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

SOLAR ENERGY TECHNOLOGIES OFFICE

SETO CSP Program Summit 2019

Argonne NATIONAL LABORATORY

# LOW-COST HIGH TEMPERATURE CERAMIC HEAT EXCHANGERS

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Oakland, CA

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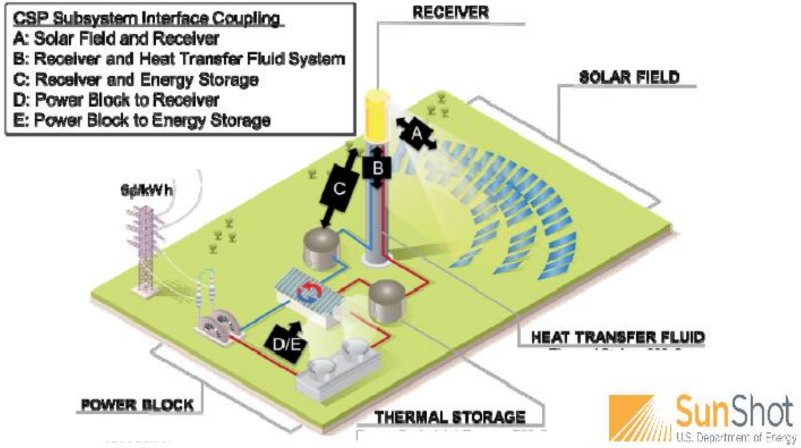
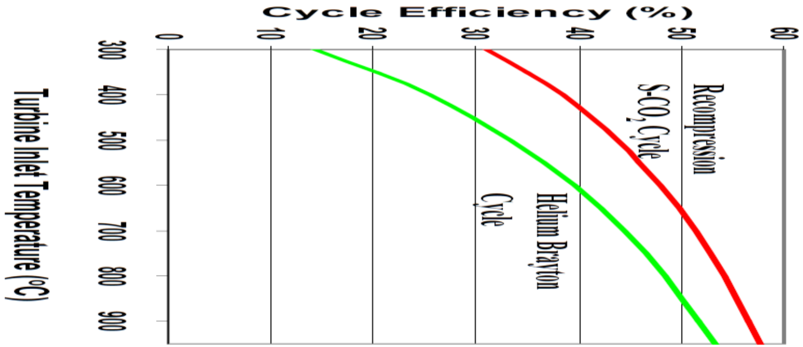
energy.gov/solar-office

# Background




V. Dostal

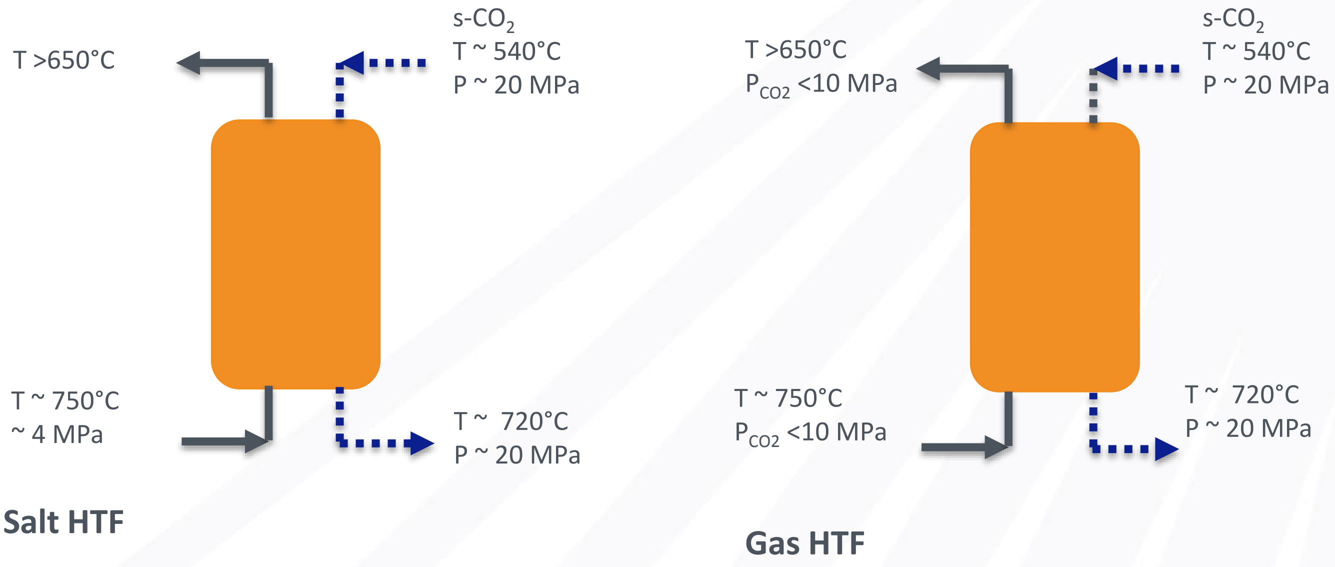
**HXs for Thermal Energy Transfer from HTF to s-$CO_2$**

T > 700°C

P ~ 20 MPa for s-$CO_2$

**Higher Temperatures (>700°C) and Pressures Require Components (HXs, TES, etc.) that Perform Reliably at the Operating Conditions**

# CSP – High Temperature Heat Exchangers




From: Gen3 RoadMap 2017

**Higher Operating Temperatures with Challenging HTFs**

- Corrosion from salt based HTF
- Oxidation
- Creep

# Proposed concept – Why ceramics?

- High melting point, high temperature thermodynamic stability
- Compatible to variety of HTFs and working fluid
- High corrosion resistance (salts, s-$CO_2$)
- High oxidation and fouling resistances
- Good thermal conductivity at elevated temperatures
- High creep resistance at operating temperatures
- Inexpensive raw materials

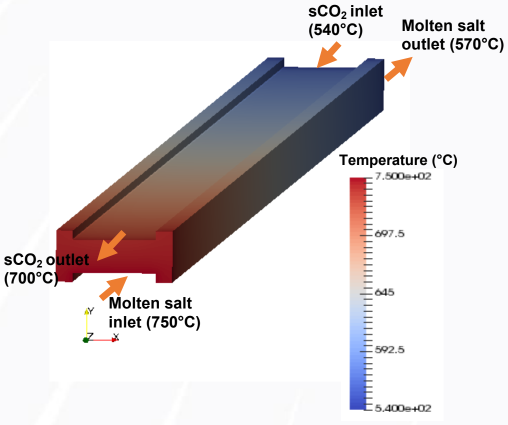
Traditional ceramic processing and machining processes are difficult and expensive

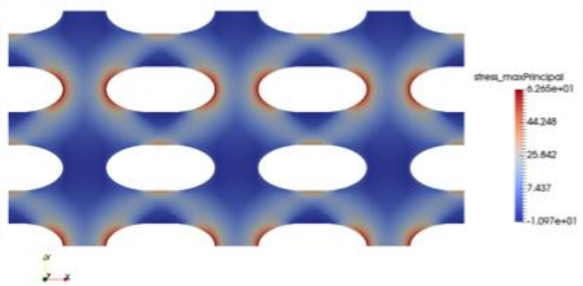
# Proposed concept – Additive manufacturing

- **Ease of Fabrication and Manufacturing**
  - Complex geometries (shapes with curvatures and sharp transitions can be fabricated)
- **Tailorable Composition and Properties**
  - composites can be fabricated by manipulating the preform compositions
- **Lower cost**
  - Reduced processing steps
  - Shorter production times
  - Design changes can be easily incorporated in manufacturing

# Key Tasks

- HX design using combined CFD & thermal/stress modeling
- Fabrication and characterization of HX plates
- Fabrication of multilayered HX of optimized design
- Joining and durability evaluations
- Experimental testing and validate simulations
- Techno-economic analysis




Maximum principal stress profiles

# Challenges and mitigation plans

**Adequate pressure drops and stresses, while maintaining necessary thermal transport**

- CFD and conjugate thermal/stress analysis will dictate optimum HX design

**Densification**

- Temperature, heating/cooling rates

**Mechanical properties (toughness) and thermal shock resistance of ceramics**

- improve toughness and reliability and benefit thermal conductivity

**Integration of various HX components, ceramic/metal joining**

- match the thermal expansions between ceramic and metal

# Key Outcomes and Impact

- An advanced low-cost, corrosion and creep resistant thermal exchange system operating at temperatures >700°C and compatible to salt and gas phase HTFs and s-$CO_2$

- Higher temperature power cycles will help SETO program to achieve its LCOE targets

- Demonstrated performance (and associated data) for a reliable ceramic HX at lab-scale

- Innovations in materials and manufacturing will will benefit not only CSP, but other power generation and process industries