BraytonEnergy

U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

SOLAR ENERGY TECHNOLOGIES OFFICE

Gen3 CSP Summit 2021

August 25–26, 2021

Virtual Event

Gen3 Gas Phase System

Development *and* Demonstration

DE-EE00008368

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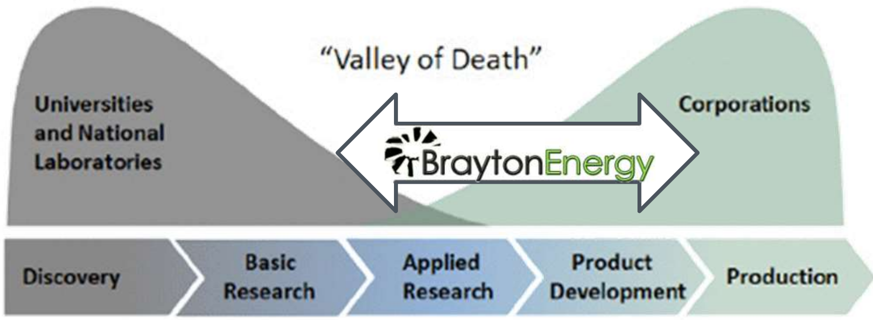
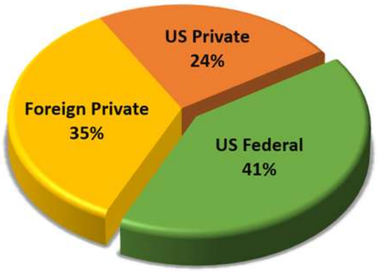
BraytonEnergy

an innovative R&D firm dedicated to making meaningful contributions in the field of environmentally responsible, sustainable energy production



- 5 Acre 38,000 ft^2 campus
- 50-person technical staff performing:
  - Engineering Research + Development
  - Design and Analysis
  - Rapid prototyping and testing
    - Fabrication, assembly, on-site advanced precision machining
  - Pilot Production

- ✓ *Turbomachinery*
- ✓ *Compact Heat Exchangers*
- ✓ *Distributed Generation/CHP*
- ✓ *Concentrating Solar Thermal*
- ✓ *Alternative Fuels*
- ✓ *Nuclear Systems*
- ✓ *Energy Storage*
- ✓ *Hybrid Vehicles*
- ✓ *Combustion*
- ✓ *UAVs*

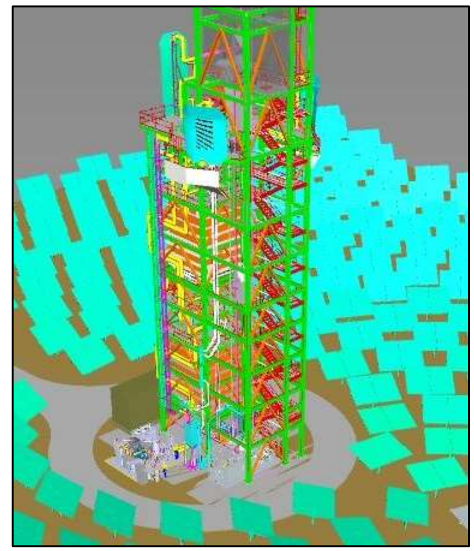


2019-2020

Gen3 Gas Phase System

- Develop a 100 MW_e commercial system that can absorb, store, and dispatch concentrated solar energy to a working fluid at conditions commensurate with an sCO_2 power cycle (700 °C, 25 MPa)
- Design a Megawatt-scale test facility to demonstrate and de-risk the technology innovations embodied in the commercial design

Greg Mehos Ph.D., P.E.



✓ Phase 1 (October 2018-December 2019)
  - System specification, design, modeling, analysis

✓ Phase 2 (January 2020-March 2021)
  - Component-level testing
  - Test facility design

Governing Program Philosophy

- De-risk, working ***backwards*** from Commercial Design
  - Engineer the 100 MW_e Commercial System
    - Large scale initially identified as "preferable" via TAC
    - 100 MW_e represented "hardest case" technologies
  - De-risk the **Commercial System** via Phase 3 Test Facility
    - Emulate full-scale commercial system in Phase 3 design to the extent possible
    - De-risk new technologies and integrated system operation
    - Employ actual commercial component/subsystem geometries where possible
  - De-risk new **Phase 3** technologies via Phase 2 Testing
    - Capture representative scale and conditions in test articles wherever possible
  - De-risk **Phase 2** testing via Phase 1/Early Phase 2
    - Design, model, and refine Phase 1, Phase 2, Phase 3, Commercial elements
    - Perform subscale and component testing
      - e.g. TES HX coupon creep and fatigue testing, particle property characterization, TES cold flow testing

Target the DoE-specified down-select criteria

- Perform full system optimization to determine lowest-LCOE configuration
  - Iterate/Update the commercial and Phase 3 designs with optimization results

Design Overview

- Nominally: employ “gaseous” phase working fluid in the receiver
- Utilize supercritical carbon dioxide (sCO_2) from the power block as the working fluid
  - Appropriate for baseload operation, leverages high-efficiency power block
    - “cold” riser and down-comer
    - “cold” working fluid control valves
    - Minimize capital costs by leveraging existing sCO_2 power block
- Supplemental analysis for peaker-type system (using hot sCO_2 circulator)

PARAMETER	UNITS	COMMERCIAL	PHASE 3	PHASE 2
FACILITY				
Location	-	Barstow, CA	Arizona, USA	Hampton, NH
SOLAR FIELD				
Layout	-	Surround Field	Surround Field	North Field
Heliostat Provider	-	*TBD*	Heliogen	Southwest Solar Tech
Mirror Size	m^2	*TBD*	1.5	9
Field Size	m^2	1,510,666	~ 7,500	216
Field Power	MW_t	~675	~ 5	0.15
TOWER				
Tower Height (optical)	m	111	~45	9.8 (recevier) 6.1 (TES)
Media Conveyance	-	Skip Hoist	Skip Hoist	batch swap
Skip Hoist Provider	-	ABB/Siemag/spg	ABB/Siemag	(forklift)
RECEIVER				
Configuration	-	Modular Tube Panels	Modular Tube Panels	Modular Tube Panels
Receiver Provider	-	Licensed Brayton Design	Brayton Energy, LLC	Brayton Energy, LLC
Working Fluid	-	sCO_2	sCO_2	sCO_2
Nominal Fluid Temp.	°C	730	730	730
Nominal Fluid Press.	Mpa	25	25	25
Power	MW_t	3 x 135	3 x 0.8	1 x 0.065
Sizes				
North Receiver	m x m	17.4 x 25.4	4.434 x 0.617	1.3 x 0.1
East/West Receiver	m x m	17.4 x 25.4	2.625 x 1.375	n/a
Peak Material Temp.	°C	761.9	761.9	761.9
Operating Life	hr	100,000 (30 years)	100,000 (30 years)	100,000 (30 years)
THERMAL ENERGY STORAGE				
Storage Type	-	Sensible Heat	Sensible Heat	Sensible Heat
Storage Media	-	300 µm Silica Sand	300 µm Silica Sand	300 µm Silica Sand
Capacity	MWht	2106	10	0.056
	hr	11.4	10	3.5
Heat Exchangers	-	Counterflow, Flowing Bed	Counterflow, Flowing Bed	Counterflow, Flowing Bed
Heat Rate	MW_t	185	1	0.016
Configuration	-	Int-Supported Brazed Cell	Int-Supported Brazed Cell	Int-Supported Brazed Cell
Heat Exchanger Provider	-	Licensed Brayton Design	Brayton Energy, LLC	Brayton Energy, LLC
Operating Life	hr	100,000 (30 years)	100,000 (30 years)	100,000 (30 years)
CYCLE				
"Cycle"	-	sCO_2 Brayton	sCO_2 Circulator Analogue	sCO_2 Circulator Analogue
Engine/Circulator Provider	-	*TBD*	Sandia National Lab.	Brayton/Echogen
Work (or Analogue)	-	Turbine Work Extraction	Heat Rejection to Amb.	Heat Rejection to Amb.
Heat Rate	MW_t	100-150	1.0	0.1
Equiv. Cycle Power	MW_e	50-75	~ 0.5	n/a

Baseline Gen3 System (Baseload)

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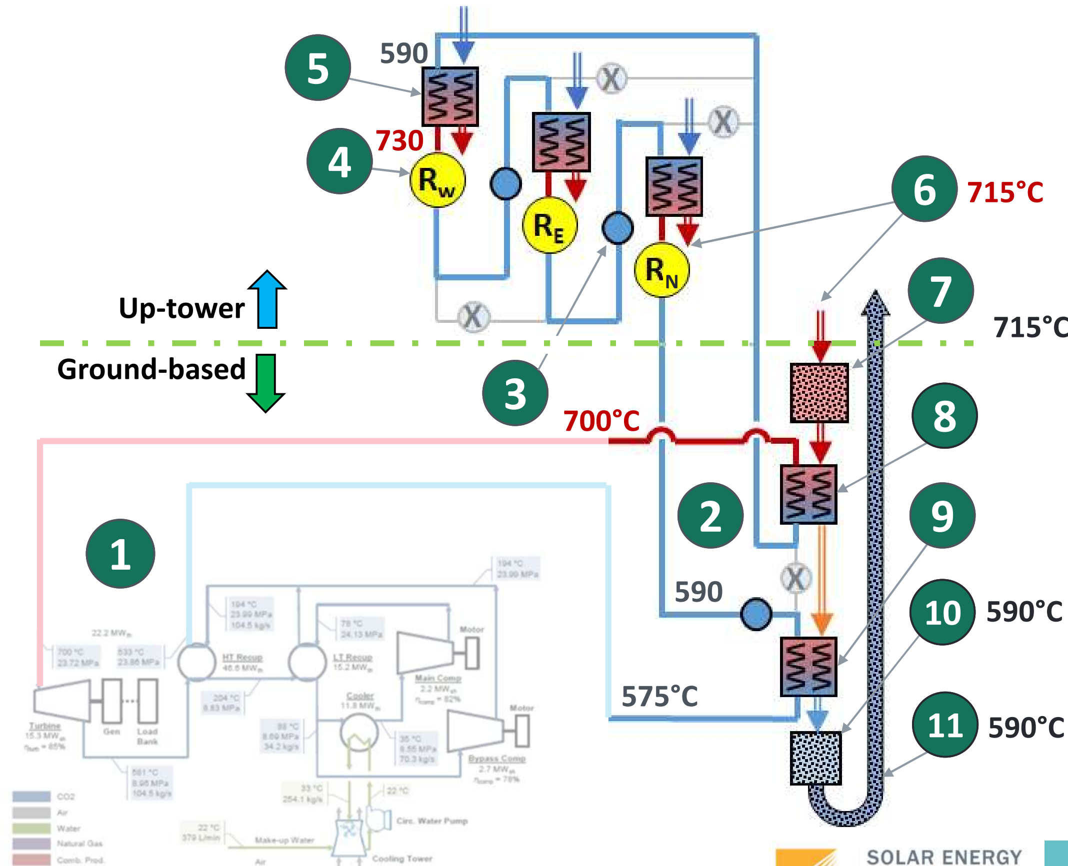
1. RCBC sCO_2 power block
2. Low temp. high press. sCO_2 piping
3. Low temperature flow valves
4. TES charging receivers
5. TES charging heat exchangers
6. TES low pressure particle shaft
7. TES hot particle storage silo
8. High temp. TES discharge heat exchanger
9. Low temp. TES discharge heat exchanger
10. TES cold particle storage silo
11. TES particle lift

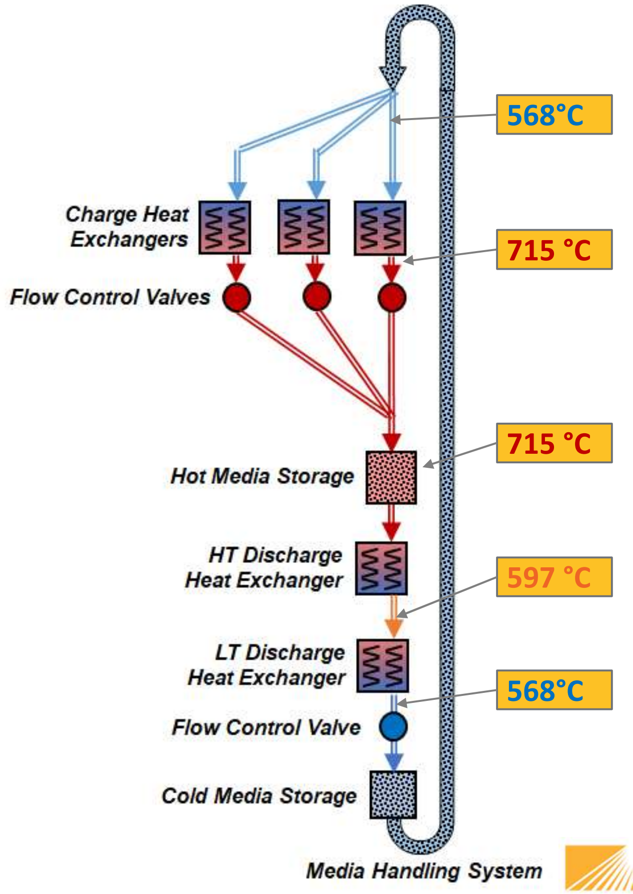
- Mass flow is dictated by power block
- Heat input is constrained by peak allowable receiver material temp.
- Control parameters shown in red



Particle-Side Schematic

- Charge heat exchanger particle outlet temperatures are controlled to 715 °C via sand flow rate
  - This temperature ensures that TIT can achieve 700 °C at design conditions, with design approach temperature

- Split discharge heat exchanger enables media to reject heat to sCO_2 inlet temperature (553 °C)
  - Otherwise, rejection temperature is limited to charging heat exchanger sCO_2 outlet conditions of 600 °C
    - This higher temp. is a result of heat exchanger approach temps.



Phase 3 Test System (3 MW_t)

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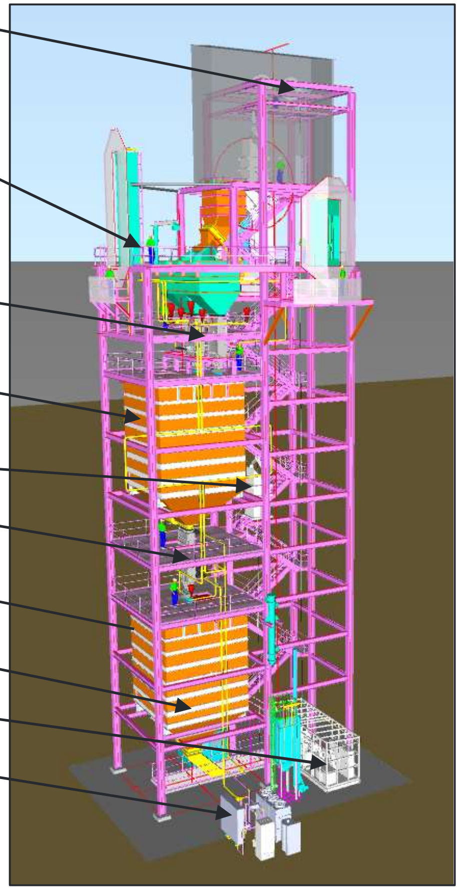
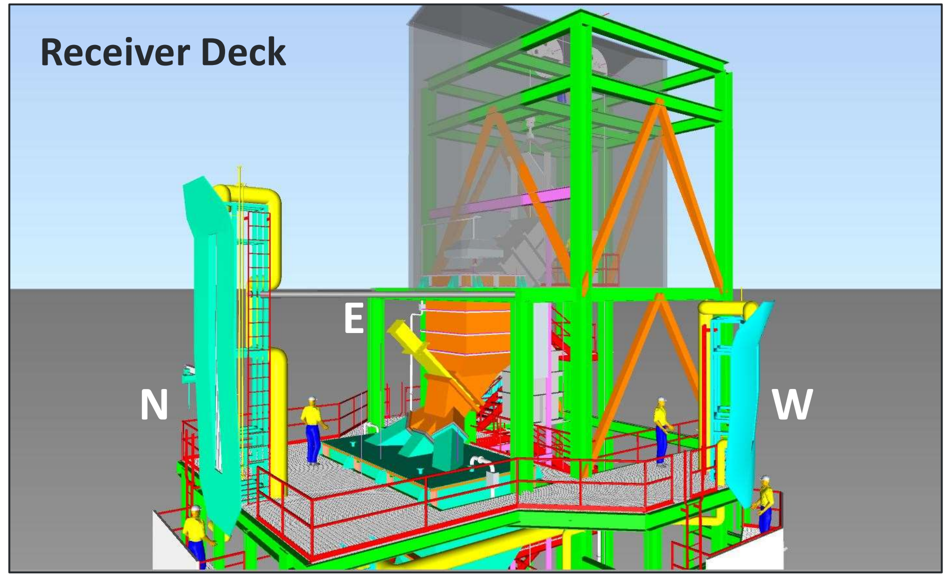
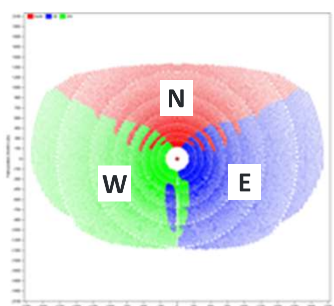
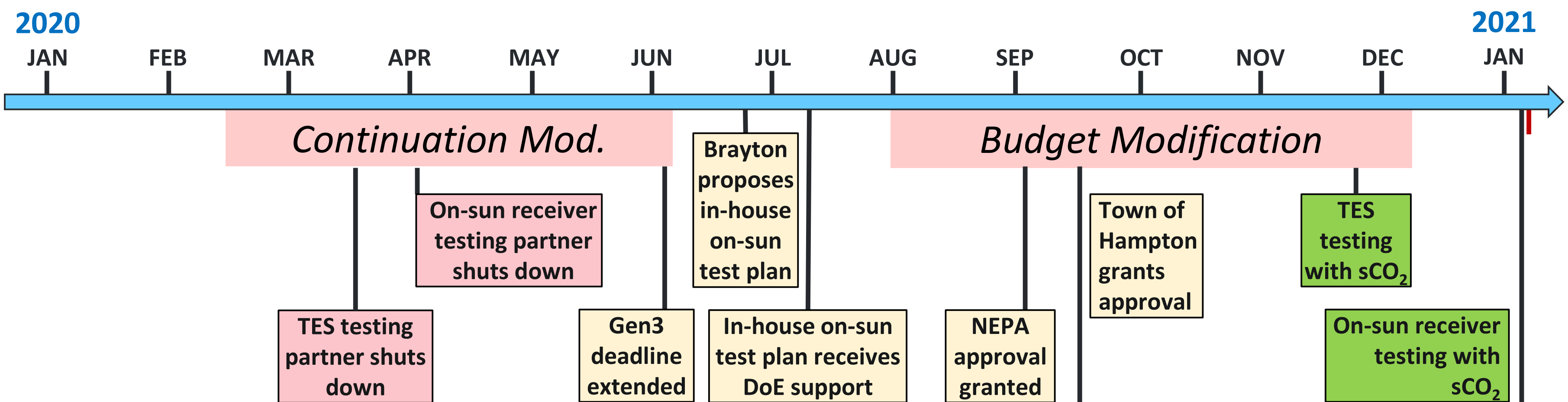




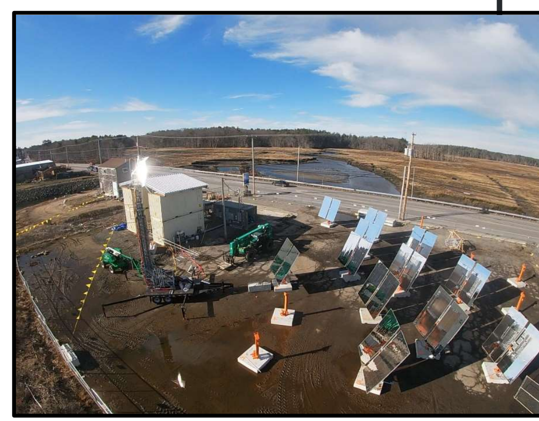


- Tower Height = 40 m
- 5 MW_t field
- 3 x 1 MW_t Receivers
- 12 MWh_t Storage
- Surround field emulates full-scale layout

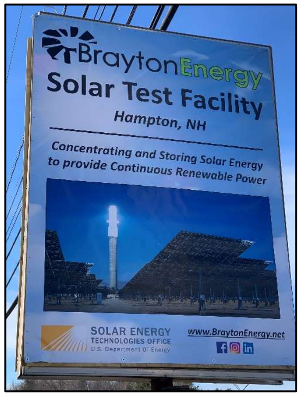
Phase 2 Testing Execution Timeline



- Brown field to operating solar field with sCO_2 capabilities in under 4 months
- Includes novel heliostat design, fabrication, and delivery
- Required extensive financial outlay prior to budget approval



Progress


BraytonEnergy
Solar Test Facility
Hampton, NH
Concentrating and Storing Solar Energy to provide Continuous Renewable Power
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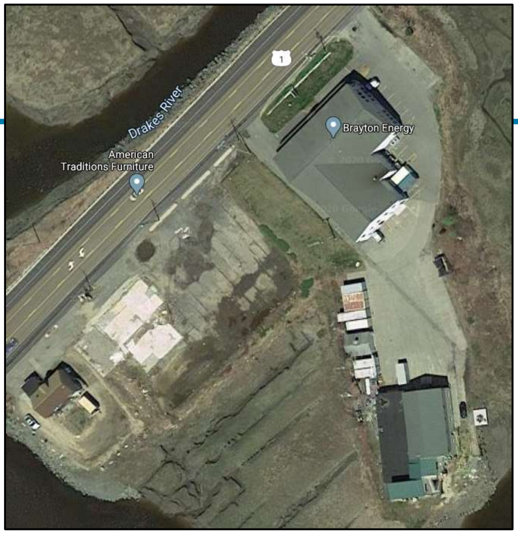
Drakes River
American Traditions Furniture
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06 September


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17 December
Camera 01
12/17/2020 8:21:33 AM


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25 December
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Solar Test Facility: January 2021

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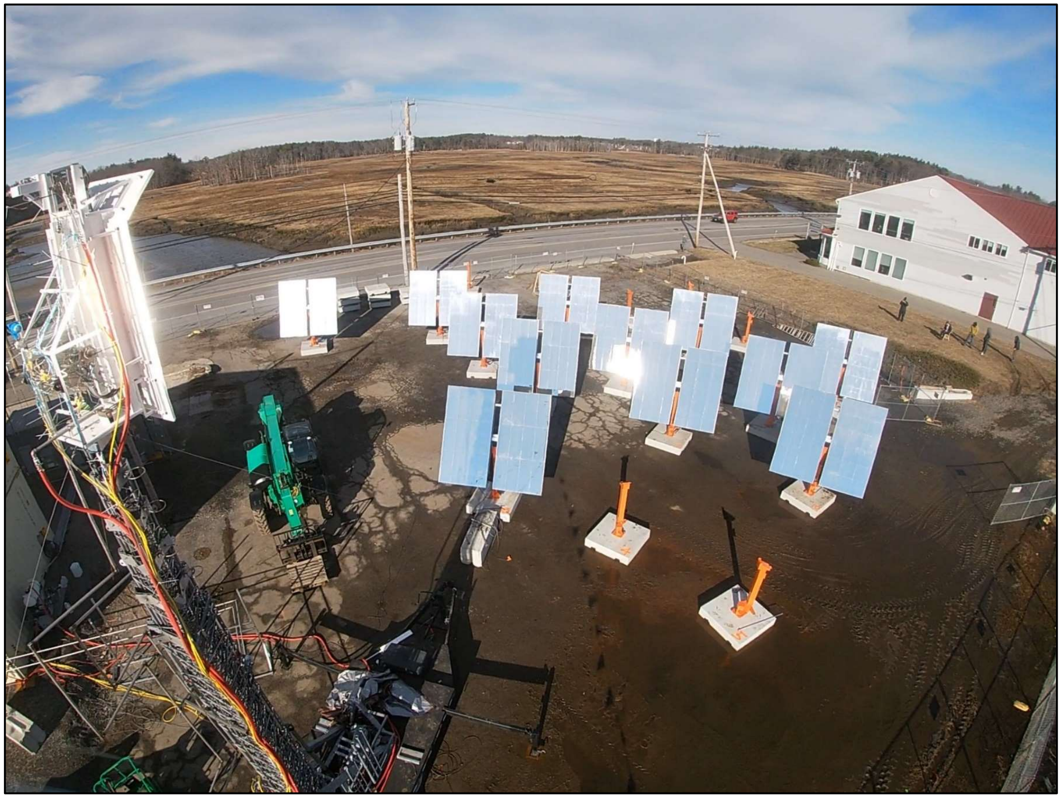

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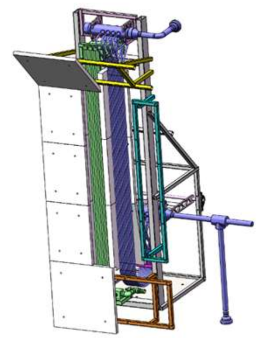
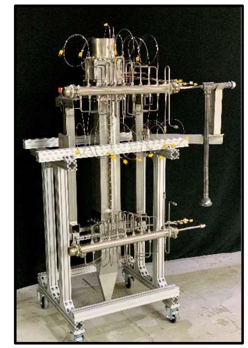
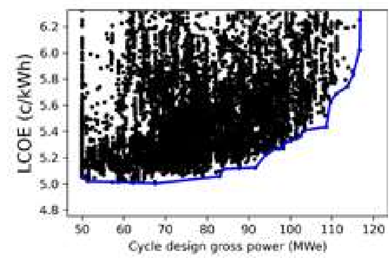
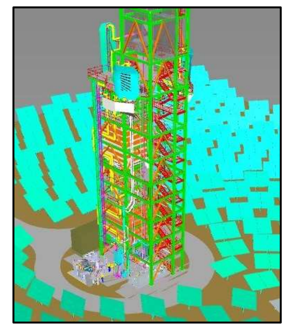
Gas Phase: Key Results and Conclusions

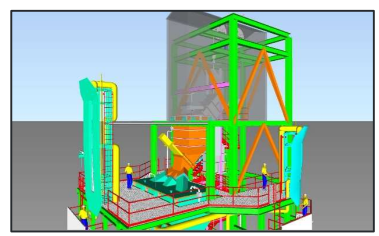
- Novel **Solar Receiver** and **TES Heat Exchanger** designs
  - 30-year operating life under sCO_2 conditions (750 ^oC, 25 MPa)
  - Designs tested on-site at Brayton by January 2021
- Detailed **Integrated Commercial System Design**
  - **BASELOAD** system (83 MW): LCOE = 5.02 ¢/kWh_e
  - **PEAKER** system (65 MW_e): LCOE = 2.83 ¢/kWh_e
    - *PPA price (year 1) = 3.40 ¢/kWh_e*
- Phase 3 **Test Facility Design** submitted
  - Emulates the form, fit, and function of the Commercial System
    - Incorporates ***commercial-scale components*** to showcase manufacturability and performance











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Thank You

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