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Solar Fuels R&D in the United States of America: SolarPACES Task II

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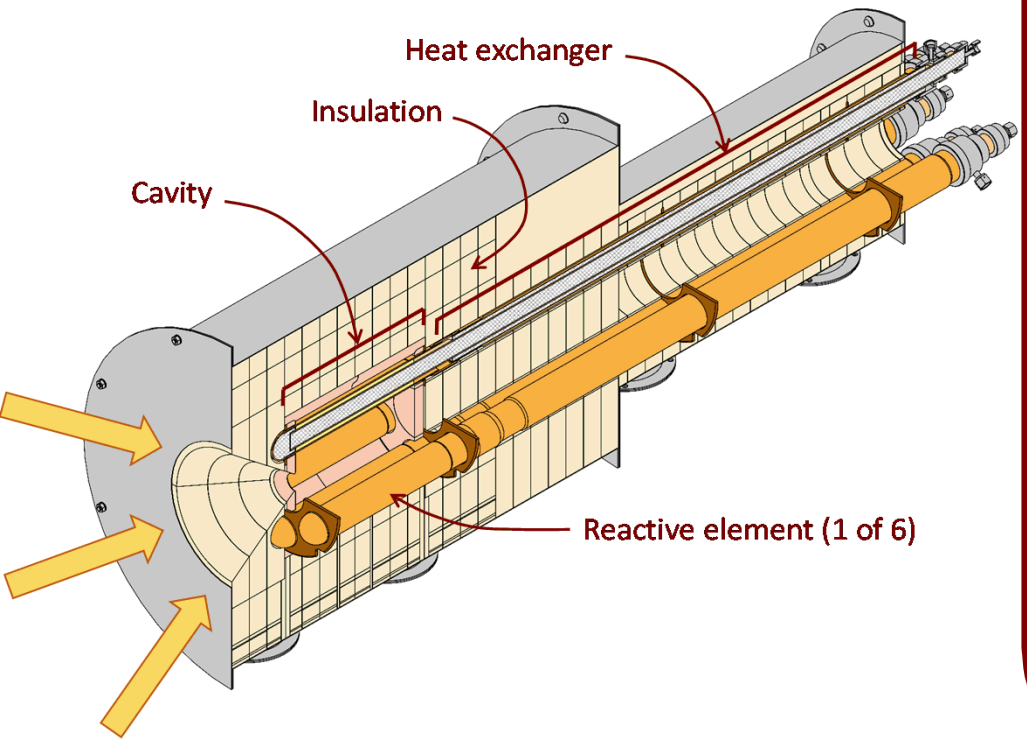
Sandia National Laboratories

Many thanks to the researchers who kindly provided the material for this Task II update.

University of Minnesota Redox Reactor

- Continuous Co-production of separate streams of syngas and hydrogen
- Demonstrated 90% effective heat recovery of gas-phase sensible heat



Prototype Reactor

- Mechanically robust with 6 tubular fixed beds, each integrated with counterflow heat exchanger
- porous fiber ceria particles developed with industry
- Demonstrated for >9000 cycles in solar simulator

- Integrated gas phase heat recovery
  - **93-95% sensible heat recovery from reactant and product gases in an integrated ceramic HX**
- Process under development is based on partial oxidation of methane coupled with water splitting
  - **Efficiency approaching 50% based on measured reaction rates, conversion and selectivity**
  - **Demonstrated on-sun for 7 hours with 1 of 6 tubular reactive elements, achieving 7% efficiency**

Credit: UMN Solar Energy Laboratory, Jane Davidson group, jhd@umn.edu

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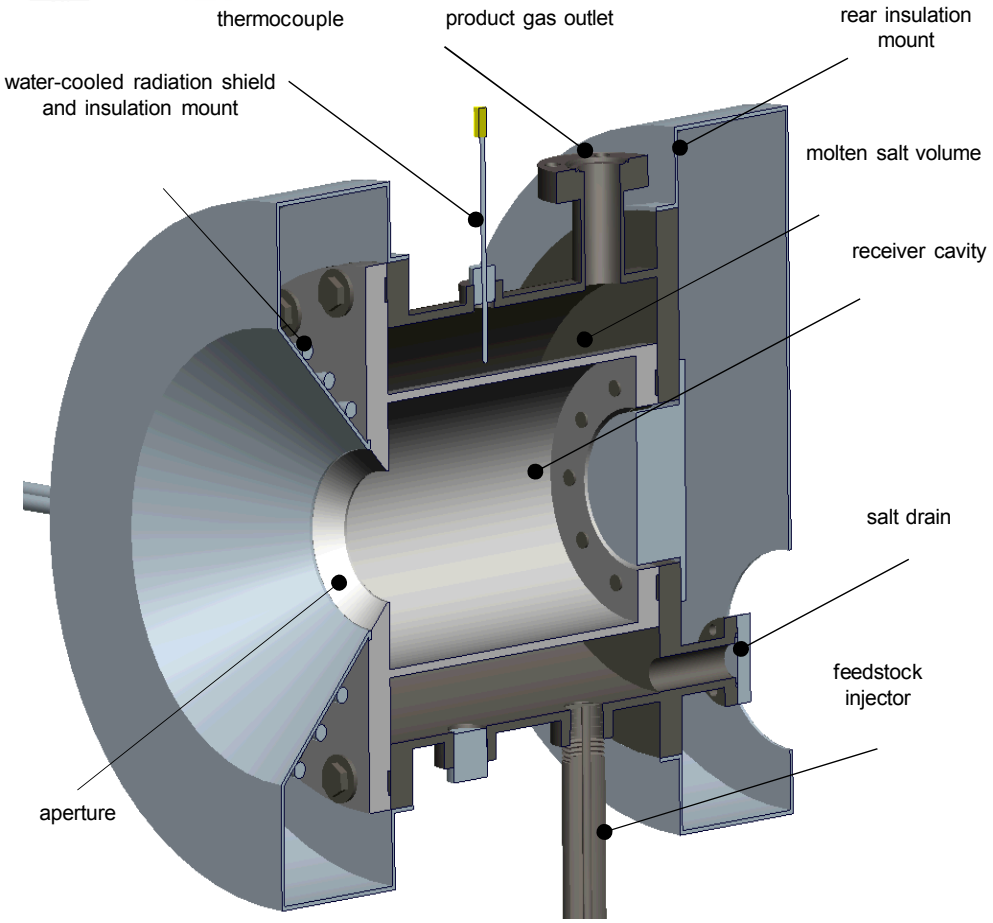
University of Minnesota Molten Salt Solar Gasifier



Carbonate Salts

Ternary eutectic blend of Li, K, and Na carbonates

- Provides thermal storage to enable continuous operation during solar transients
- Rapid heat transfer to the feedstock
- Catalyzes gasification reactions producing a ten-fold increase in reaction rates
- Yields clean product gas – retains ash, tar and sulfur
- **3 kW prototype reactor successfully demonstrated in UMN's solar simulator at a competitive 30% efficiency.**
- New feed delivery to improve feedstock delivery has been installed.

Credit: UMN Solar Energy Laboratory, Jane Davidson group, jhd@umn.edu

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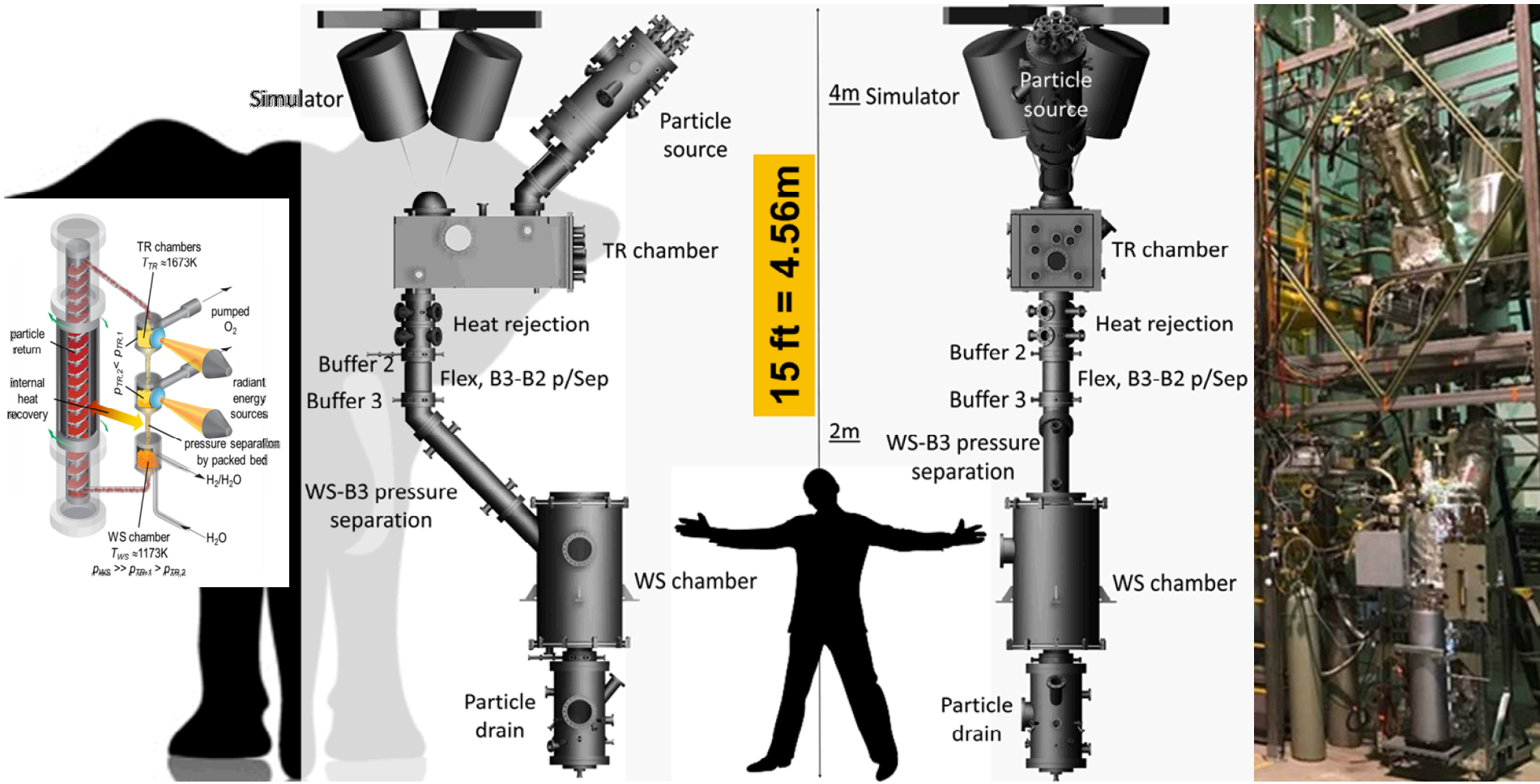
Cascading Pressure Reactor: Sandia, DLR, ASU, Bucknell, CS Mines



Vacuum and Staged Reduction: Concept to Practice

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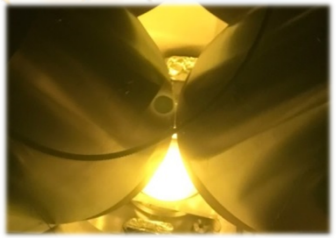
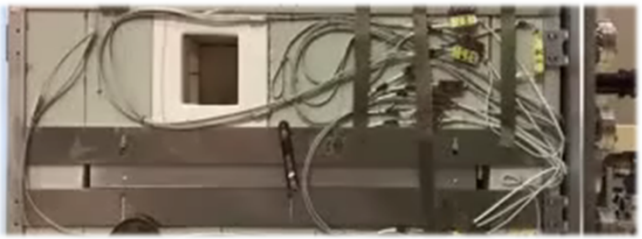
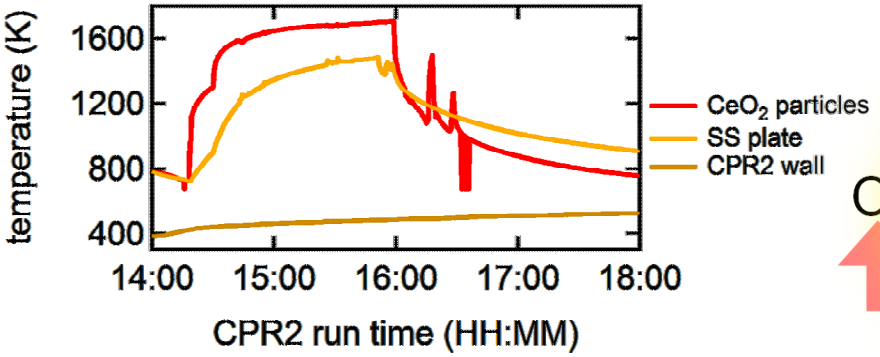
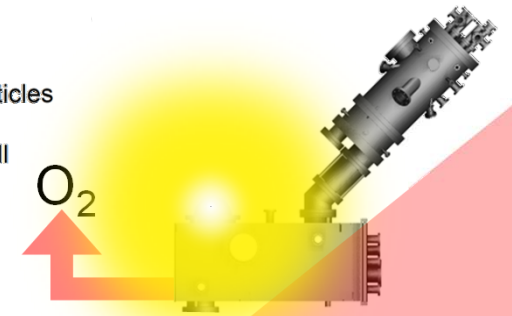
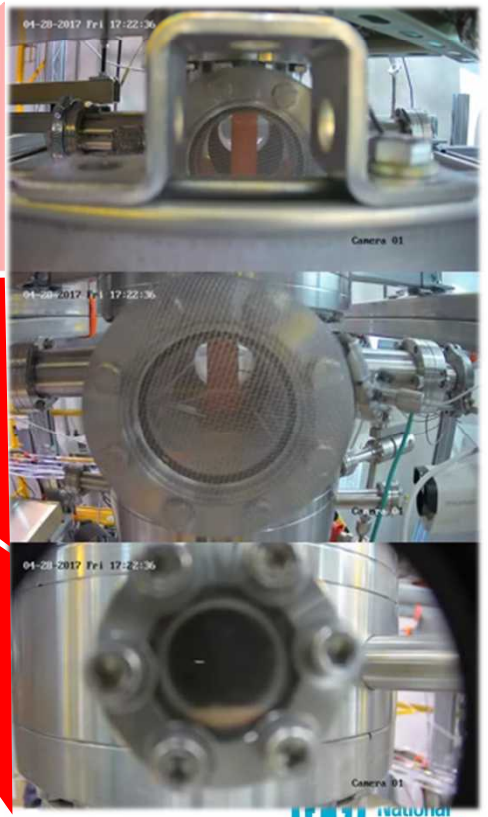
Cascading Pressure Reactor: Sandia, DLR, ASU, Bucknell, CS Mines

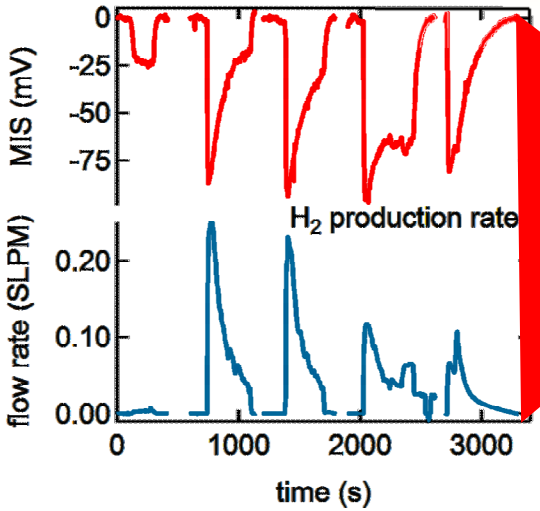










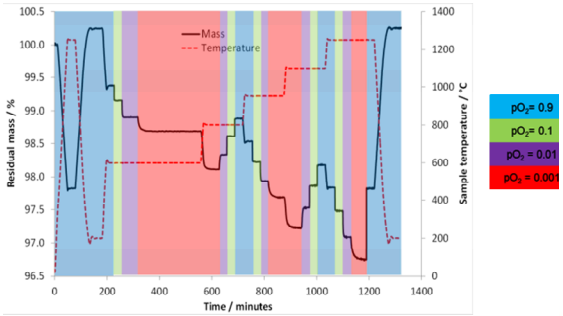
T_R~1700 K

0.25 SLPM peak H_2 rate

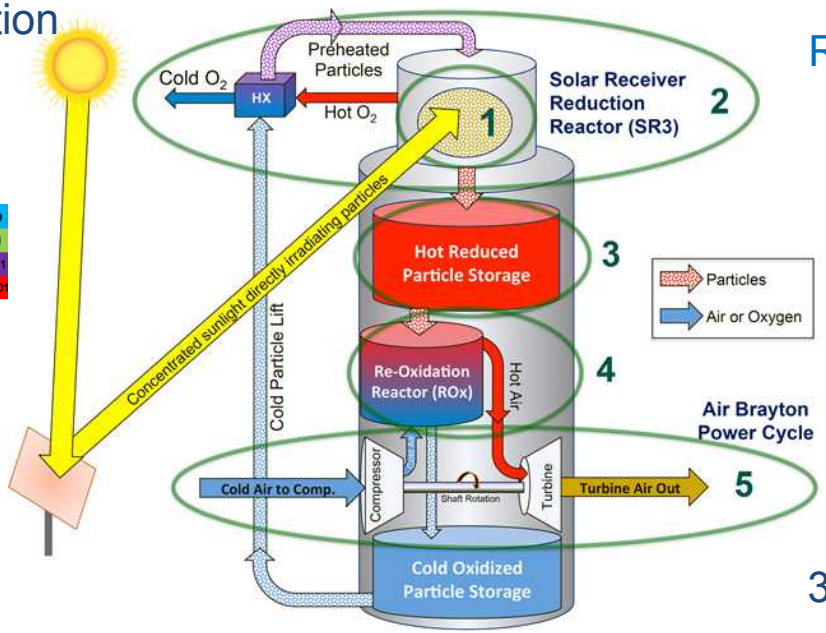
H_2O

PROMOTES: High Performance Reduction/Oxidation Metal Oxides for Thermochemical Energy Storage

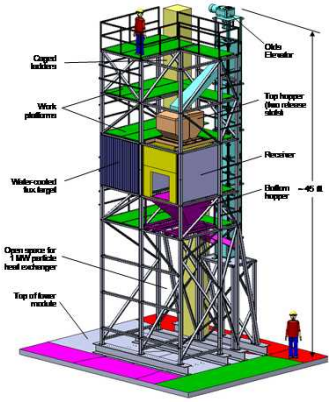
1. Materials Enabled Innovation (ΔH_{total} > 1200 kJ/kg)



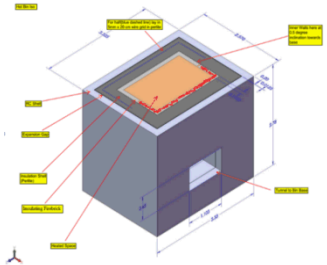
5. High Temp/High Efficiency Air Brayton Power Cycle.



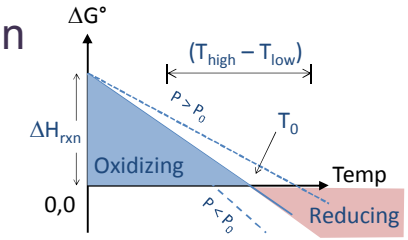
2. Falling Particle Receiver + Reactive Metal Oxides



3. Particle Storage at T > 1000 ° C



4. Pressurized oxidation reactor. Air acts as reactant and heat transfer fluid. Open cycle – no gas storage.



KEY PARTNERS: Sandia National Laboratories, Georgia Institute of Technology, King Saud University, Arizona State University

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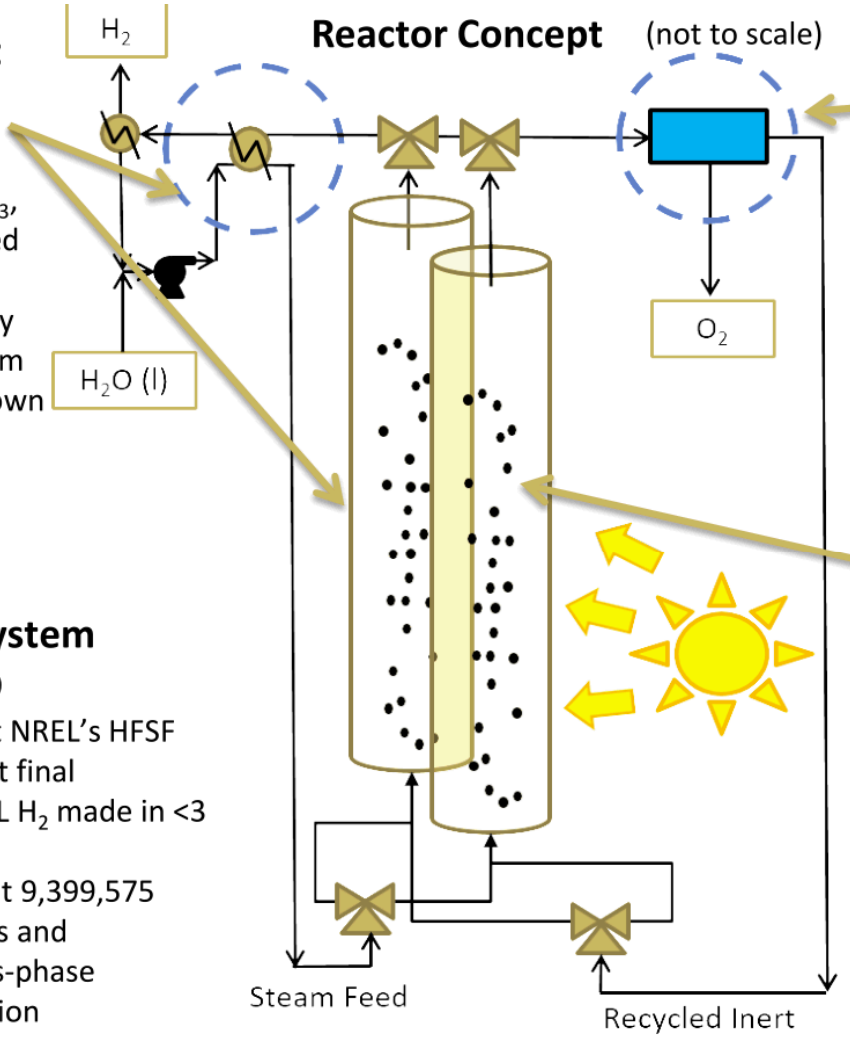
UC at Boulder: Multi-Cavity Reactor

Containment Materials R&D

- Synthesized Al_2O_3, mullite, BN coated SiC
- Improved stability (>60%) with 10 nm Al_2O_3 coating shown with TGA
- Test system for coated tubes constructed

Overall System R&D

- On-sun testing at NREL's HFSF on target to meet final deliverable; 1.91L H_2 made in <3 hours
- Issued U.S. Patent 9,399,575 (2016): "Methods and apparatus for gas-phase reduction/oxidation processing".



Multiple Fluid Beds in Solar Cavity (near-isothermal)

SEOS for Recycled Inert Gas R&D

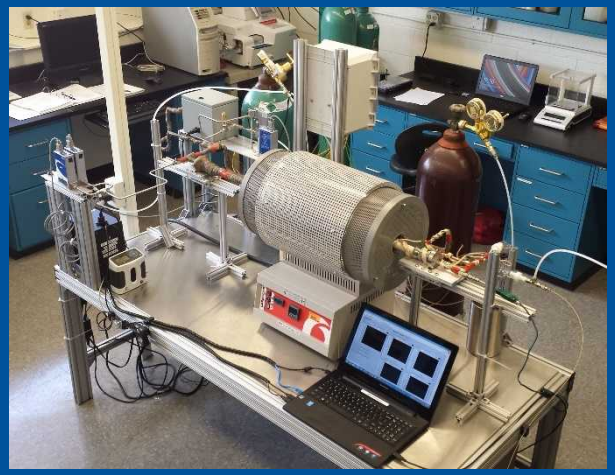
- Demonstrated 12% efficiency with electrically heated high-temperature O_2 transport membrane
- Investigating effect of O_2 concentration on reduction kinetics and productivity

Active Materials R&D

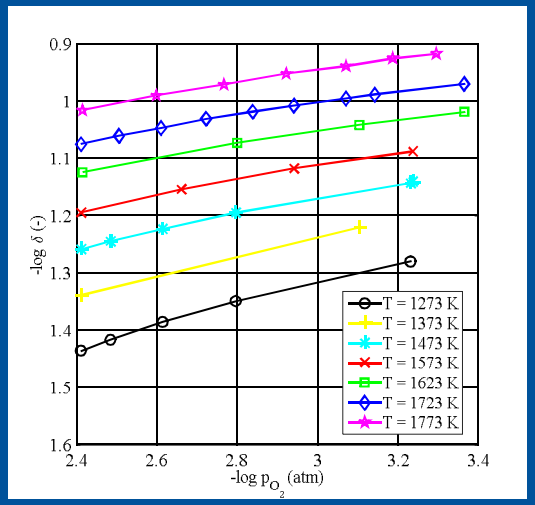
- Demonstrated no loss in reactivity from 100th to 200th redox cycle while generating ~ 300 µmol H_2/g active material

Credit: CU Boulder, Al Weimer group

U. of Florida: Thermodynamic and Kinetic Analysis of STF Materials



Development of a packed bed reactor for studying thermodynamics and kinetics of heterogeneous oxidation/decomposition reactions.



Measured nonstoichiometry versus oxygen partial pressure data for an exemplary perovskite, $Y_{0.8}Sr_{0.2}MnO_3$.

Credit: UFL, Scheffe group

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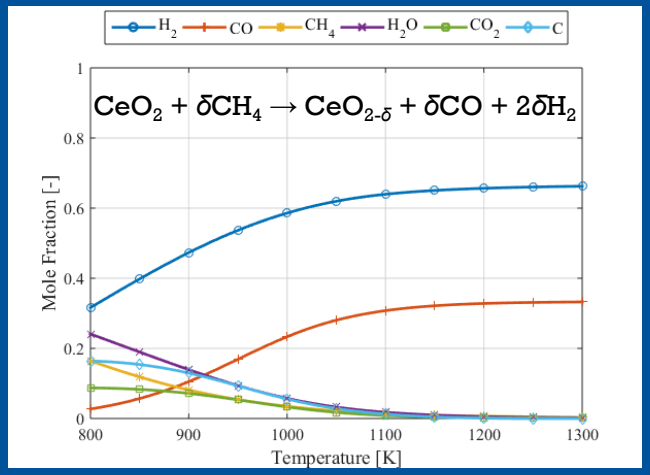
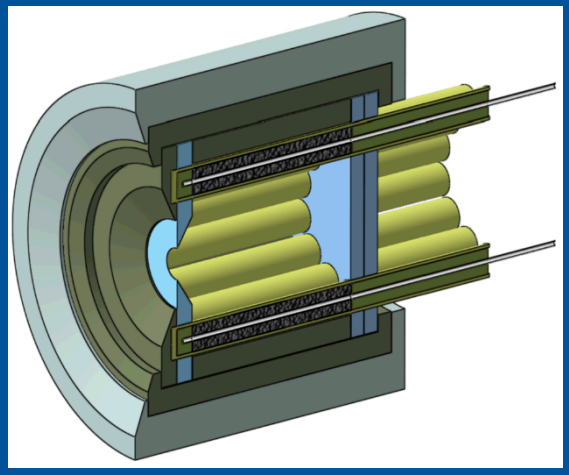
UFL: Investigation of Solar Methane Reforming via the Ceria Redox Cycle



Thermodynamic and kinetic assessment of the above reaction to determine favorable operating conditions



Exploratory experimental studies in a prototype solar reactor are underway. We aim to demonstrate solar to fuel conversion efficiencies > 20%

Credit: UFL, Scheffe group

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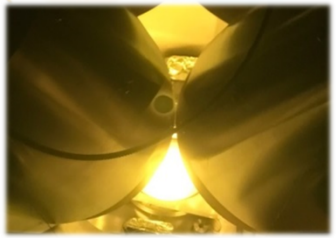
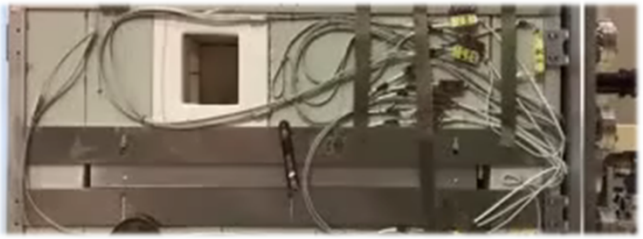
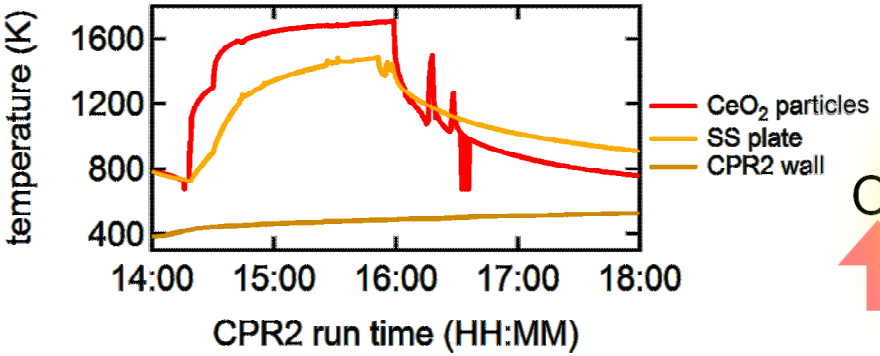
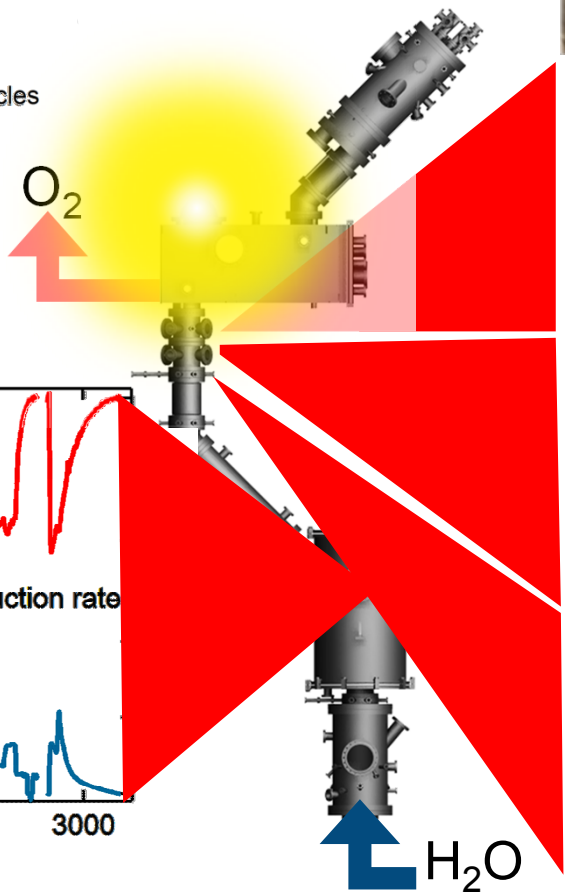
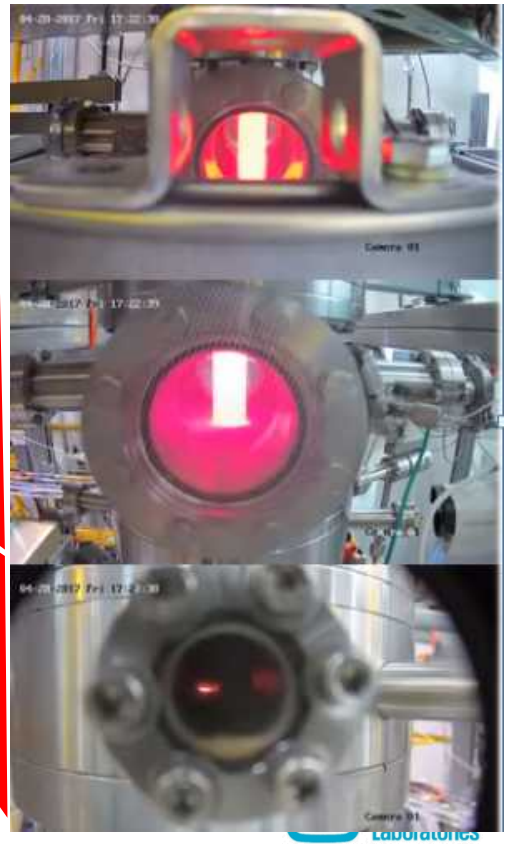
Cascading Pressure Reactor: Sandia, DLR, ASU, Bucknell, CS Mines









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