BENCH-SCALE PROCESS FOR LOW-COST CARBON DIOXIDE (CO_2) CAPTURE USING A PHASE-CHANGING ABSORBENT

DE-FE0013687

GE Global Research

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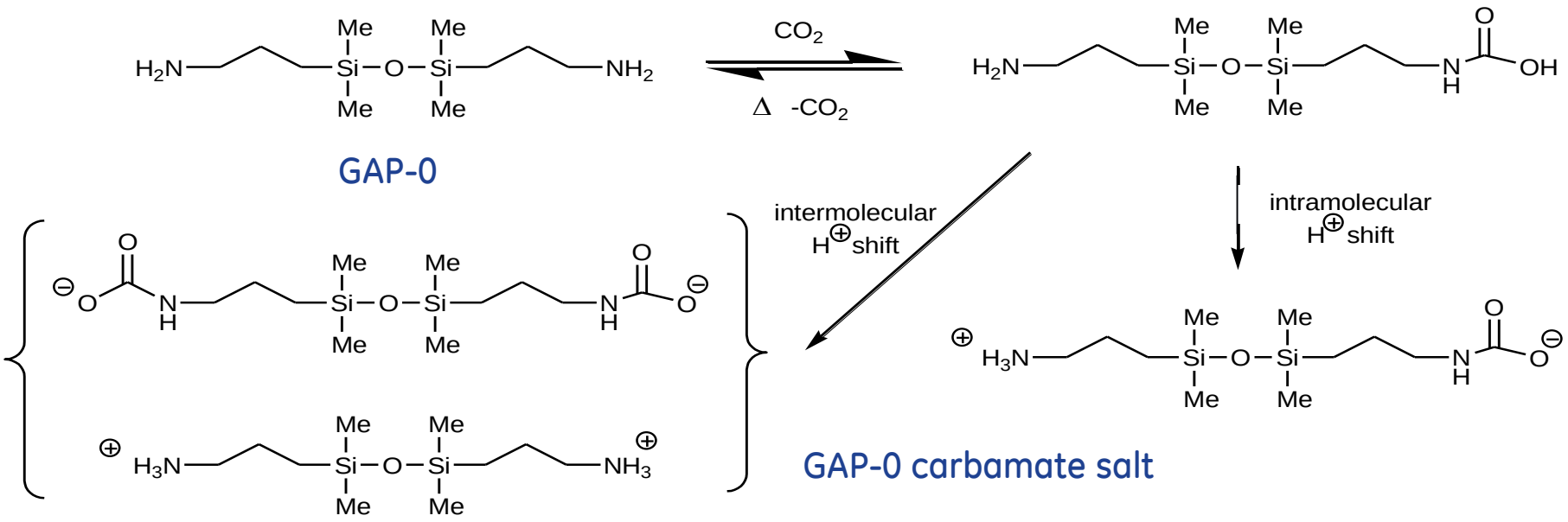
2016 NETL CO_2 Capture Technology Project Review Meeting
August 10, 2016

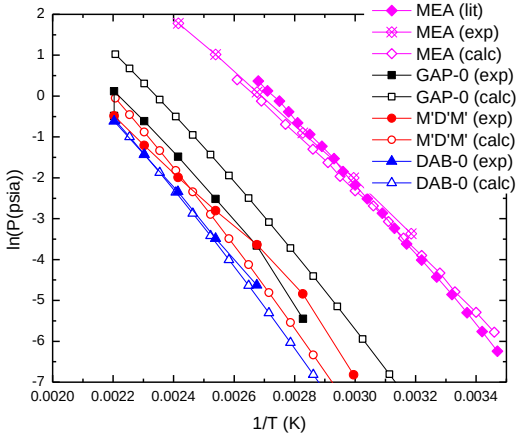
Chemistry of GAP-0 reaction with CO_2

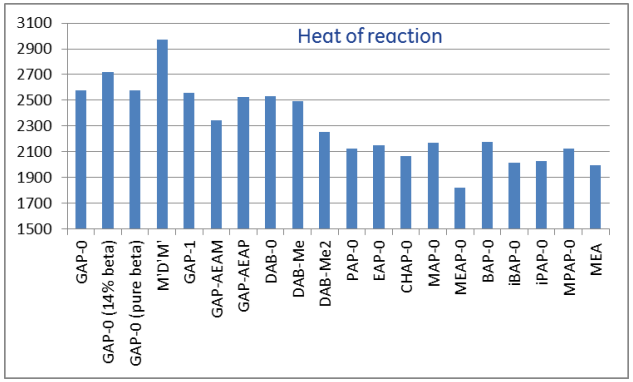


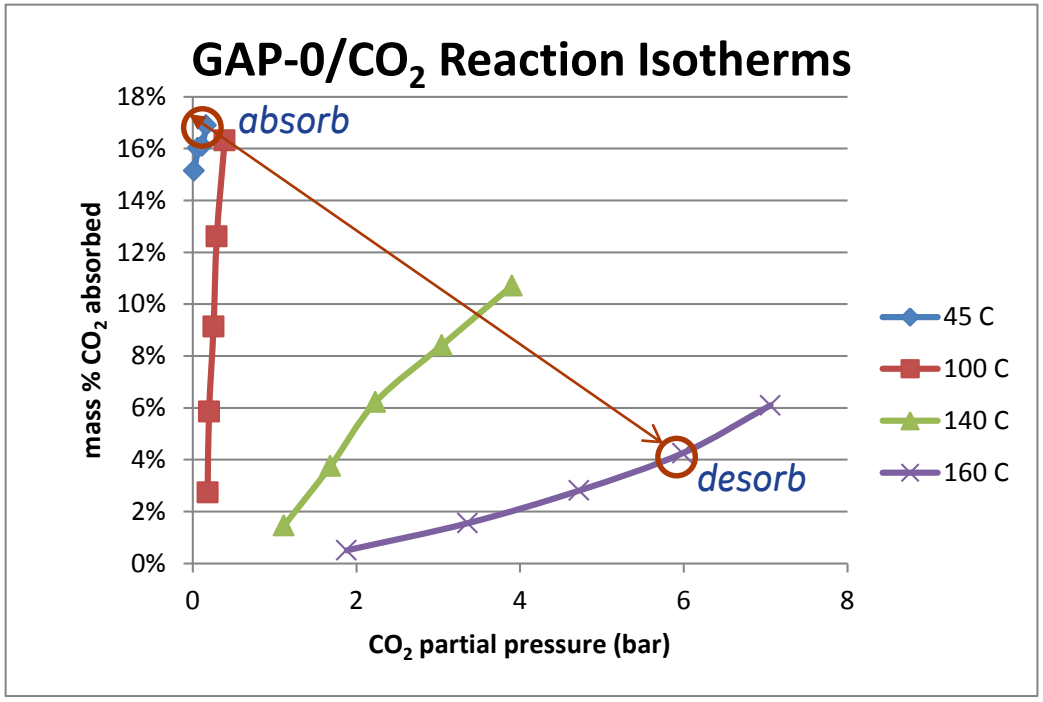
- Extensive screening of multiple solvents
- Absorbs CO_2 very rapidly in the 40-50°C range
- High CO_2 loading (>17% weight gain, >95% of theoretical value)
- Carbamate readily decarboxylates at higher temps
- Carbamate is solid → new process configuration

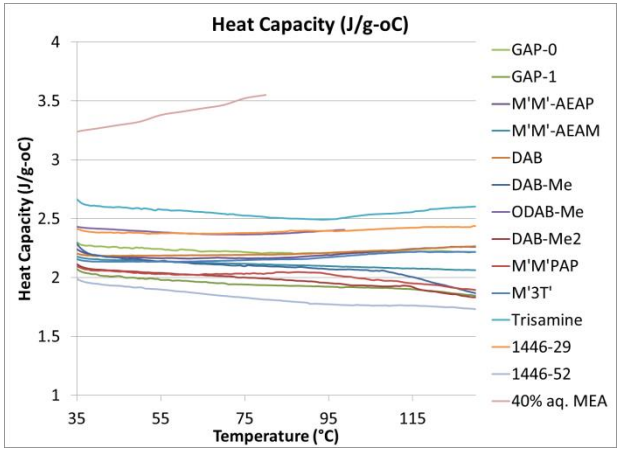
GAP-0 Properties

- Lower vapor pressure vs. MEA
- Higher heat of reaction vs. MEA
- Lower heat capacity vs. MEA
- >11% Dynamic CO_2 capacity @ 6 bara

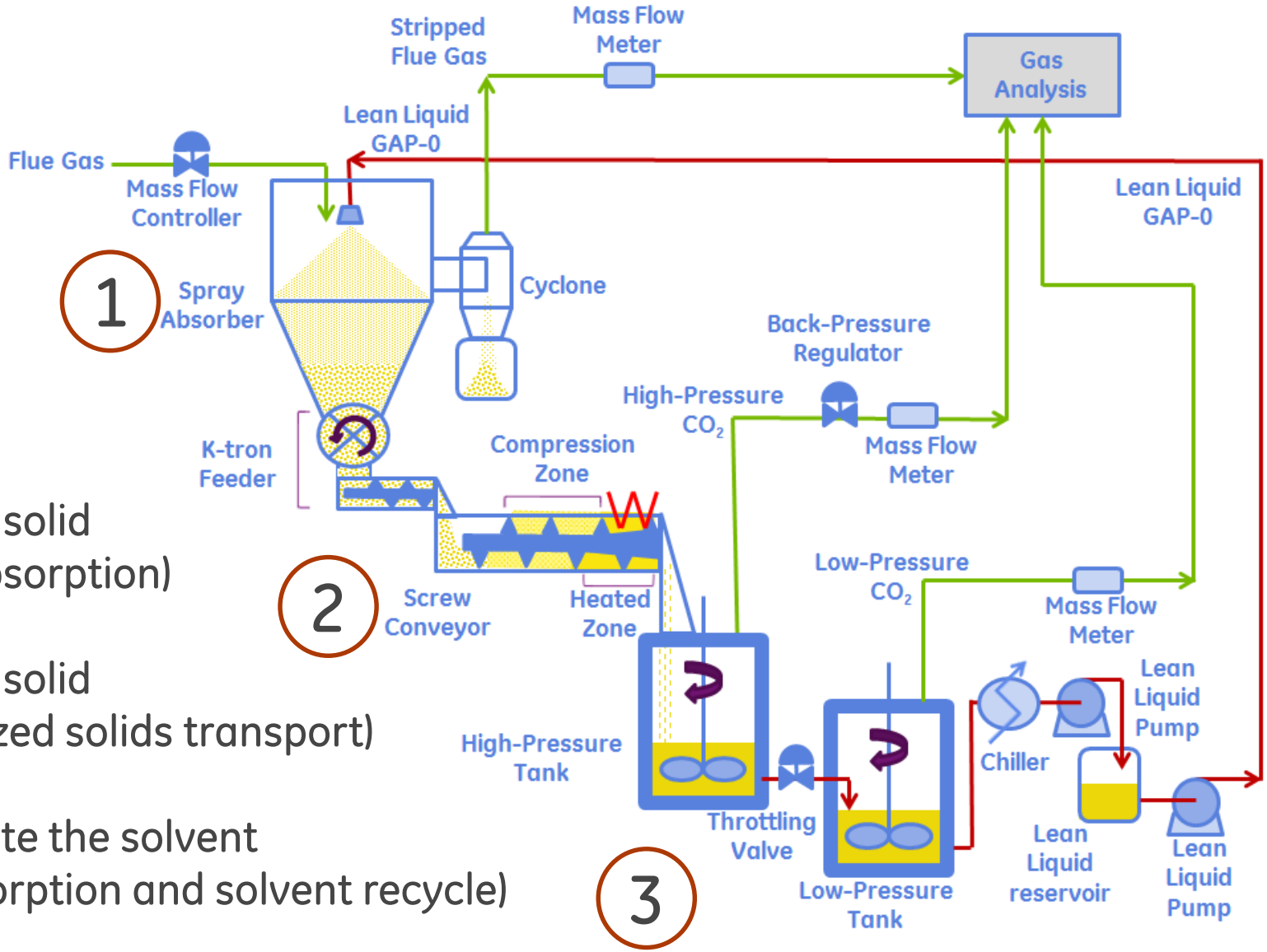








Phase-Changing CO_2 Capture System



1 Make the solid
(Spray absorption)

2 Move the solid
(Pressurized solids transport)

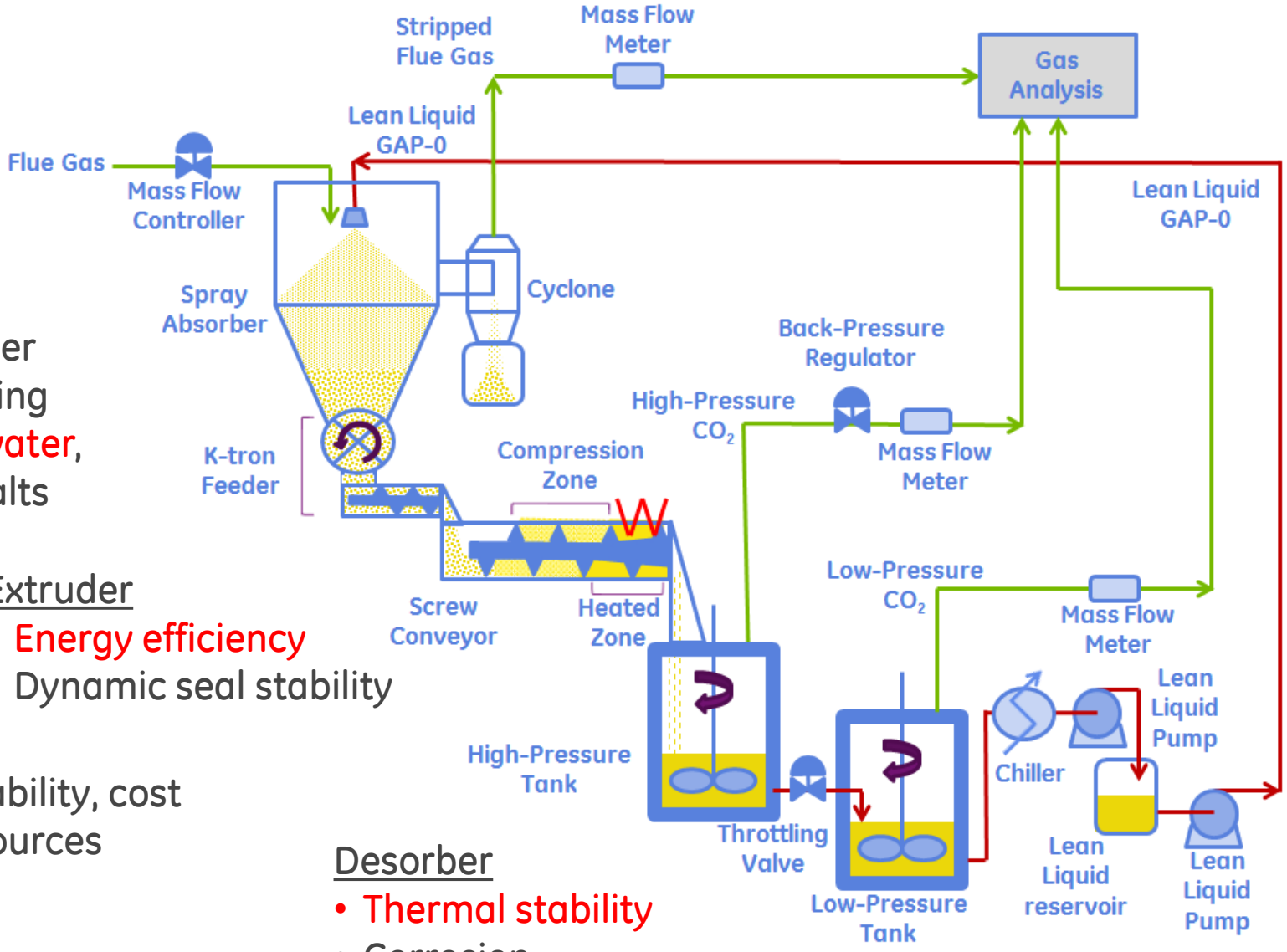
3 Regenerate the solvent
(CO_2 desorption and solvent recycle)

Project Structure

- ✓ Budget Period 1: Design and Build [2014]
  - ✓ Spray absorber, extruder, desorber
  - ✓ Preliminary Technical and Economic Assessment
  - ✓ Go/No-go: 90% CO_2 Capture, <$50/tonne CO_2
- ✓ Budget Period 2: Unit Operations Testing [2015]
  - ✓ Optimize individual unit operations separately
  - ✓ Solvent manufacturability study and EH&S risk assessment
  - ✓ Update Technical and Economic Assessment
  - ✓ Go/No-go: 90% CO_2 Capture, <$45/tonne CO_2
- ➢ Budget Period 3: Continuous System Operation [2016]
  - ➢ Integrate unit ops into continuous system, generate engineering data for scaleup
  - ➢ Final Technical and Economic Assessment
  - ➢ Goal: 90% CO_2 Capture, <$40/tonne CO_2

3-year, $3M Project
$2.4M DOE share
1/1/2014 – 12/31/2016

Risk Assessment



<u>Absorber</u>
- Heat management
- GAP-0 β-isomer
- Atomizer fouling
- Presence of water, heat stable salts

<u>Extruder</u>
- Energy efficiency
- Dynamic seal stability

<u>Project</u>
- Solvent availability, cost
- Expertise resources

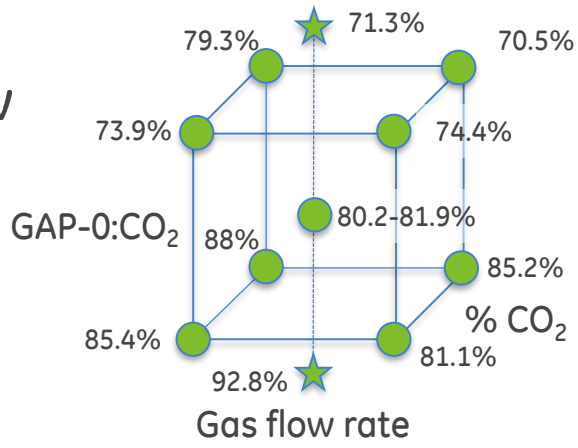
<u>Desorber</u>
- Thermal stability
- Corrosion

Absorber experiments – dry flue gas

- Designed experiment:
  - 2-16% CO_2, 150-200slm
  - 0.9 - 0.6 mol GAP-0:mol CO_2
    - 30-220mL/min GAP-0

➢Solids produced at all conditions

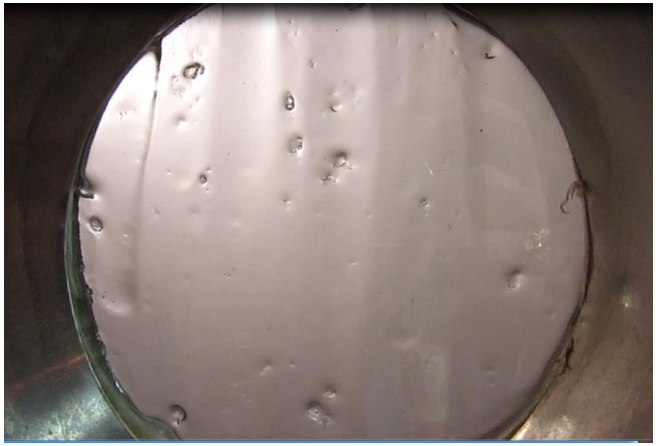
- Statistics support linear model
  - Significant terms: GAP-0 : CO_2 ratio, Gas flow
  - For maximum conversion:
    - lower gas flow (longer residence time)
    - lower GAP-0 : CO_2 ratio (more excess CO_2)



Absorber experiments – humid flue gas

Dry – powder clings to dry windows

5vol% – solids impact wet windows



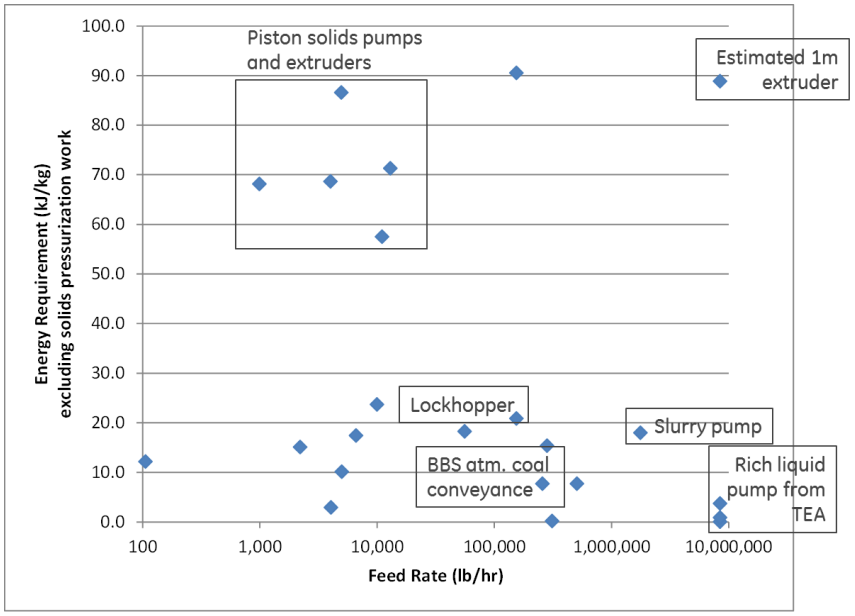
6.5vol% – wet droplets impact wet windows

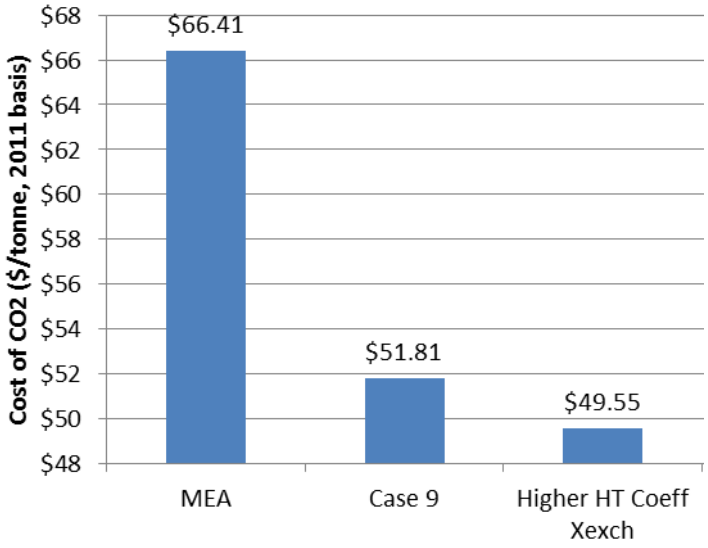
Dry – "cake flour"

6.5vol% - "hair gel" (videos MVI_0155, MVI_0162)

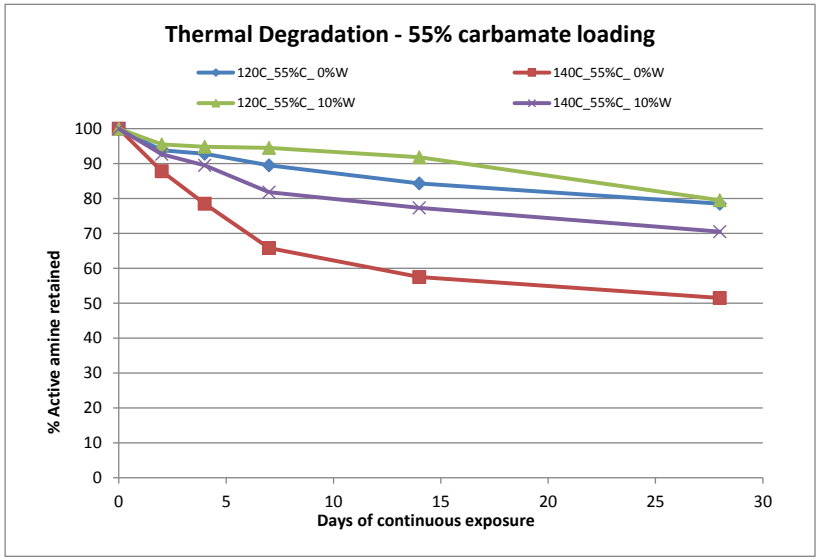
Mass balance: 1-3wt% water in rich phase
Expect higher water content at lower feed % CO_2

CO_2-rich Slurry is an opportunity…

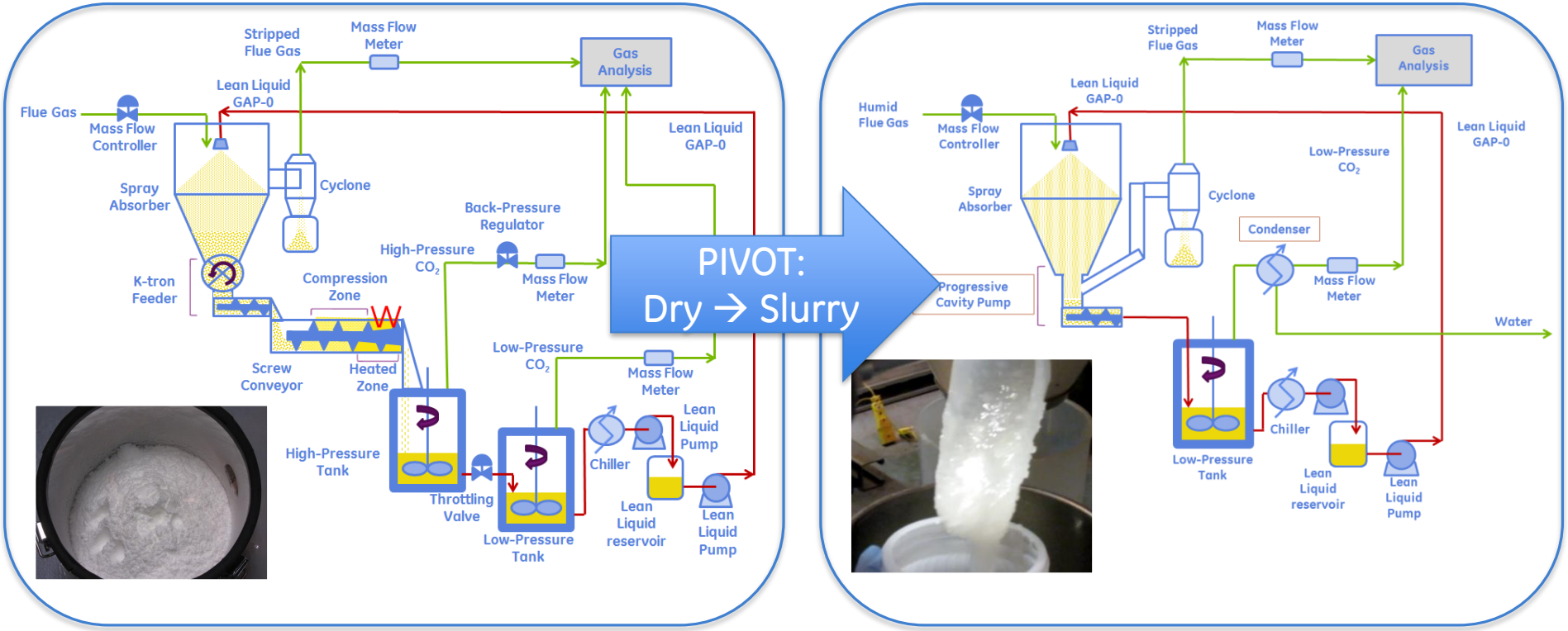




- Replace extruder with less costly rich transfer method
- More efficient RLHX with fluid than solids
- Water inhibits urea formation

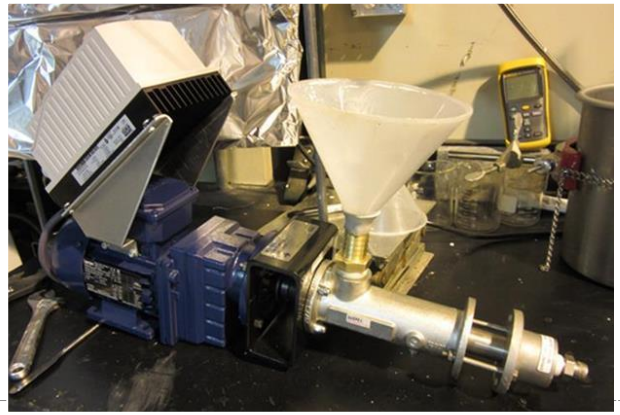


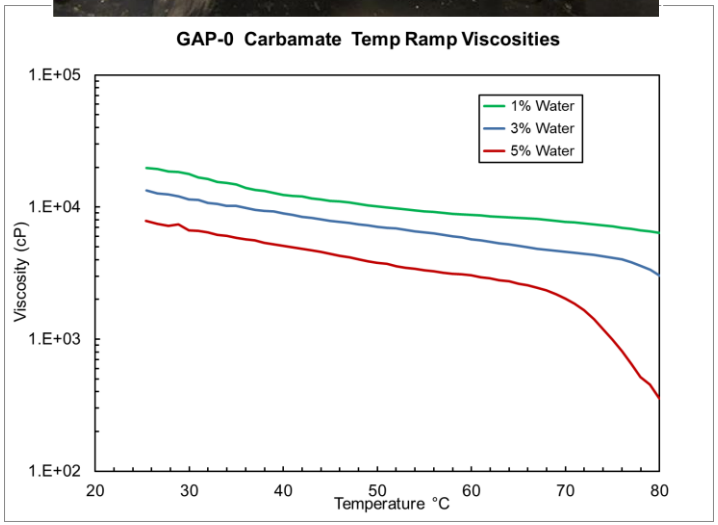
Phase-Changing CO_2 Capture Process Pivot



- Slurry handling / pump selection and integration
- Desorber heat transfer performance (2 → 1 stage)
- Cost impact of slurry

Slurry handling & absorber/pump integration

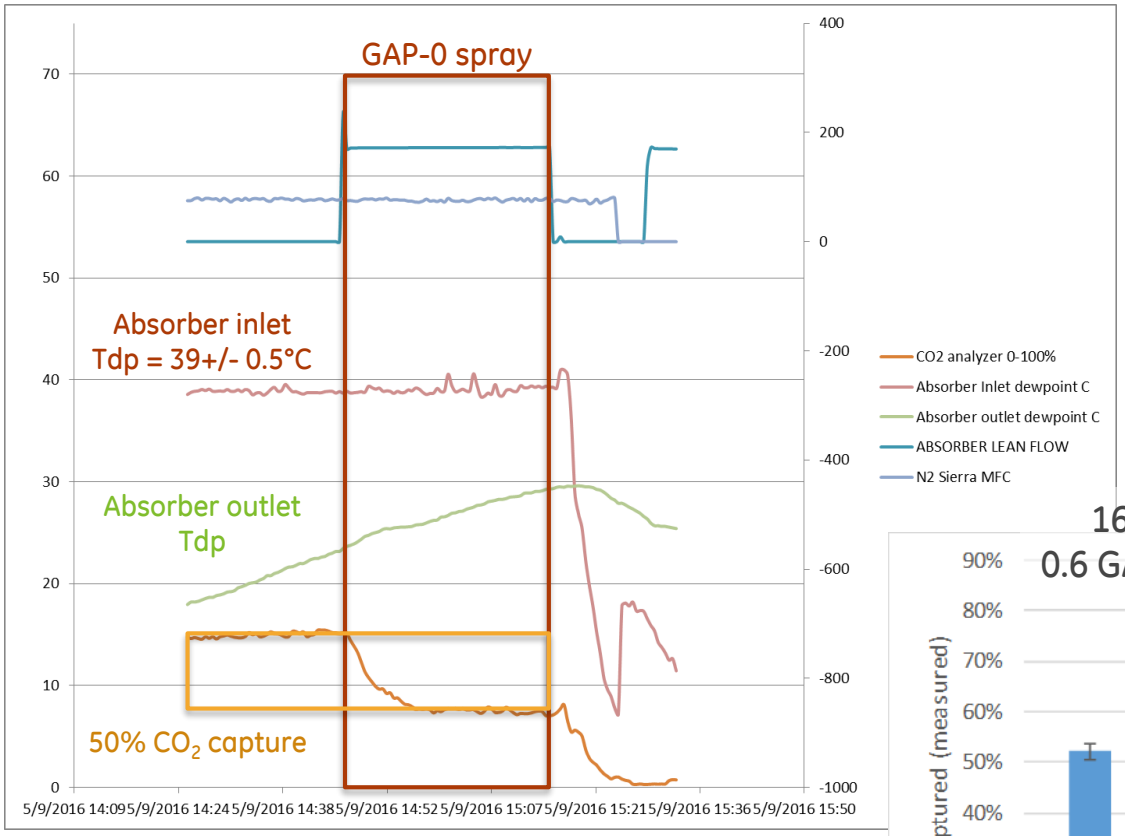




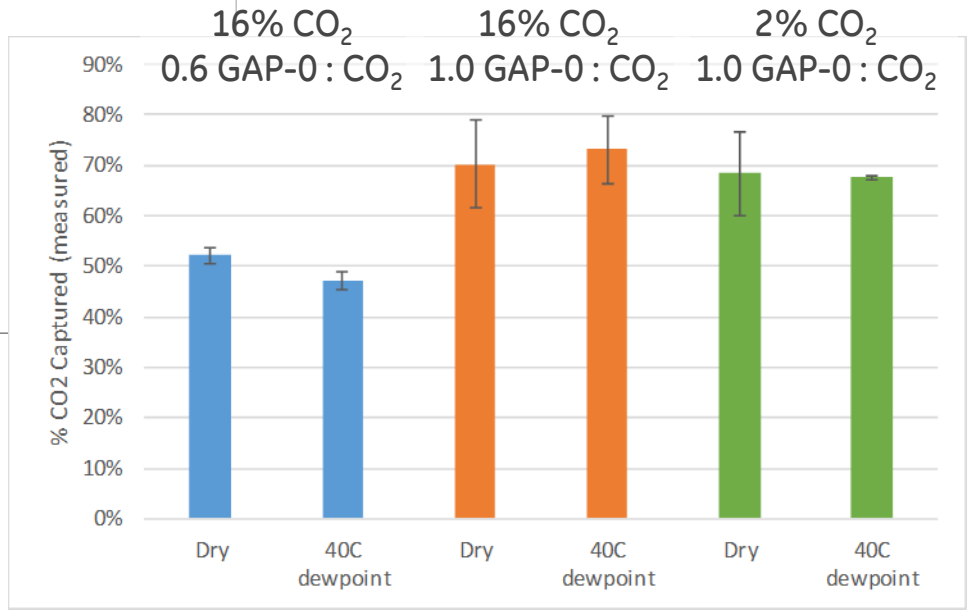
Viscosity measurement → pump selection

Pump integration w/ spray absorber

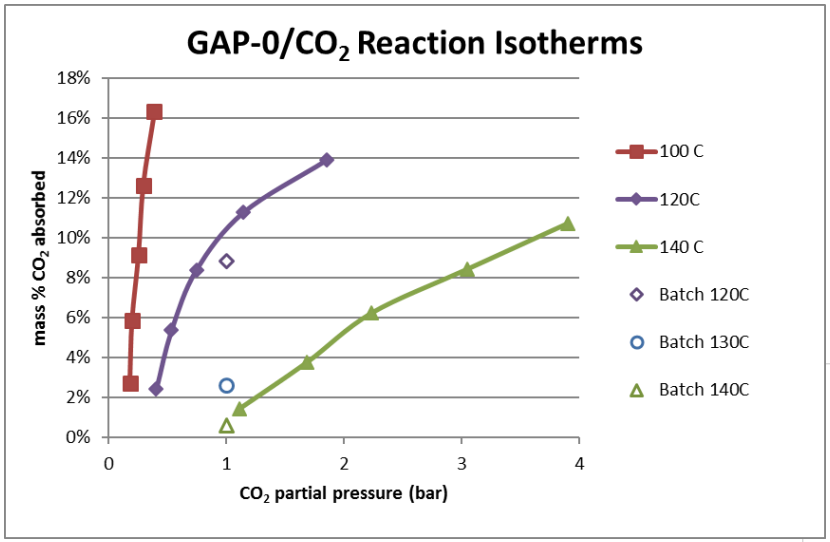
Continuous spray absorber operation



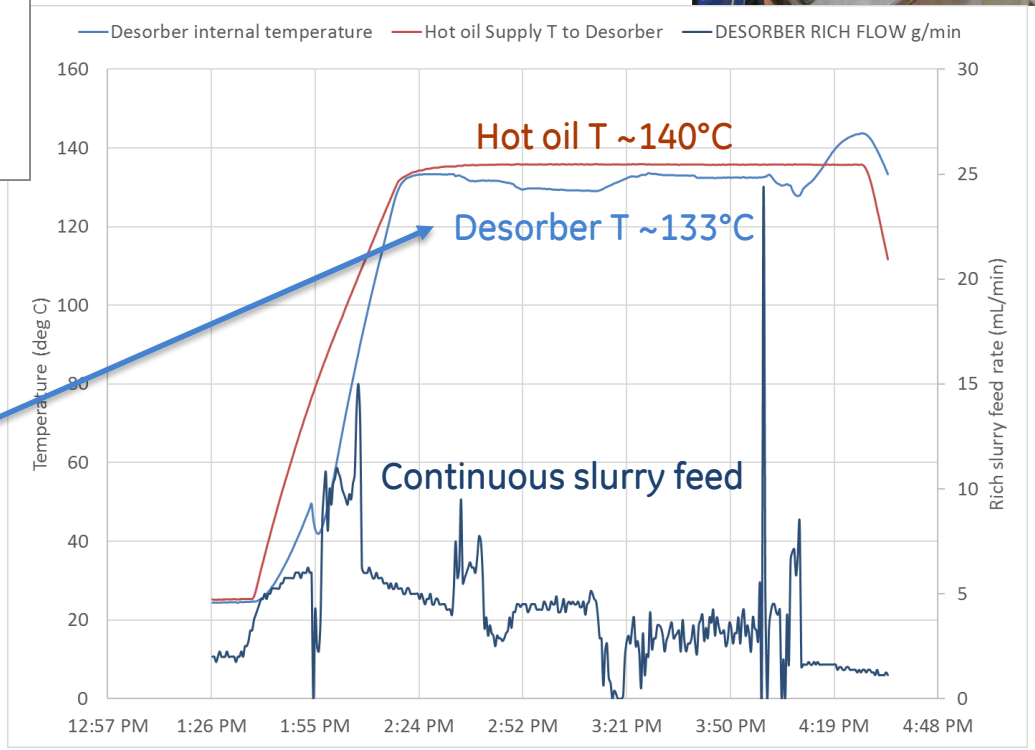
- Pump integration enables continuous operation
- CO_2 capture % comparable to dry FG



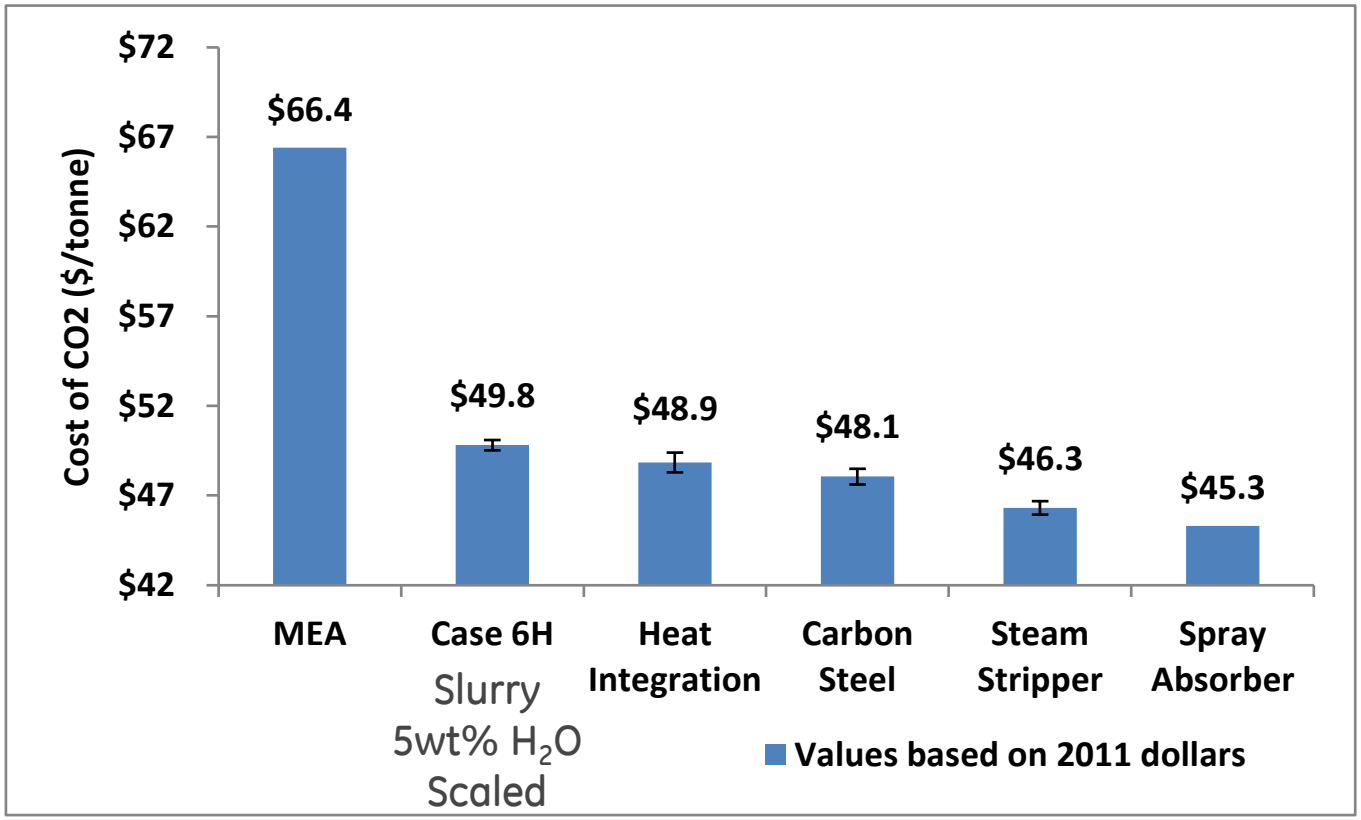
Desorber performance



- Batch desorber experiments consistent with equilibrium isotherms
- Stable desorber T during continuous operation with upgraded HX



Economic analysis – 550MW net



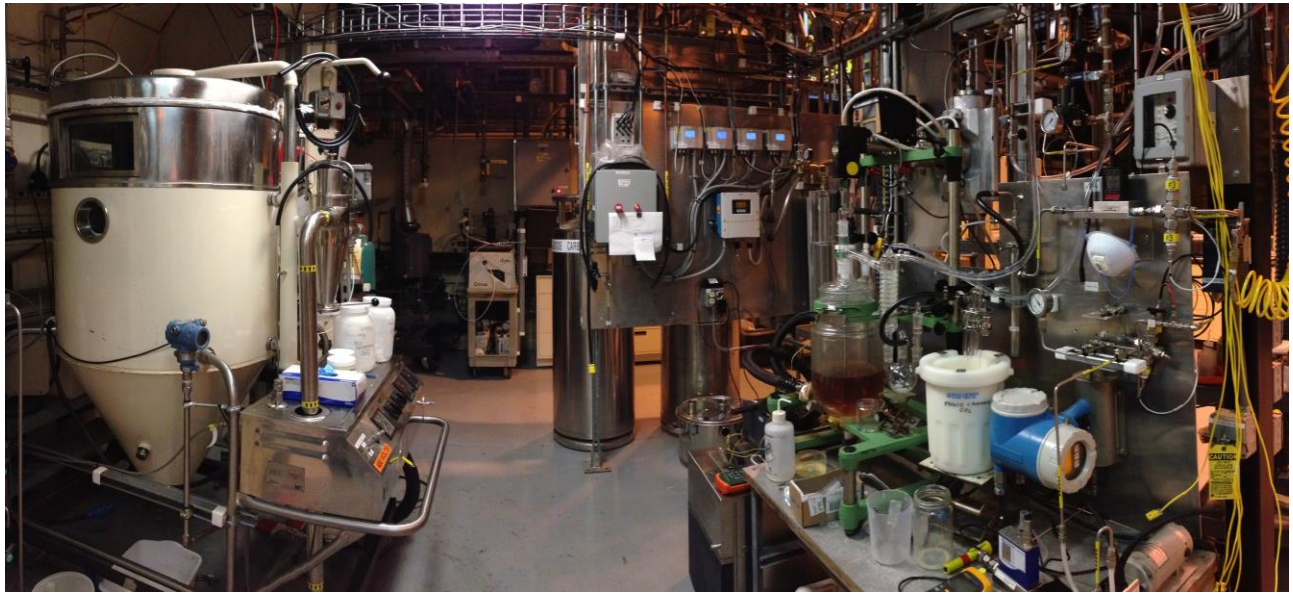
- Replacement of all unit ops with carbon steel – inhibitors
- Spray absorber optimized for slurry production
- Enhanced desorption at low temperature – steam stripper

Future Work

- Current Project
  - Continuous System testing and optimization
  - Develop scale-up strategy
  - Prepare final TEA (target <$40/tonne CO_2)
- Next Project: De-risk solvent management
  - Advanced desorption/steam stripper
  - Oxidative stability
- Scale-up Potential

Thank You

- NETL
  - David Lang, Lynn Brickett, Elaine Everitt
- GE GRC Project Team
  - Mike Bowman, Stanlee Buddle, Joel Caraher, Wei Chen, Mark Doherty, Rachel Farnum, Mark Giammattei, Terri Grocela-Rocha, Dan Hancu, Barbara Miebach, Robert Perry, Gosia Rubinsztajn, Surinder Singh, Irina Spiry, Paul Wilson, Benjamin Wood



Acknowledgement. The information, data, or work presented herein was funded in part by the Advanced Research Projects Agency – Energy (ARPA-E), U.S. Department of Energy, under Award Number DE-AR0000084 and DOE- NETL under Award Number DE-NT0005310.