PCI
Precision Combustion, Inc.

Solar Energy Powered Material-Based Conversion of CO_2 to Fuels

DE-SC0015855 SBIR Phase II   PI: Jeffrey G. Weissman

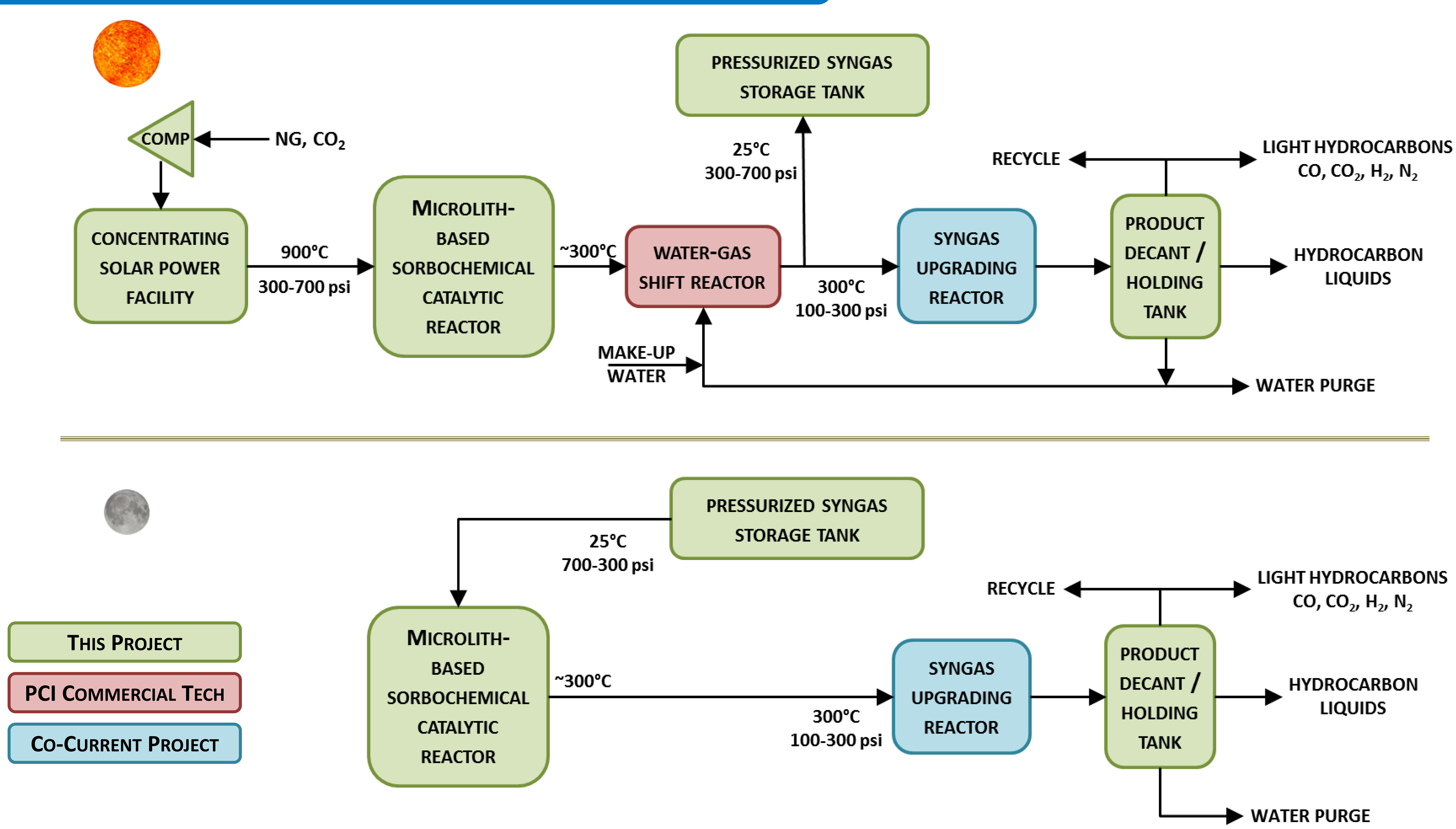
Project Goals

- Convert CO_2 to commercially viable fuels / chemicals
- Use CSP (Concentrating Solar Power) as high quality thermal energy to drive process
- Process scalable from MW to GW sizes and enables distributed deployment
- Enable continuous CO_2 upgrading in a transient solar energy input environment
- \$2.50 - \$3.00/GGE product value

PCI's Approach

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

Process Schematics For On- and Off-Sun Operating Modes



Technologies Being Optimized In This Phase II Project

- Energy storage / CO_2+CH_4 reforming materials
  - Uses $CaO+CO_2 \leftrightarrow CaCO_3$ 100% reversible reaction for chemical energy storage at 40-50% wt./wt. CO_2 capacities
  - Platinum-group metal catalysts for close to equilibrium conversion of CO_2+CH_4 to $CO+H_2$
- Reactor designs that minimize thermal gradients, enhance catalytic activity and limit carbon formation
- Optimization of process to match seasonal and diurnal variations in solar energy input
- Integration with Gen 2 or Gen 3 solar receivers

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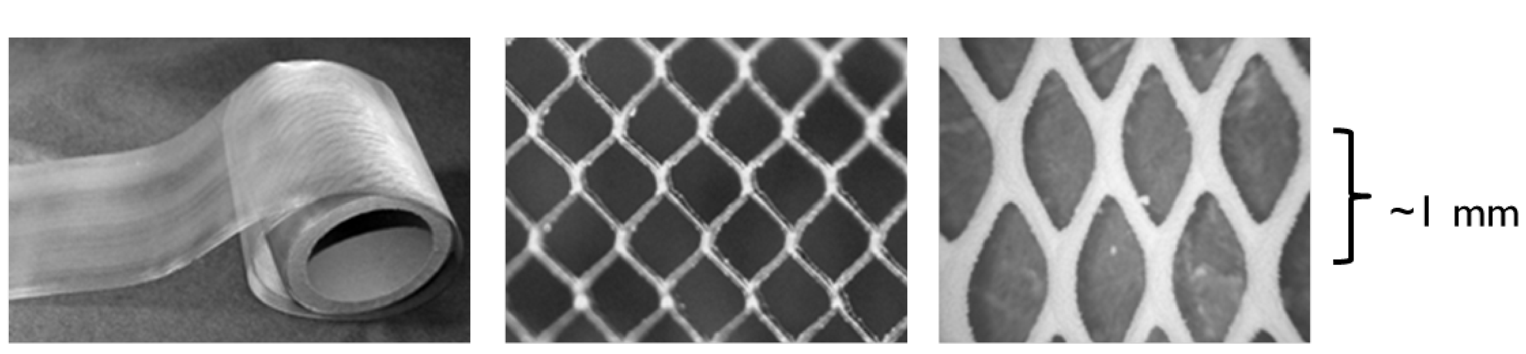
PCI's Portfolio of CO_2 Capture and Upgrading and Process Technologies

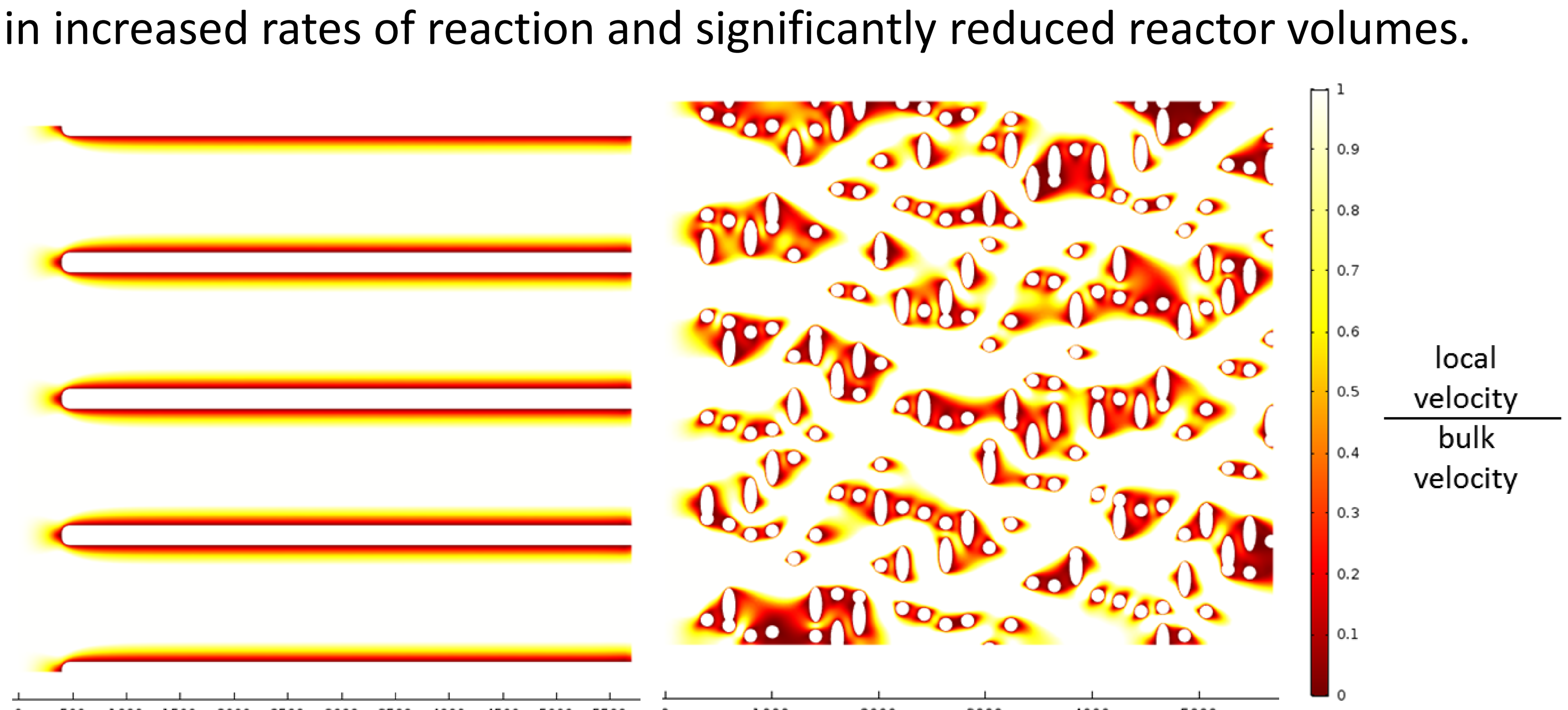
Carbon Capture and Storage *mildly exothermic / endothermic*	$CO_{2(g)} \leftrightarrow CO_{2(s)}$	**DOE SBIR Phase II – unique sorbent approach**
Carbon Dioxide Reforming *highly endothermic*	$CO_2 + CH_4 \rightarrow 2CO + 2H_2$	***this project***
Chemical Energy Storage *endothermic / exothermic*	$CO_{2(g)} + CaO_{(s)} \leftrightarrow CaCO_{3(s)}$	***this project***
Solid Oxide Electrolytic Cells *highly endothermic*	$CO_2 \rightarrow CO + ½O_2$ $H_2O \rightarrow H_2 + ½O_2$	**NASA SBIR Phase II, additional projects – thermally stable cell design**
Water-Gas Shift *mildly exothermic*	$CO + H_2O \leftrightarrow CO_2 + H_2$	**prior SBIR support - Microlith® substrate enhanced reactor technology**
CO, CO2, H2 upgrading *highly exothermic*	$xH_2 + yCO + zCO_2 \rightarrow C_nH_{2n+2} + C_mH_{2m}$	**DOE SBIR Phase I – novel highly compact reactor approach**

ADVANTAGES of Microlith® Substrates

- **Enables 5-10x process intensification with corresponding reduction in reactor volume**
- **Greatly reduces boundary layer formation, with reduced pressure drop for similarly performing reactors**
- **Enables pseudo-turbulent mixing in laminar flow regimes**
- **Enhances heterogeneous catalytic activity for highly endothermic or exothermic reactions**

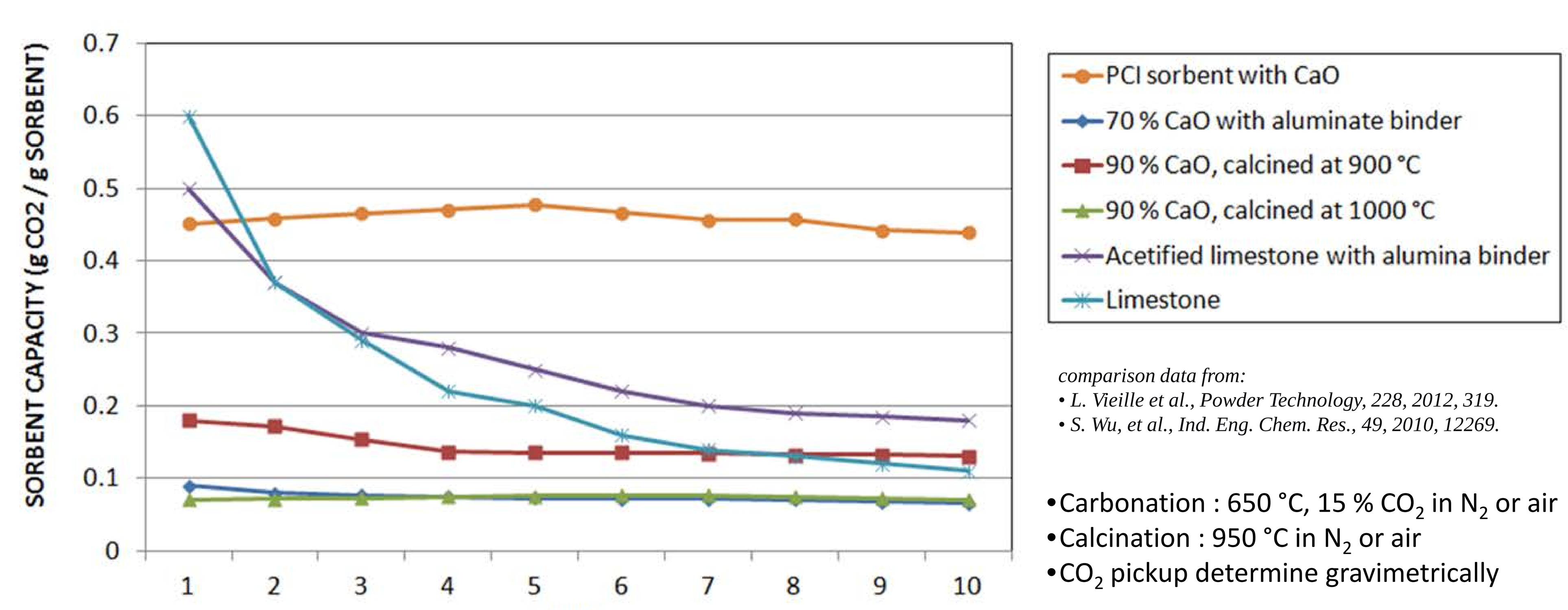


Laminar flow Boundary Layer formation in Honeycomb monolith (*left*) and Microlith® substrates. BL defined as less than 99% of bulk flow. Microlith exhibits discontinuous boundary layer - enhances mixing, reduces bulk to surface transport rates, and enhances convective transfer rates, resulting in increased rates of reaction and significantly reduced reactor volumes.

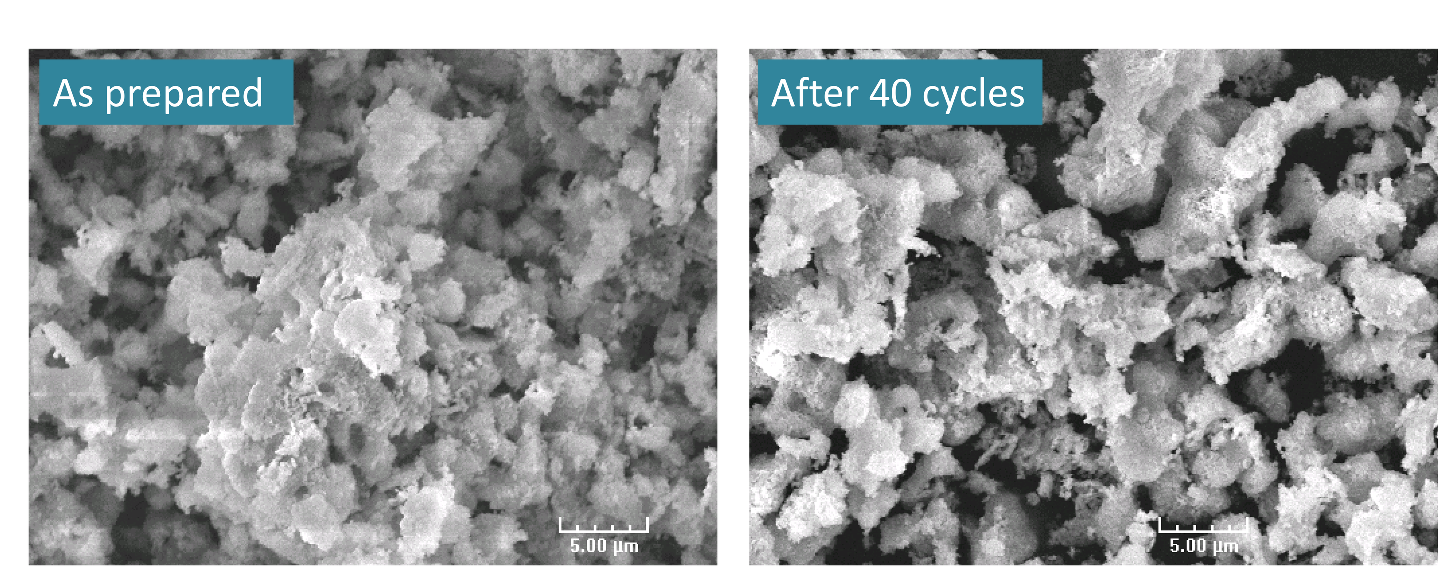


PCI's Energy Storage / Carbon Capture Material

- **Modified $CaCO_3$; commercially manufacturable**
- **For high temperature (>700 °C) applications**
- **Capture efficiency stable for 100's cycles**
- **Near 100% capture from 0.04-100% inlet CO_2 conc.**



- Carbonation : 650 °C, 15 % CO_2 in N_2 or air
- Calcination : 950 °C in N_2 or air
- CO_2 pickup determine gravimetrically



Precision Combustion, Inc. provides reactors and systems for more efficient use of fossil fuels, sorbent systems, fuel cells, clean and efficient combustion, emissions control, and chemical manufacturing.

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