# $CO_2$ Upgrading Utilizing Solar Cavity Reactor Receiver

## Solar Energy-Powered Material-Based Conversion of CO2 to Fuels


**Jeffrey Weissman and Codruta Loebick (PCI)**
**National Renewable Energy Laboratory (subcontract)**


**DE-SC0015855 (6/2016 - 8/2019) – Program Manager : Andy O'Palko**

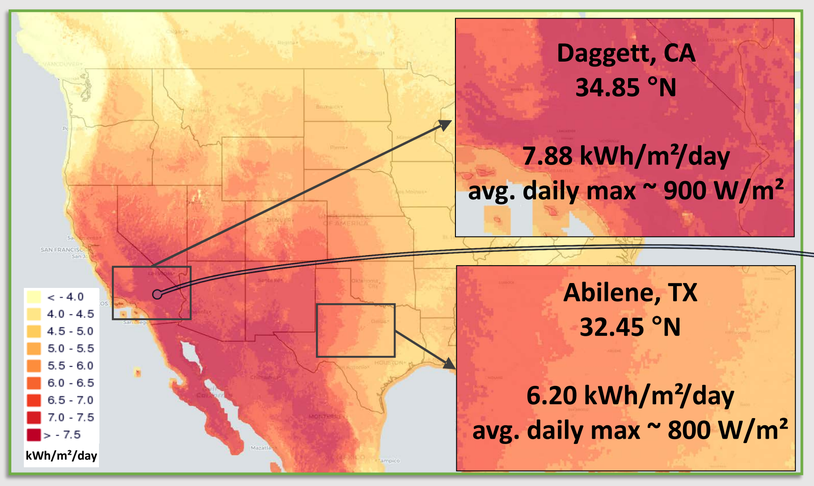

## Project Overview

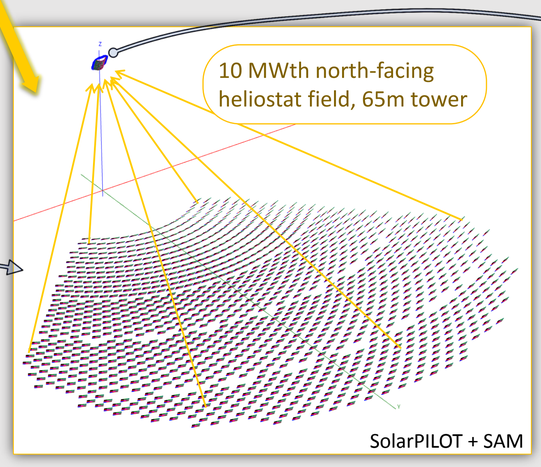
- Use Concentrating Solar Power (CSP) high thermal flux to drive process with unique Solar Cavity Reactor Receiver (SCRR)
- **SCRR is a new concept for using CSP to facilitate heterogeneous catalytic reactions at high product yields and efficiencies - based on catalytically coated Microlith® substrate technology**
- **Enables continuous $CO_2$ upgrading in a transient solar energy input environment**
- Converts $CO_2$ to commercially viable fuels / chemicals based on advantages of PCI's reactor platform and catalyst and materials technologies
- Natural / Shale gas is the hydrogen source; $CO_2$ from carbon capture, pipeline, etc.
- Process is scalable from MW to GW sizes and enables distributed deployment
- ~$3.00/gallon gasoline equivalent product value is achievable

## PCI's Approach to $CO_2$ Upgrading

- Combines diurnal CSP and nocturnal chemical energy storage into a tightly integrated process
- High efficiency CSP energy utilization enabled by PCI's Microlith® substrate which enhances heat and mass transfer via boundary layer disruption and improved thermal conductivity and mass and heat convection
- Reactor designs that minimize thermal gradients, enhance catalytic activity and limit carbon formation
- Process optimized to match seasonal and diurnal variations in solar energy
- Integration with Gen 2 or Gen 3 solar receivers – dish, cone or tower placements

## System Specifications and Parameters



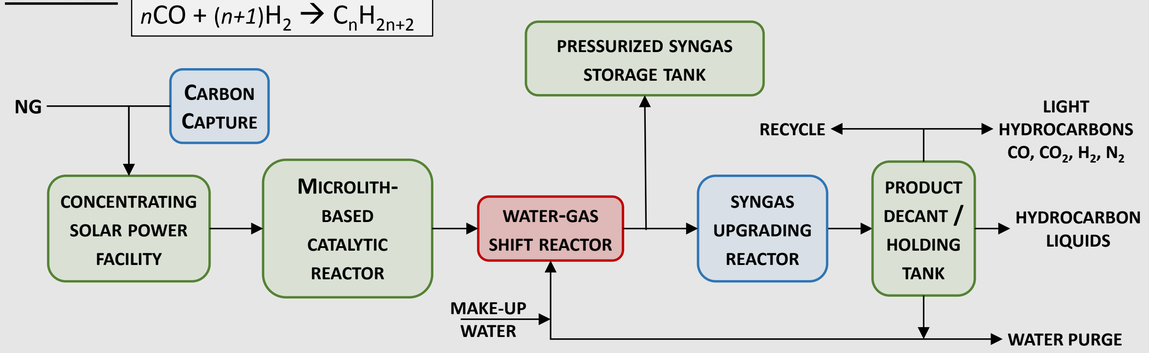

| Solar Field Element | Daggett, CA | Abilene, TX |
|---|---|---|
| Elevation | 641 m | 522 m |
| Average temperature | 17.4°C | 17.9°C |
| Average wind speed | 2.3 m/s | 3.4 m/s |
| Heliostat count (facets) | 1,310 (11,790) | 1501 (13509) |
| Heliostat area | 12,973 $m^2$ | 14,865 $m^2$ |
| Solar field optical efficiency | 72.2% | n/d |

| Solar Field Element | Assumption | Notes |
|---|---|---|
| Receiver specification | Planar-cavity | Adapted from novel near-blackbody design |
| Aperture height | 4.0 m | External cylindrical (NREL) |
| Aperture diameter | 7.0 m | 25x2.6° cavities, cutoff at ± ~32.5° |
| Heliostat specification | Multi-faceted | Comprised of 9 facets (3x3) |
| Facet height | 0.825 m | based on eSolar ST3 |
| Facet width | 1.375 m | based on eSolar ST3 |
| Heliostat cost | $75 /$m^2$ | 2020 SunShot |

## Process Schematics For On- and Off-Sun Modes

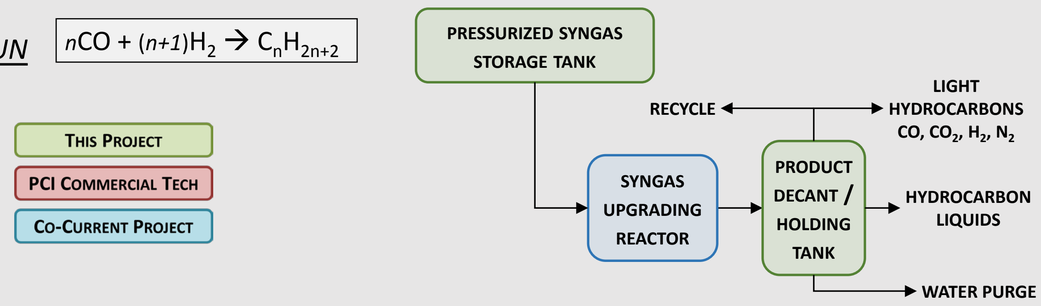
*On-Sun*

$CO_2 + CH_4 \rightarrow 2CO + 2H_2$
$nCO + (n+1)H_2 \rightarrow C_nH_{2n+2}$



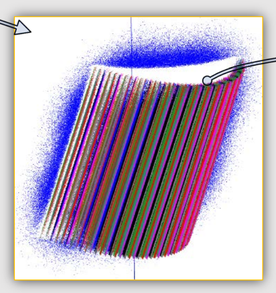

*Off-Sun*

$nCO + (n+1)H_2 \rightarrow C_nH_{2n+2}$

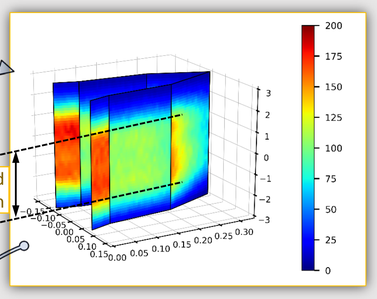



## Modeling Tools Employed

- SolarPILOT (NREL) : field layout and efficiency
- System Advisor Model (NREL) : evaluate and refine field sizing and performance
- SolTRACE (NREL) : determine heat flux on receiver exterior surface
- FLUENT : temperature, flow and concentration profiles in SCRR
- CHEMCAD : process modeling

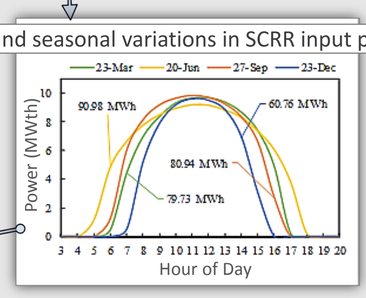


SolTRACE optimized SCRR external form and receiver and heliostat aiming



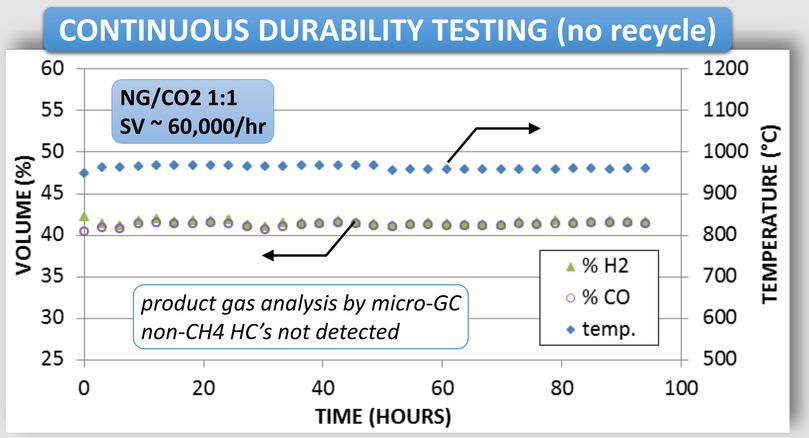

FLUENT modeling of thermal behavior using SolTRACE input, optimizing receiver vertical and horizontal dimensions

Daily and seasonal variations in SCRR input power

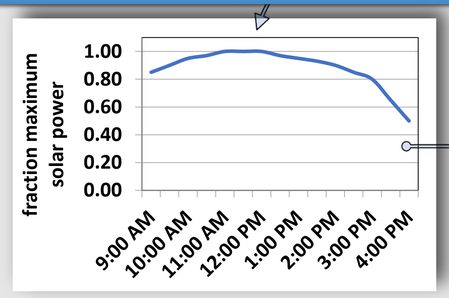



## SCRR Laboratory Performance Evaluation

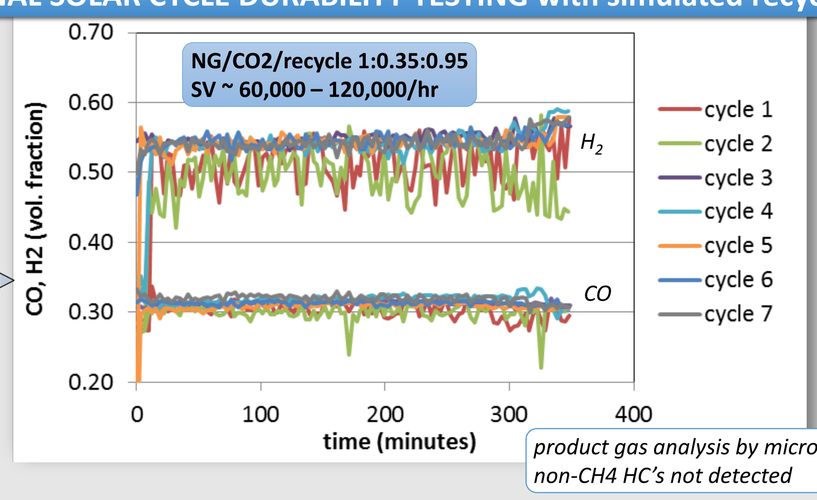
### CONTINUOUS DURABILITY TESTING (no recycle)




### Simulated diurnal cycle used in testing

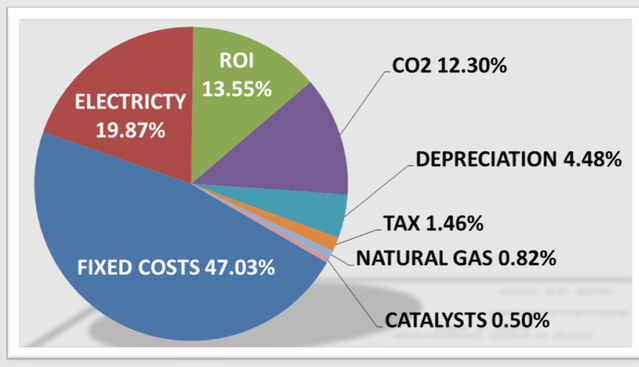


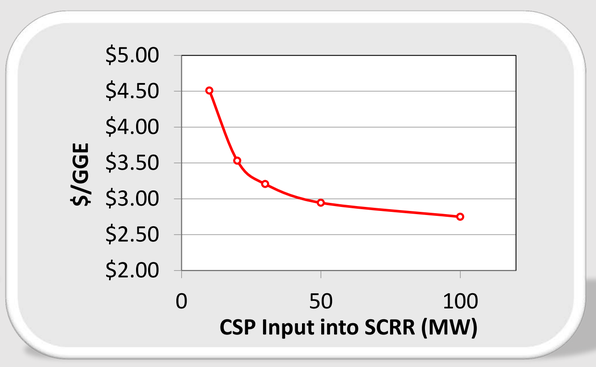

### DIURNAL SOLAR CYCLE DURABILITY TESTING with simulated recycle




## Techno-Economic Analysis

- Based on NREL detailed costing model and assumptions
- Determines producer cost after profit of gallon gasoline equivalent based on fuel LHV
- CO2 costs include carbon capture, cleaning, etc.
- Fixed costs are major contributor to overall $/GGE
- 50 MW thermal input plant size required to meet DOE goals





**Precision Combustion, Inc., 410 Sackett Point Rd, North Haven, Connecticut 06473**
**www.precision-combustion.com**





**For more information contact:**
**Anthony Anderson**
**203.287.3700 x290**
**aanderson@precisiom-combustion.com**

**Technical contact:**
**Jeffrey Weissman**
**203.287.3700 x255**
**jweissman@precisiom-combustion.com**