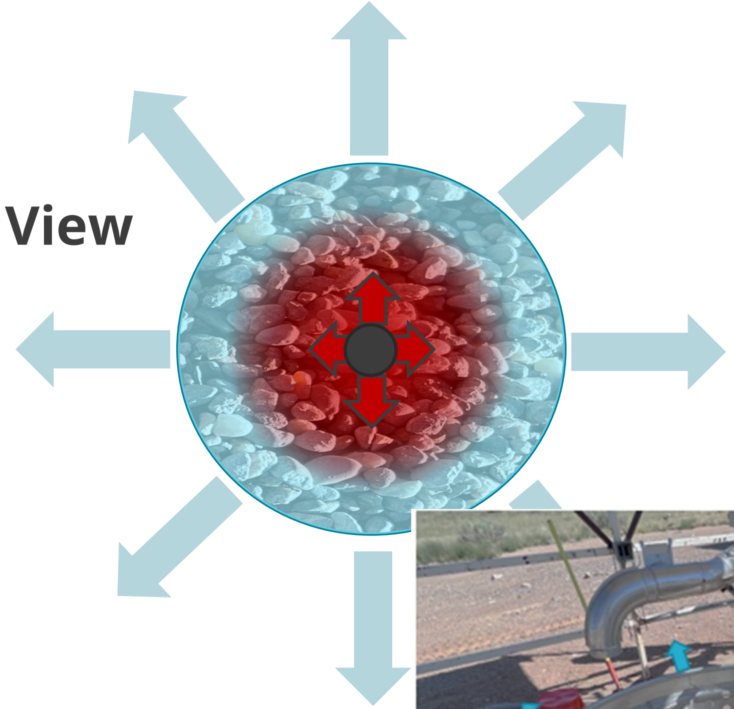


3. Radial Charging/ Discharging Packed Bed (PI: Nathan Schroeder)

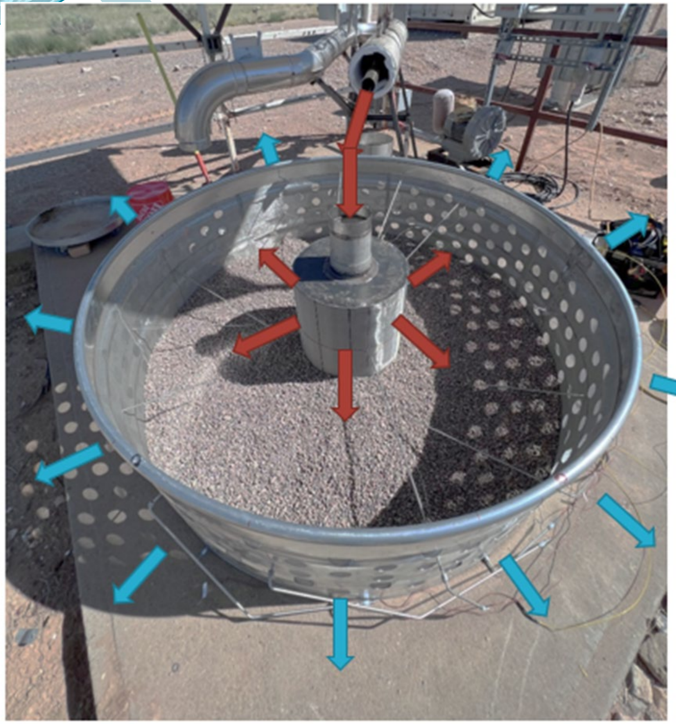
- Radially charged packed beds heat the gravel from a central injection well
- Air velocity decreases with distance from the central well decreasing parasitic power consumption
- High temperature region surrounded by storage material decreasing heat loss

Radial packed beds have decreased parasitic power consumption and heat loss

Plan View

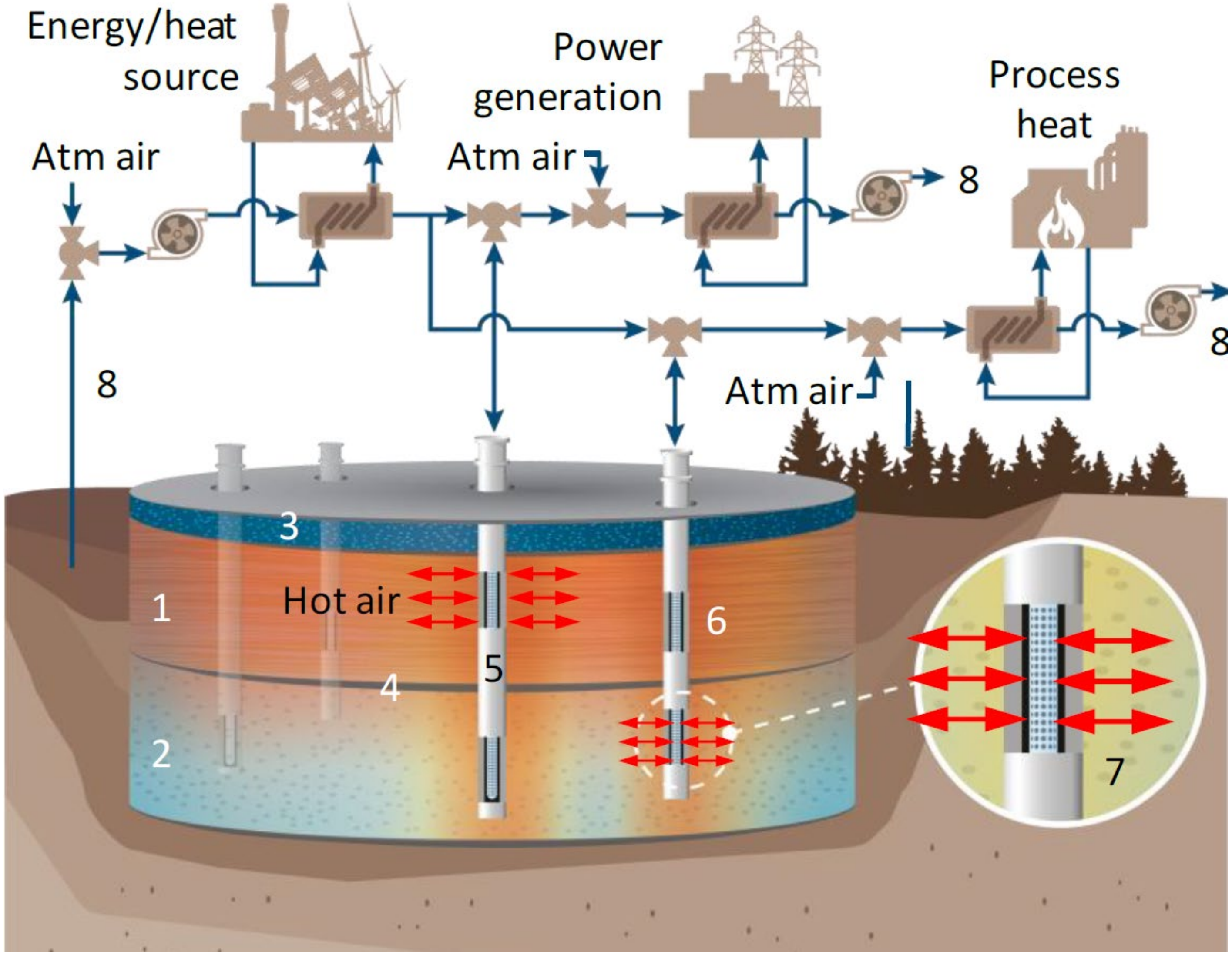


100 kWh Packed Bed @ NSTTF



3. Terrestrial Heat Repository for Months of Storage (THERMS)

- Radial packed bed system capable of storing heat for weeks to months
- Separated regions can be used for various storage durations
- Usage
  - Energy Generation
  - Process Heat
  - District Heating

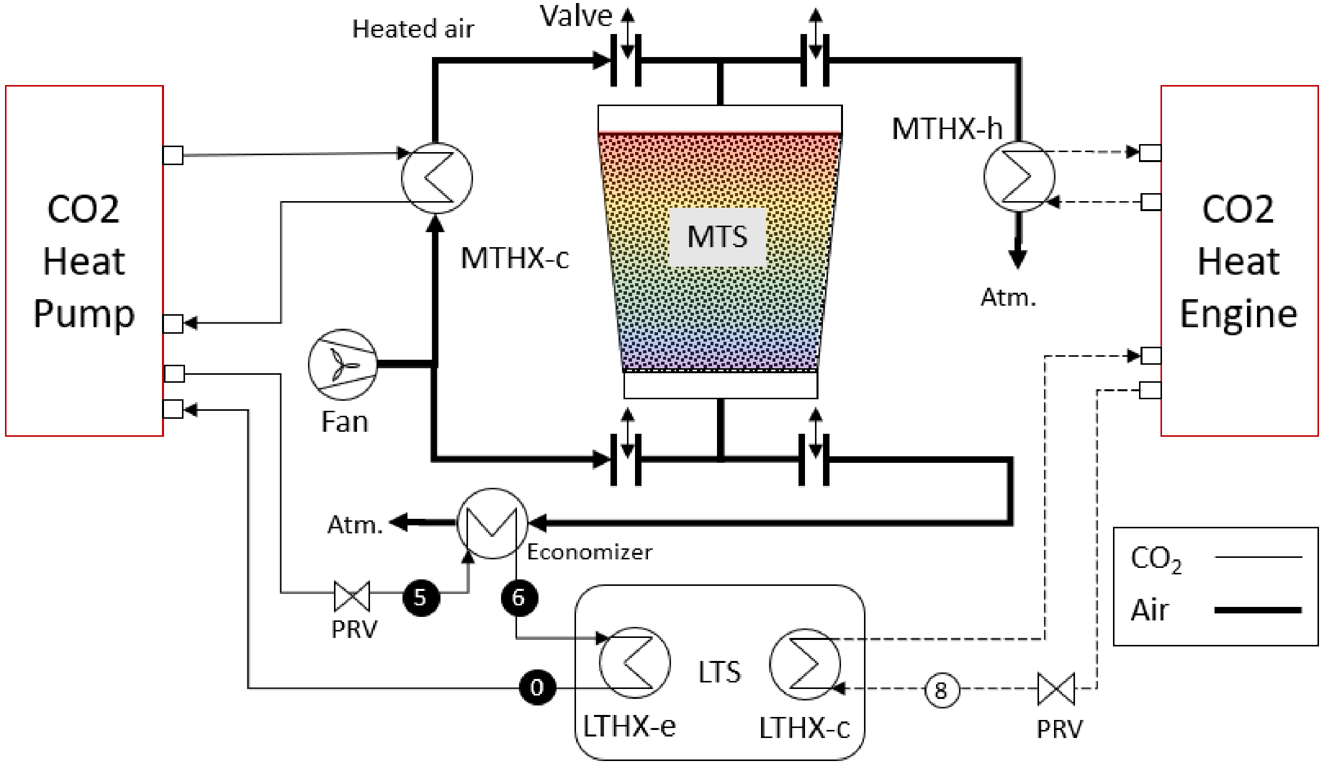


Source: Cliff Ho, Sandia National Labs

4. PTES and CSP (PI Ken Armijo)

Pumped Thermal Energy Storage (PTES)

- complement established energy storage systems
- repurpose waste heat from existing systems like natural gas plants
- Serve as electricity production systems as standalones, where a heat pump and a heat engine interact via both hot and cold storage to produce electricity using a reciprocating Joule cycle



4. Hybrid CSP + PTES System (PI Ken Armijo)

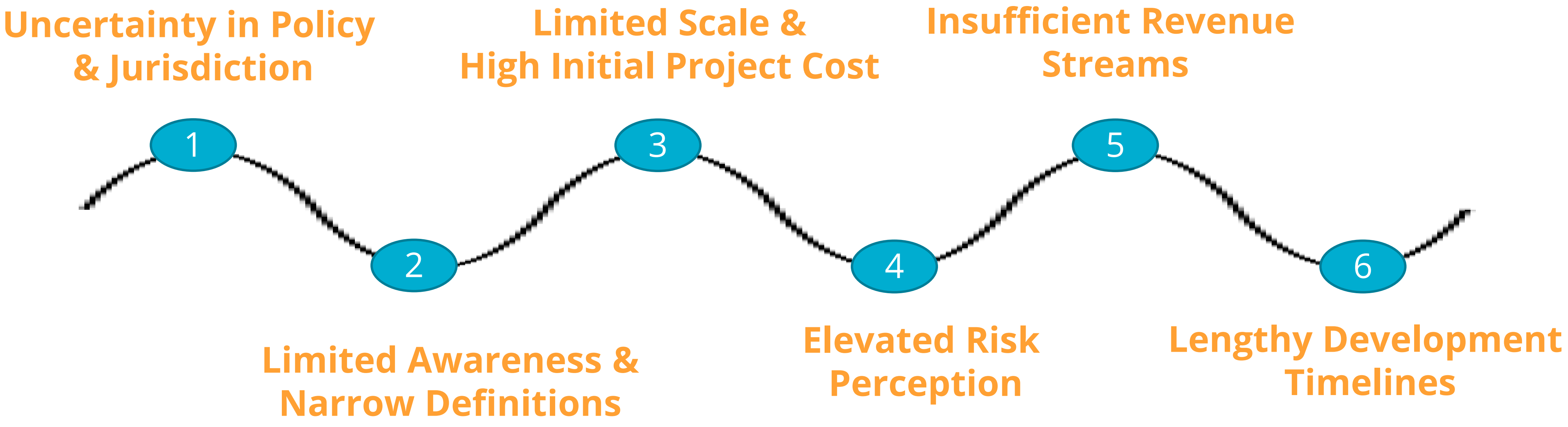
A CSP plus PTES system design was developed at the National Solar Thermal Test Facility (NSTTF) at Sandia National Laboratories. Two different system arrangements were considered to determine the optimal pilot-scale demonstration configuration.

The system is composed of three thermal storage subsystems:

1. A High Temperature Storage (HTS) implementing solid particles at temperatures above 650℃.
2. A Medium Temperature Storage (MTS) with temperatures ranging from 25℃ to 170℃ or 750℃ depending on the configuration being analyzed. (Packed bed)
3. A Low Temperature Storage (LTS) system at 0℃.

Concluding Thoughts

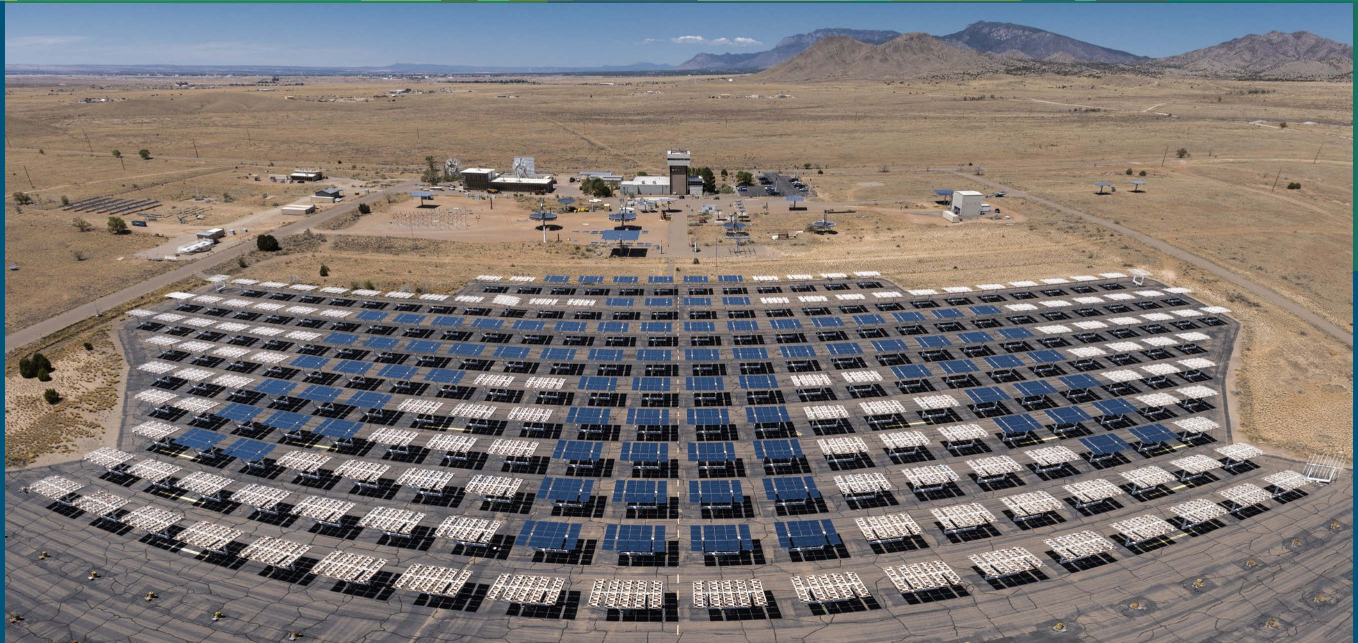
Challenges to integration of LDES



LDES Council: **JUNE 2022: The Journey to Net-Zero: An Action Plan to Unlock a Secure, Net-Zero Power System**

https://www.ldescouncil.com/assets/pdf/journey-to-net-zero-june2022.pdf

THANK YOU



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