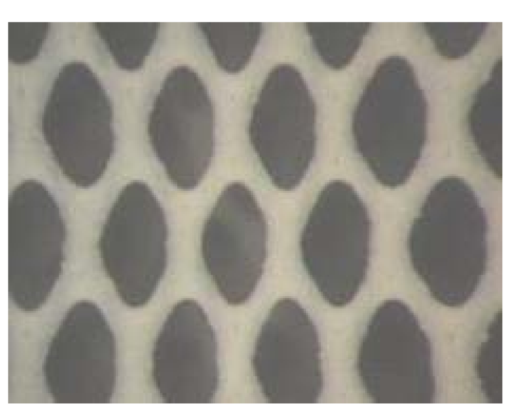
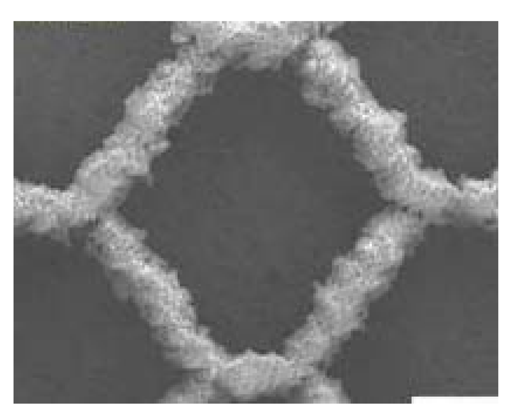
Solar Energy Powered Material-Based Conversion of CO_2 to Fuels

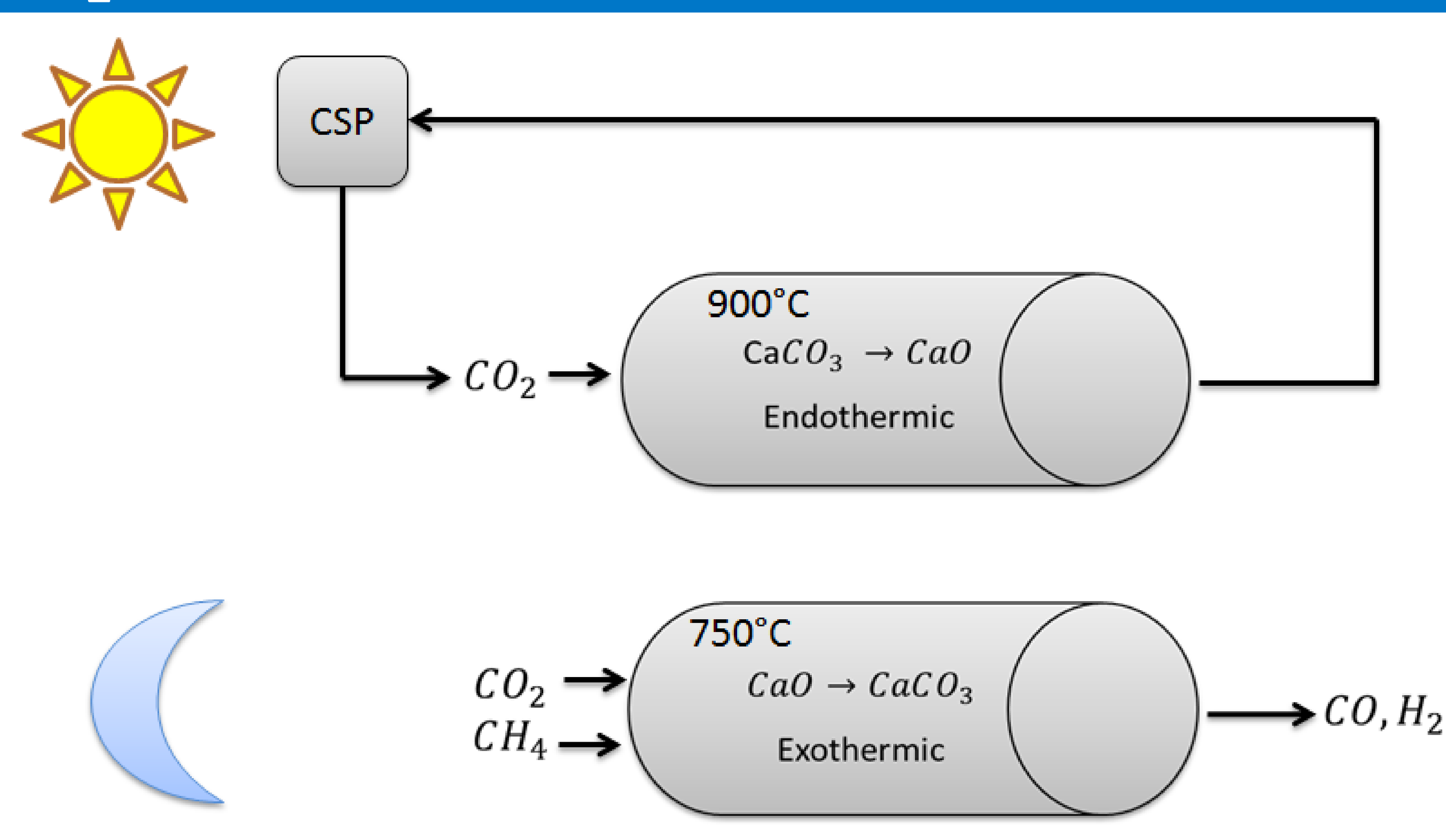
DE-SC0015855 PI: Jeffrey G. Weissman Supported by: NREL / Southern Company

PCI's Innovative Approach

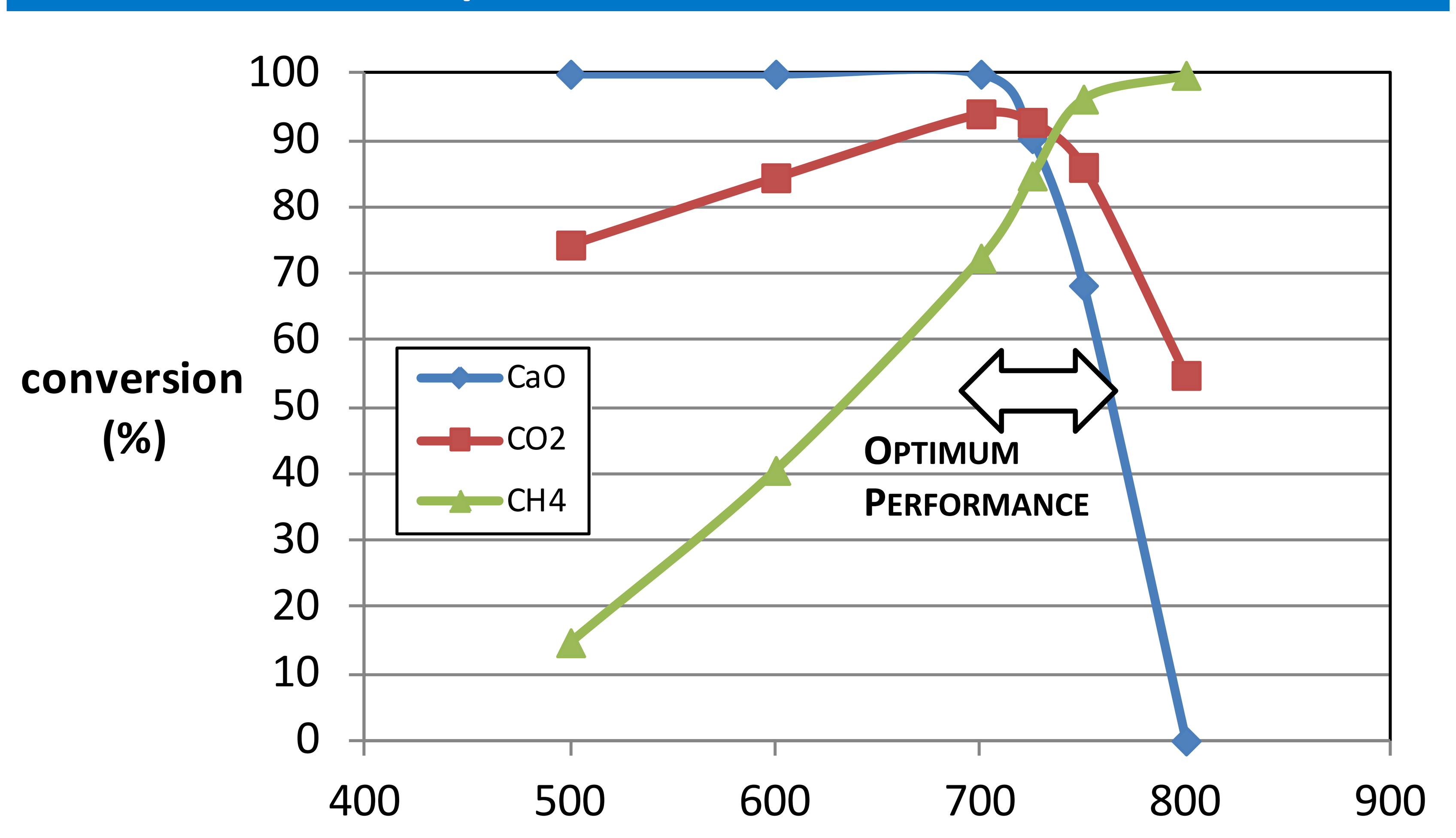
- Combines multi-step multi-vessel energy storage, release and CO_2/CH_4 conversion into a single reactor
- Uses unique *sorbothermal* catalyst optimized for
  - energy storage and release via $CaO + CO_2 – CaCO_3$ cycle
  - CO_2 'dry-reforming' with CH_4 to H_2 and CO
- Uses PCI's Microlith® substrate for enhanced heat and mass transfer via boundary layer disruption

Two Step Process in a Single Reactor for Conversion of CO_2 and Natural Gas into Syngas and Chemicals



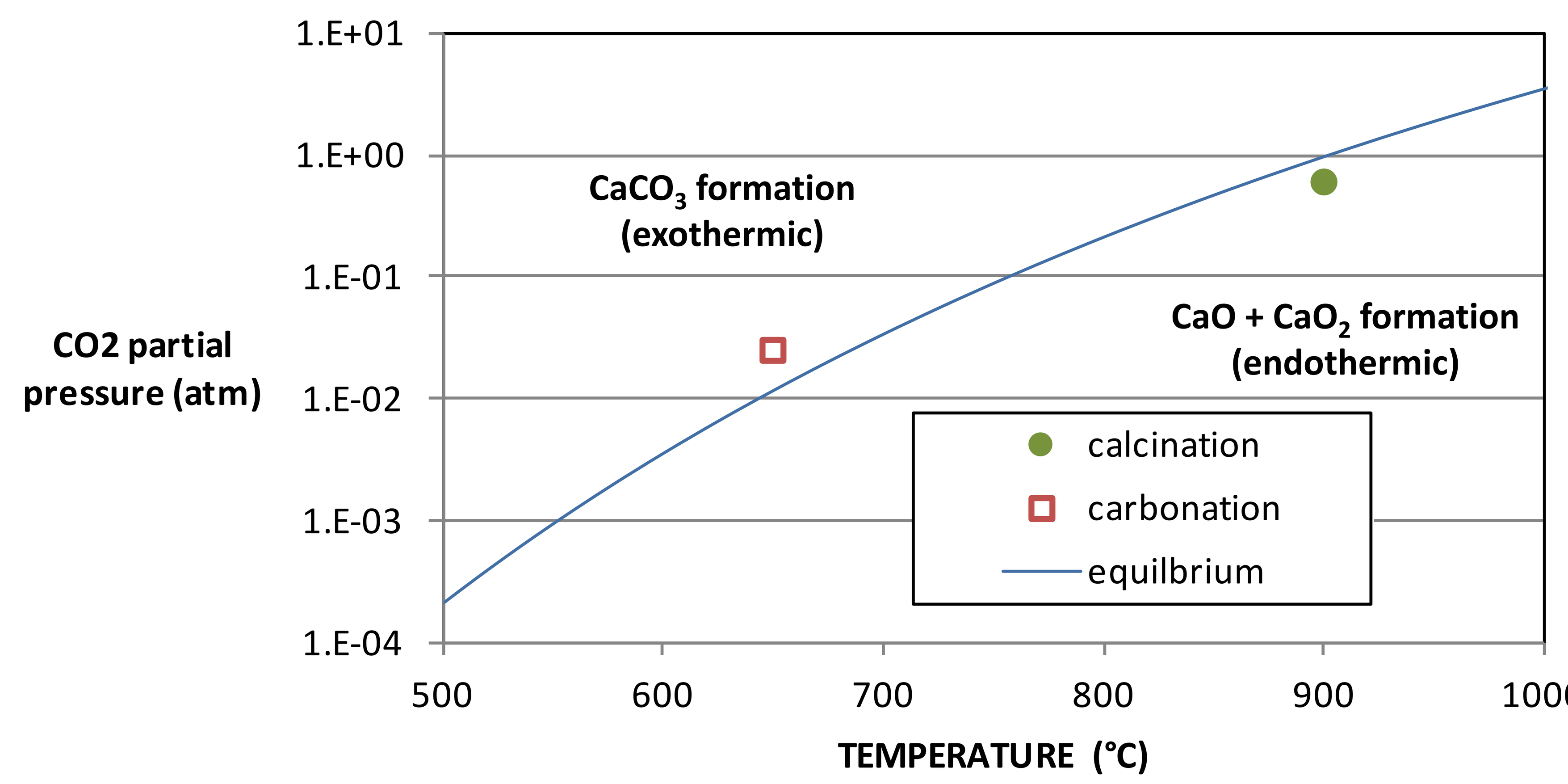
CaO, CO_2 and CH_4 Conversions for the Simultaneous Reaction of CO_2 with Gas-Phase CH_4 and Solid-Phase CaO



Based on Gibb-free energy minimization to calculate equilibrium for feed compositions of CO_2:CH_4 of 3:1 and CO_2:CaO of 3:2

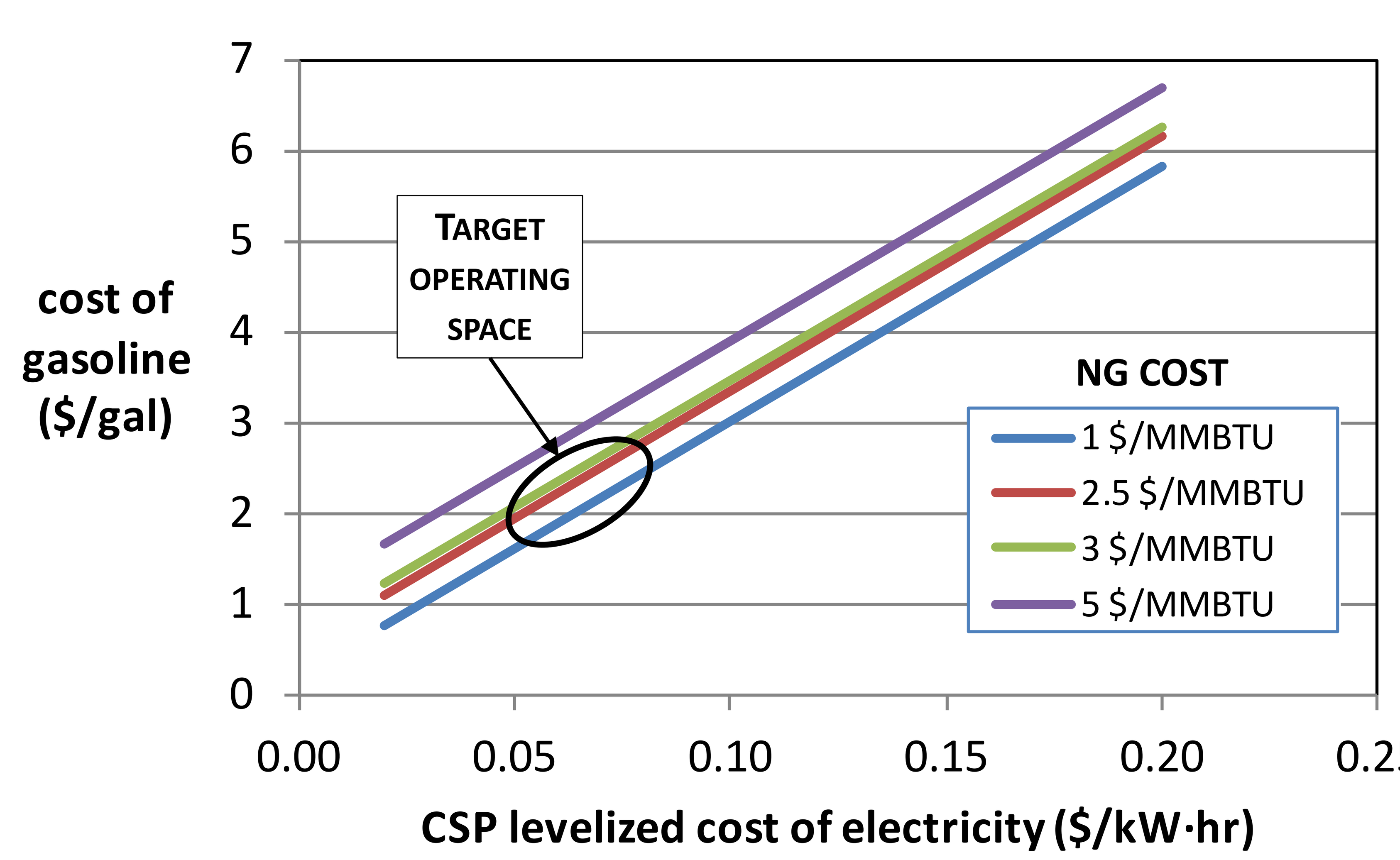
A Novel Materials Approach Combined with Solar Energy Collection, Storage, and Conversion Processes

- CaO-$CaCO_3$ equilibrium behavior



  - based on E. H. Baker, J. Chem. Soc., 87, 1962, 464.
- Concentrated Solar Power Collection and Storage via $CaO + CO_2 / CaCO_3$ cycle
  - for example: G. Wettermark, *Thermochemical Energy Storage, Proceeding of* NATO Advanced Study Institute on Energy Storage Systems, Cesme, Turkey, June 27- July 8, 1988; pp. 673-681.
- Thermodynamic driven conversion involving metal oxides coupled with syngas formation
  - *for example, Meier, Anton, and Aldo Steinfeld. "Solar Energy solar energy in Thermochemical Processing solar energy in thermochemical processing." Solar Energy. Springer New York, 2013. 521-552.*

Overall Process Economics for Gasoline Production vs. Natural Gas and CSP Costs



Levelized cost of concentrated solar power (CSP) electricity is currently 0.13 $/kw-hr, DOE target is 0.06. Assumes overall process efficiency of 75%

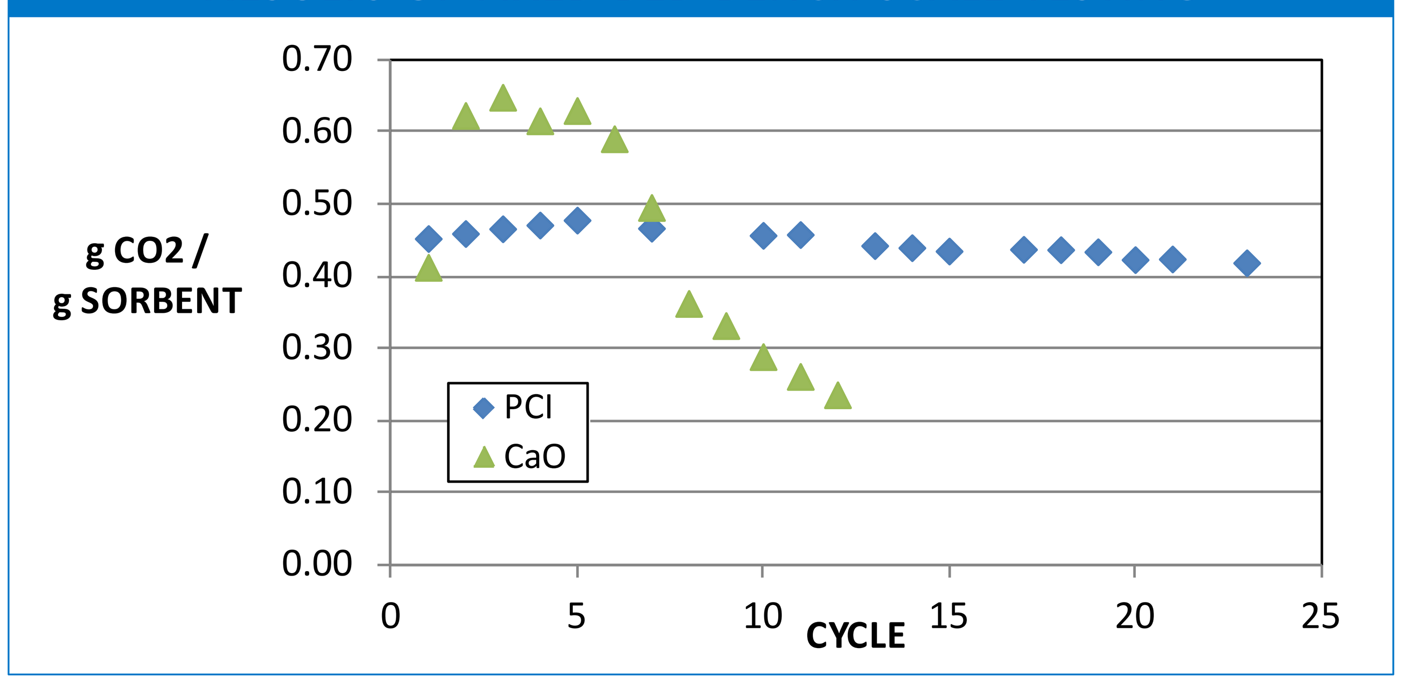
Precision Combustion, Inc., 410 Sackett Point Rd, North Haven, Connecticut 06437

STABLE REGENERABLE MATERIAL FOR HIGH TEMPERATURE CARBON DIOXIDE CAPTURE AND UTILIZATION

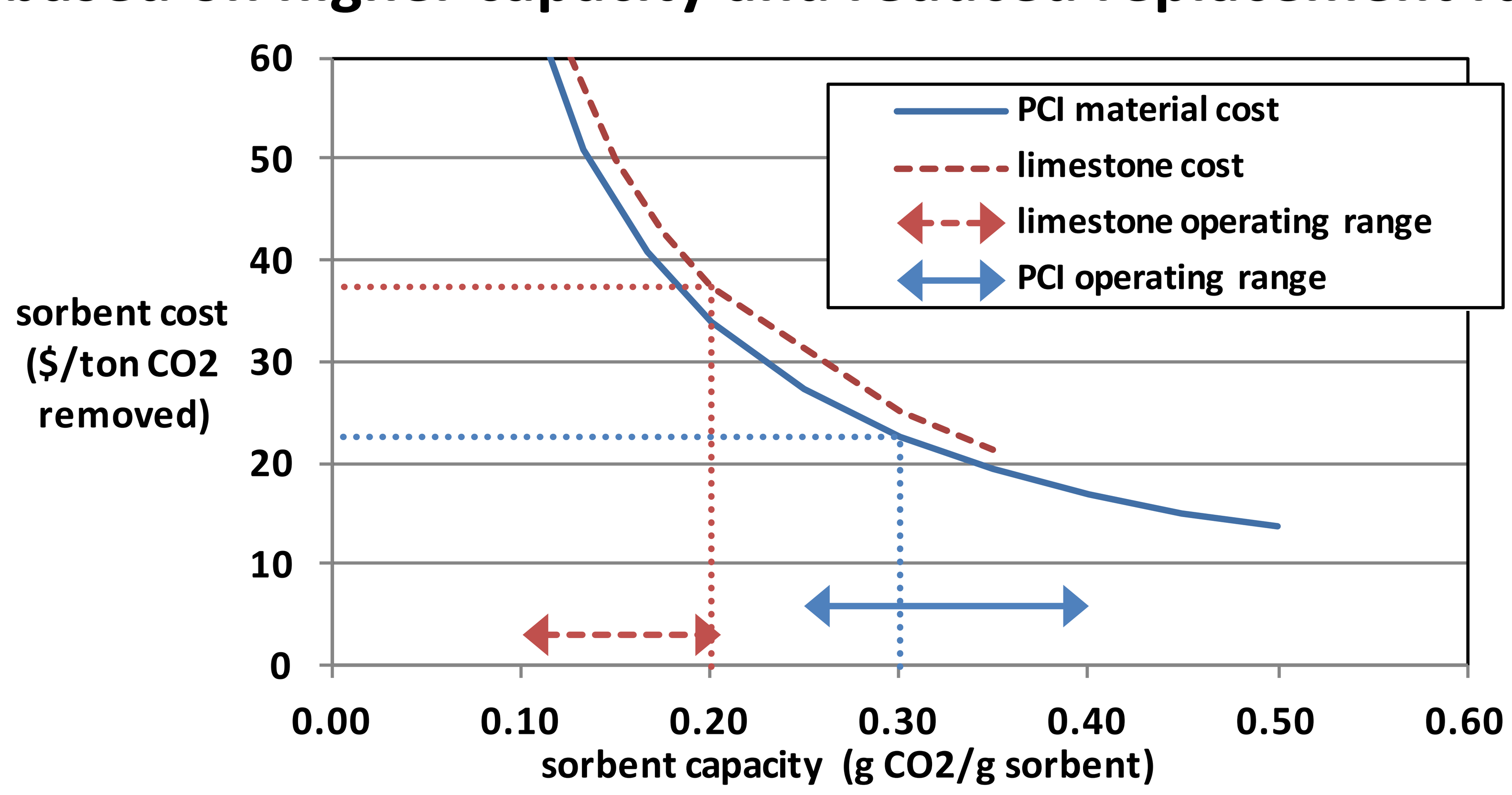
PCI'S NOVEL STABILIZED MATERIAL

- Developed for high temperature CO_2 processes
- CaO-based with stabilizers
- Tested for CO_2 sorption cycling
- Drop-in replacement for solid sorbents in fluidized beds

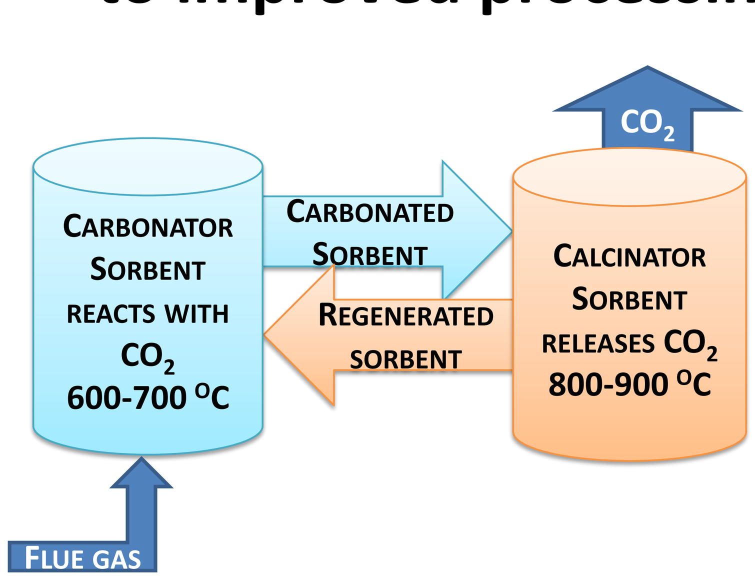
RESULTS OF FIXED BED BENCH SCALE TESTING



- Significant Cost Reduction Projected for Calcium Looping based on higher capacity and reduced replacement rates



- Applications include:
  - Fixed bed secondary capture
    - effective at CO_2 conc. < 1 %
  - Fluidized / Spouted / Ebullated Bed Primary Capture
    - effective over wide range of CO_2 conc.
    - based on sulfur-tolerant composition
    - Superior capture and durability will translate to improved processing economics

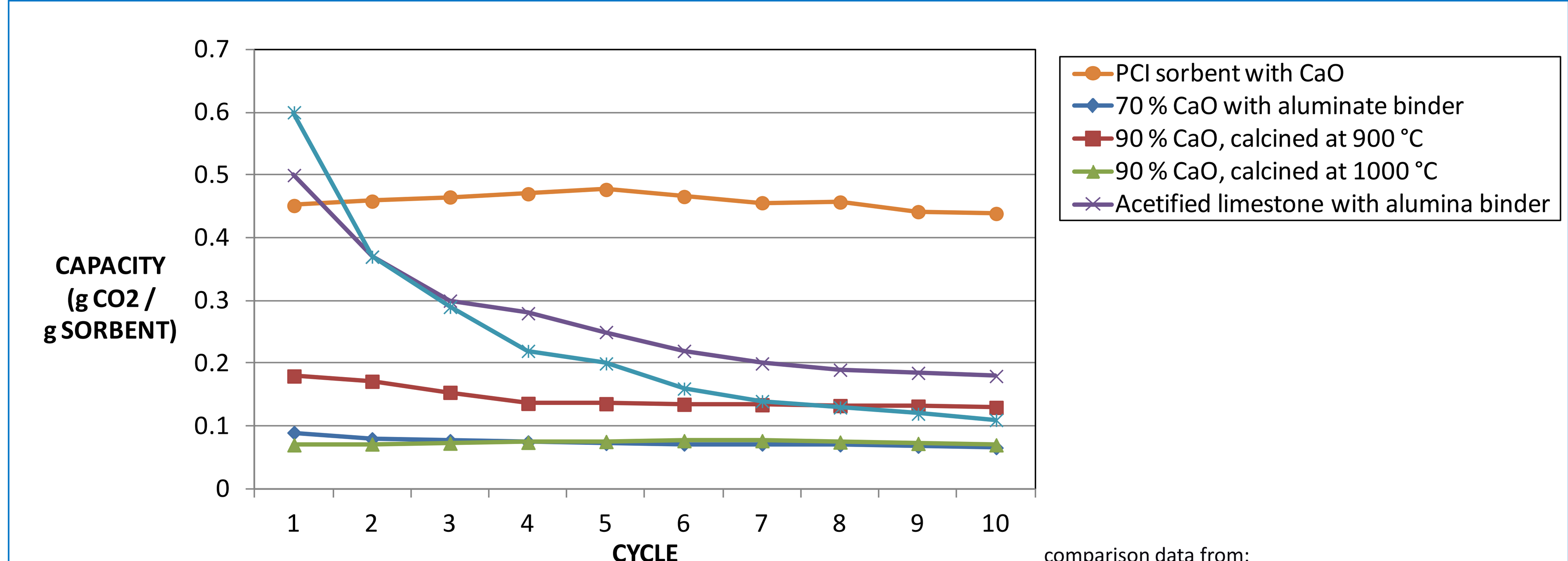


- Material proven highly effective in SUNSHOT program for Solar Thermal Energy Storage (DE-EE0006535)
  - Performing under subcontract to Southern Research (PI – Santosh Gangwal)

ADVANTAGES OVER LIMESTONE / STABILIZED CaO

- Resists Deactivation (other materials sinter)
- Stable for at least 50 cycles (others - either rapid loss or low capacity)
- Achieves 0.3-0.5 g CO_2 / g sorbent capacity (others < 0.2 g/g)

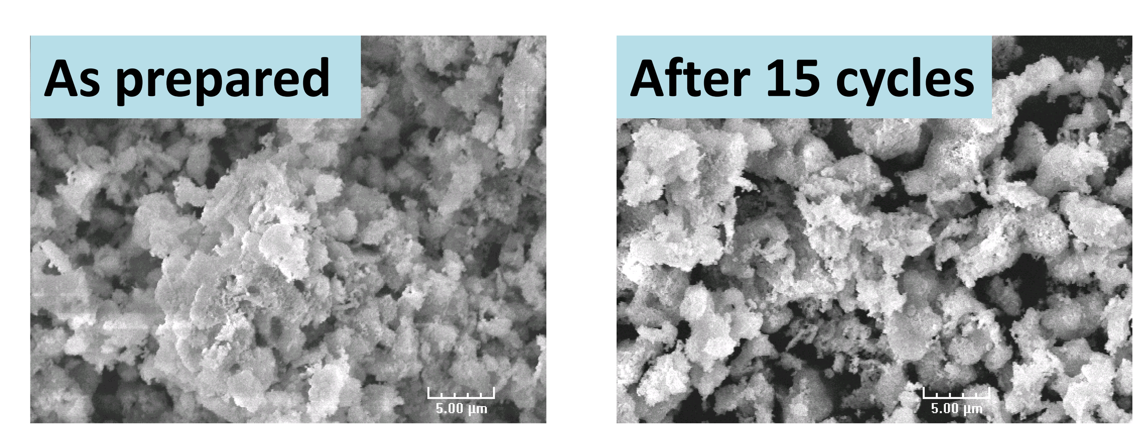
COMPARISON WITH STABILIZED SORBENTS



comparison data from:
- L. Vieille et al., Powder Technology, 228, 2012, 319.
- S. Wu, et al., Ind. Eng. Chem. Res., 49, 2010, 12269.

PCI test Cycle: Carbonation – 750 °C, 1 hour, 15% CO_2 in N_2; Calcining – 900 °C, 1 hour in N_2

- PCI material resists sintering
  - maintains particle size and surface area after 15+ thermal cycles



- Currently progressing to commercial scale production for SUNSHOT application

Precision Combustion, Inc. provides innovative reactors and systems for cleaner and more efficient use of fossil fuels.
We develop, manufacture, and market catalytic devices for clean and efficient combustion, emissions control, and chemical manufacturing.

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