Pilot-Scale Silicone Process for Low-Cost CO_2 Capture

GE Global Research

GE Global Research

Benjamin Wood

DOE Award: DE-FE0013755

2016 NETL CO_2 Capture Technology Meeting
July 8, 2016

Overview

Program Team

GE Global Research

- Pilot-scale design
- Construction/Operation of Continuous System
- EH&S Assessment
- Techno-economic Assessment
- Plant Modeling

National Carbon Capture Center

- Pilot-scale Operation
- Assessment of Data
- Integration of Components

36 Month, $6.7MM Program to Advance the Amino-Silicone Solvent Process for CO_2 Capture to Pilot Scale

Program Objectives: Design and optimize a new process for a novel silicone CO_2 capture solvent and establish scalability and potential for commercialization of post-combustion capture of CO_2 from coal-fired power plants. A primary outcome will be a system capable of 90% capture efficiency with less than $40/tonne CO_2 capture cost.

Design & Optimize Process

Establish Scalability & Commercial Value

Pilot of Post-Combustion CO_2 Capture

Technical Approach

- Design and construct pilot-scale unit and obtain parametric data to determine key scale-up parameters
- Perform an EH&S and technical and economic assessment to determine feasibility of commercial scale operation
- Develop scale-up strategy

Outcomes

- Strategy for future scale-up
- Technical and economic feasibility determined
- Environmental assessment

Anticipated Benefits of the Proposed Technology

- 90% CO_2 Capture
- $40/tonne CO_2 capture cost

- Continuation of previous DOE/NETL funded project (DE-FE0007502)

Scope

Phase I: 1/1/2014 - 12/31/2014

($1.5MM with 20% GE cost share)

- ✓ Develop preliminary process models and perform preliminary techno-economic analysis
- ✓ Perform preliminary EH&S risk assessment
- ✓ Design and construct pilot-scale aminosilicone desorber skid

Phase II: 1/1/2015 - 12/31/2016

($5.2MM with 20% GE cost share)

- ✓ Integrate skid with the NCCC pilot-scale system
- ✓ Water commissioning of pilot-scale system
- ✓ Study lower desorber residence times
  - ✓ Can decrease residence time by 60%
- ✓ Investigate corrosion inhibitors
  - ✓ Identified additive that decreases corrosion of carbon steel by 90%
- Develop solvent recovery methods

Scope Cont.: Items to be Completed

Phase II: 1/1/2015 - 12/31/2016

($5.2MM with 20% GE cost share)

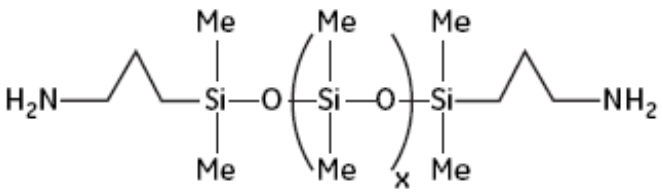
- ✓ Test steam stripper design at bench-scale
- Perform pilot-scale testing (starting August 2016)
  - Test both CSTR and steam stripper designs
- Analyze data from pilot tests at 0.5 MW scale
- Perform techno-economic analysis and update cost of carbon capture
- Perform technology EH&S risk assessment
- Develop cost estimate for full-scale manufacture of solvent

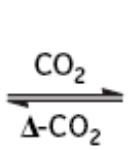
Summary of Solvent Advantages

- Lower volatility
  - Simplified separations
  - Less energy wasted vaporizing solvent and/or water
  - Lower airborne release rates
- Lower heat capacity
- Reduced corrosion
- Possibly higher mass transfer rates
- Potentially decreased issues with aerosol formation

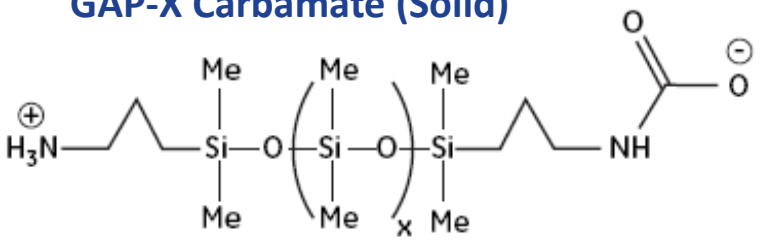
Absorbent

GAP-X (Liquid)





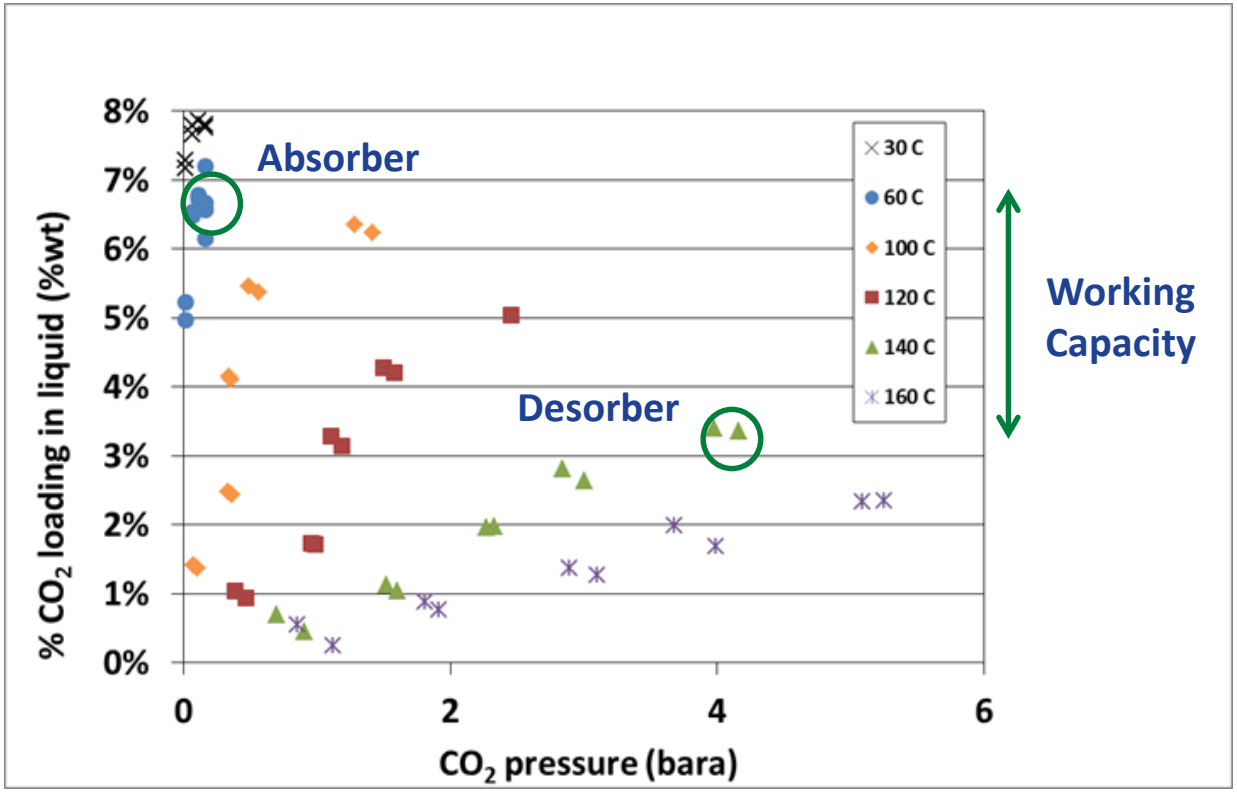
GAP-X Carbamate (Solid)



GAP-1_m Absorbent Composition

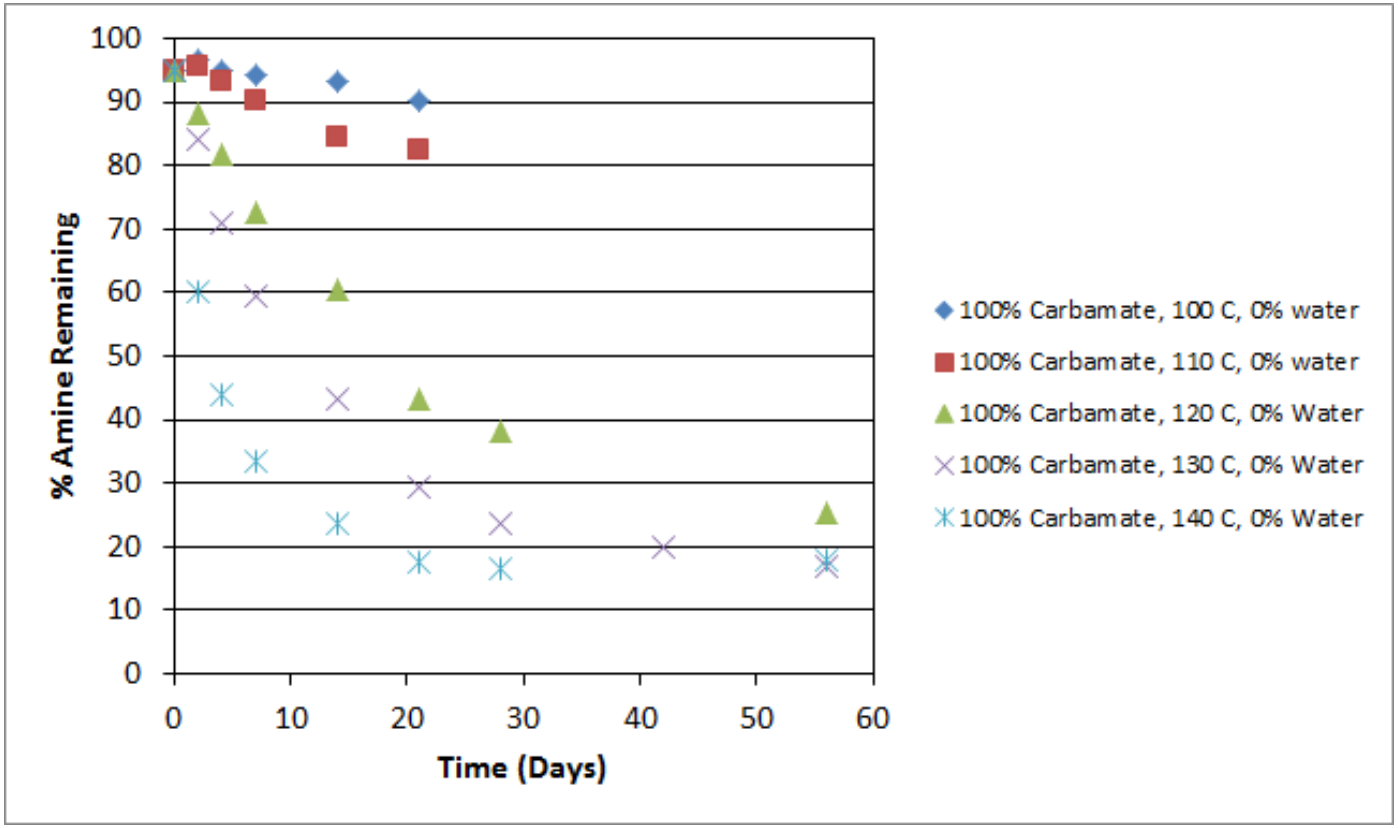
- 40% GAP-0
- 33% GAP-1
- 19% GAP-2
- 8% GAP-3

Carbamate does not precipitate in a GAP-1_m/TEG mixture



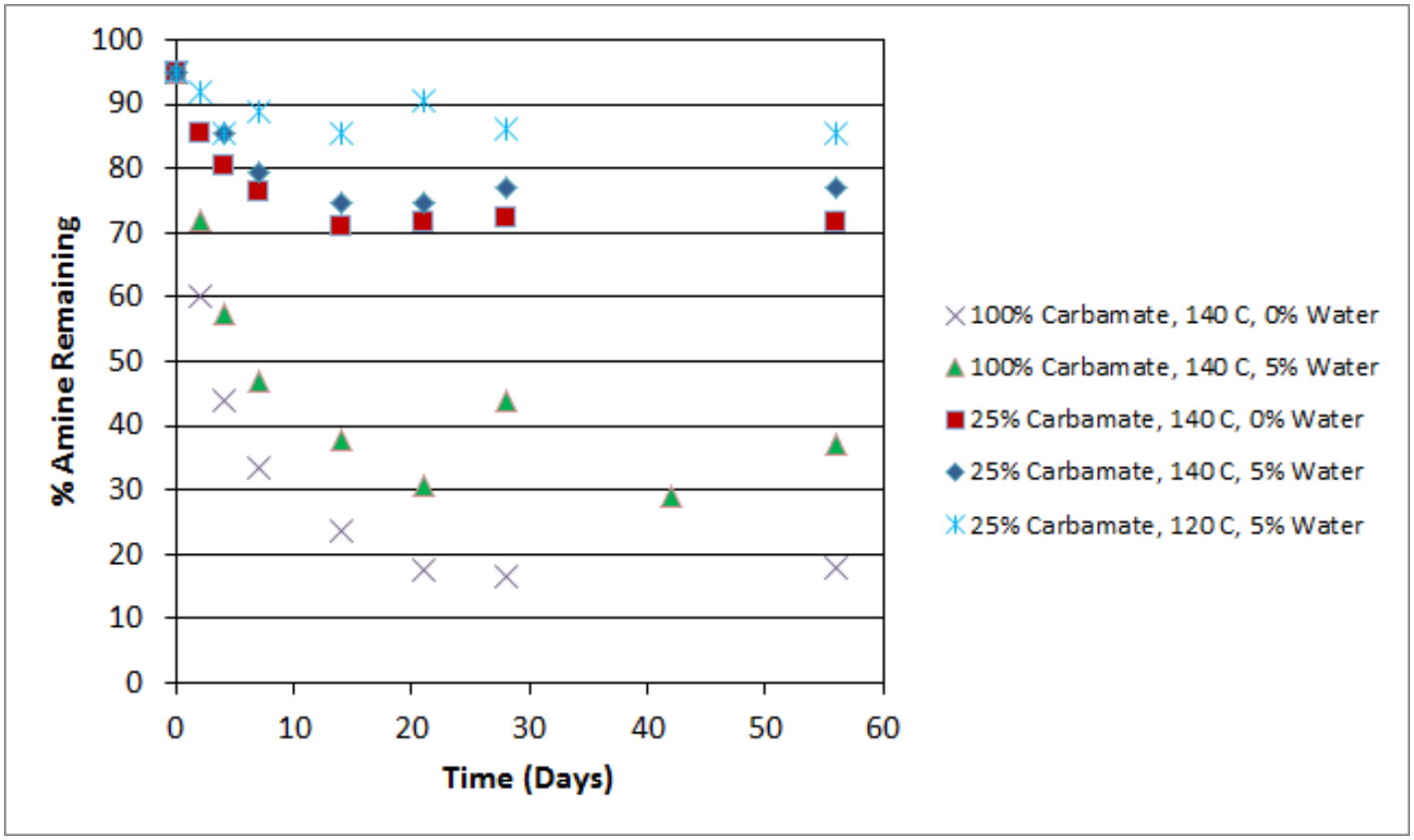
imagination at work

Accelerated Thermal Degradation Testing



- Tests conducted in pressure cells with continuous heating
- High thermal degradation at 100% CO_2 loading and 140 °C

Thermal Degradation Mitigation

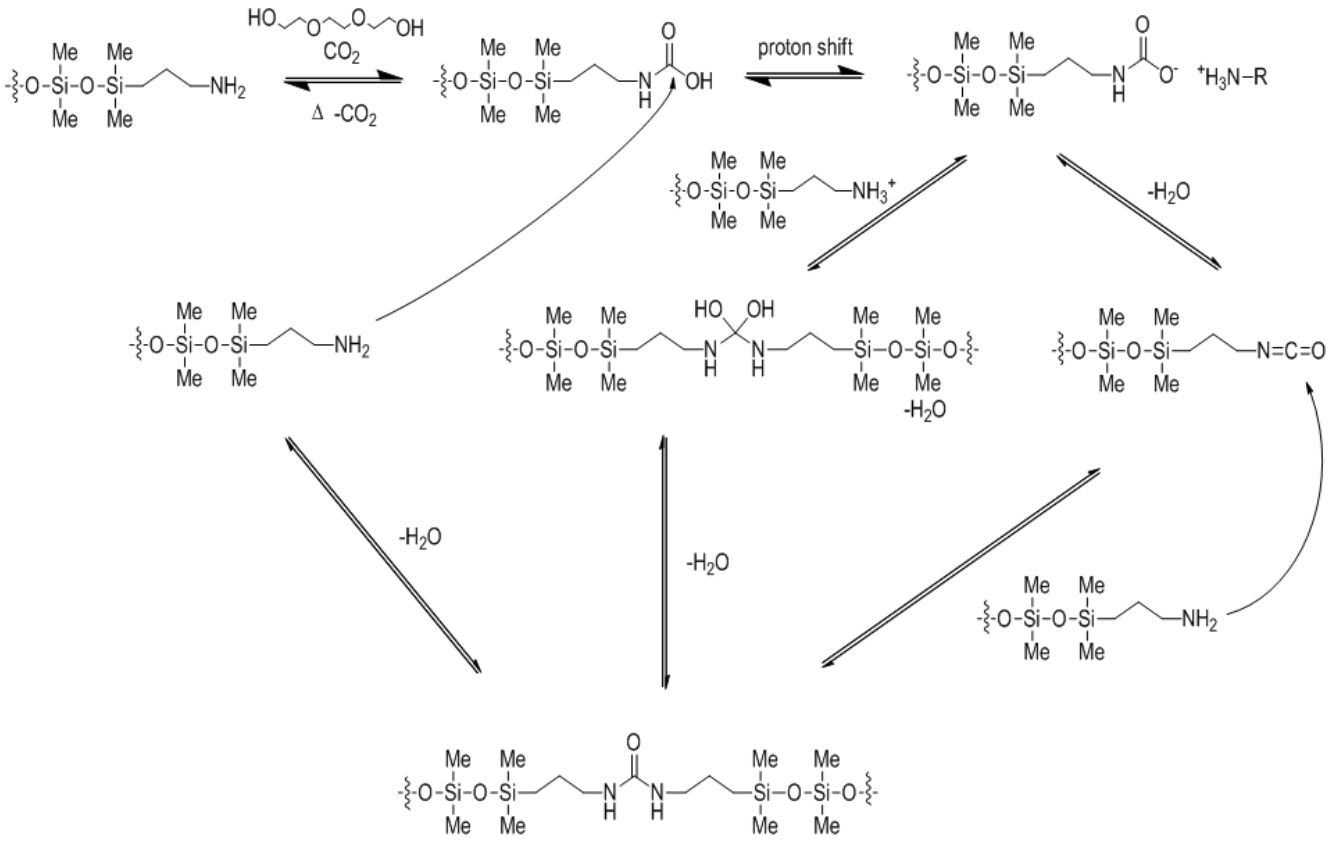


Ways to lower thermal degradation

- Lower temperature
- Lower carbamate loading
- Add water

imagination at work

Thermal Degradation Pathway

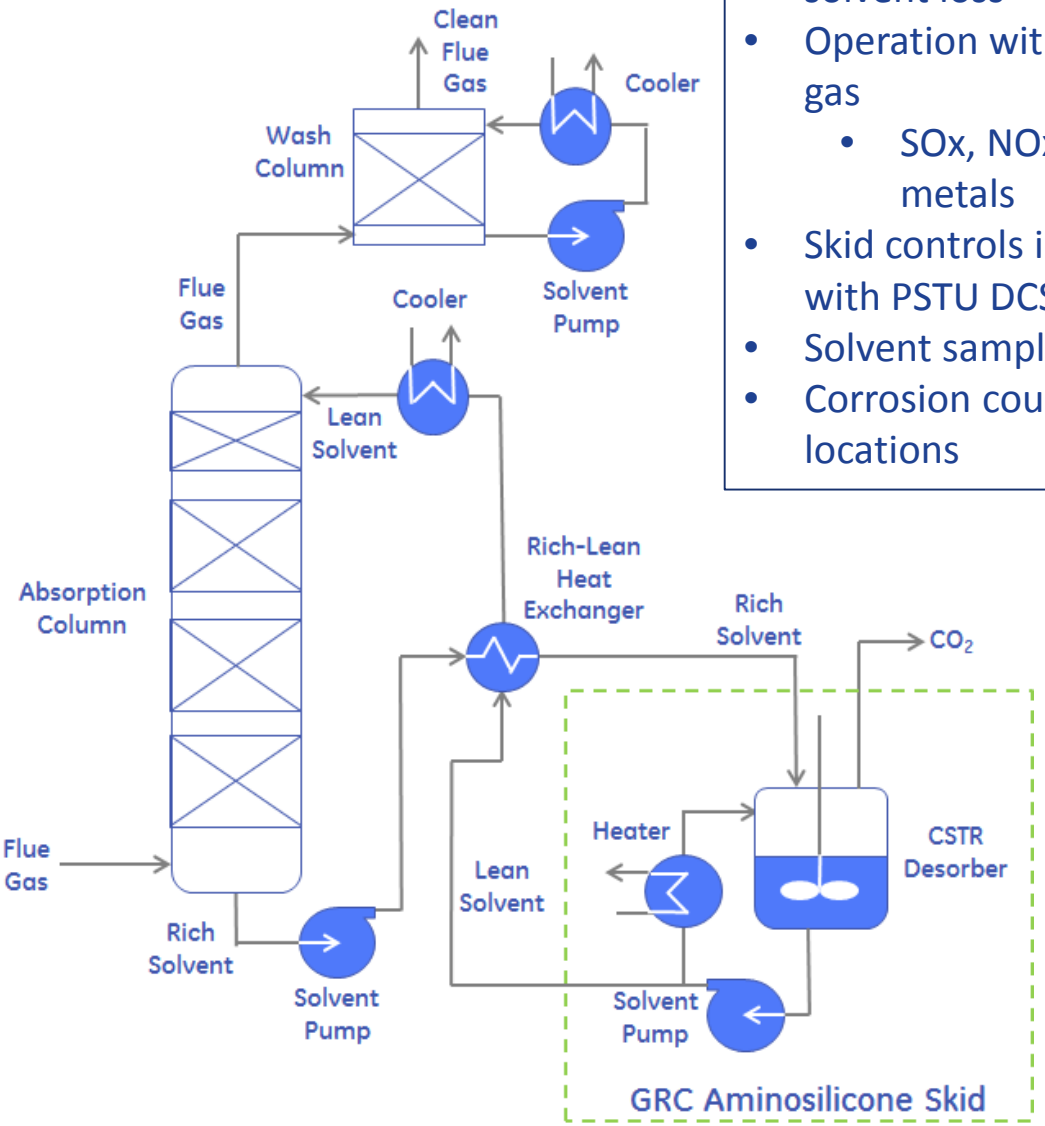


Urea Degradation Product

- Pathway demonstrates why water inhibits the thermal degradation of the solvent and high CO_2 loading facilitates degradation
- Currently working on methods for reversing formation of urea

Pilot-Scale Process

The NCCC PSTU



- Ability to measure solvent loss
- Operation with real flue gas
  - SOx, NOx, heavy metals
- Skid controls integrated with PSTU DCS
- Solvent sampling points
- Corrosion coupon testing locations

imagination at work

CSTR skid integrated with PSTU at the NCCC

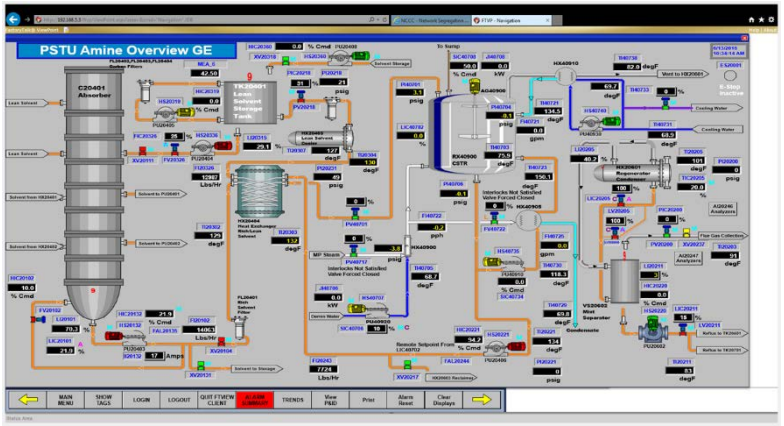
NCCC Pilot Started

- ✓ Integration of skid with PSTU
- ✓ Water commissioning, Dec. 2015

Pilot test

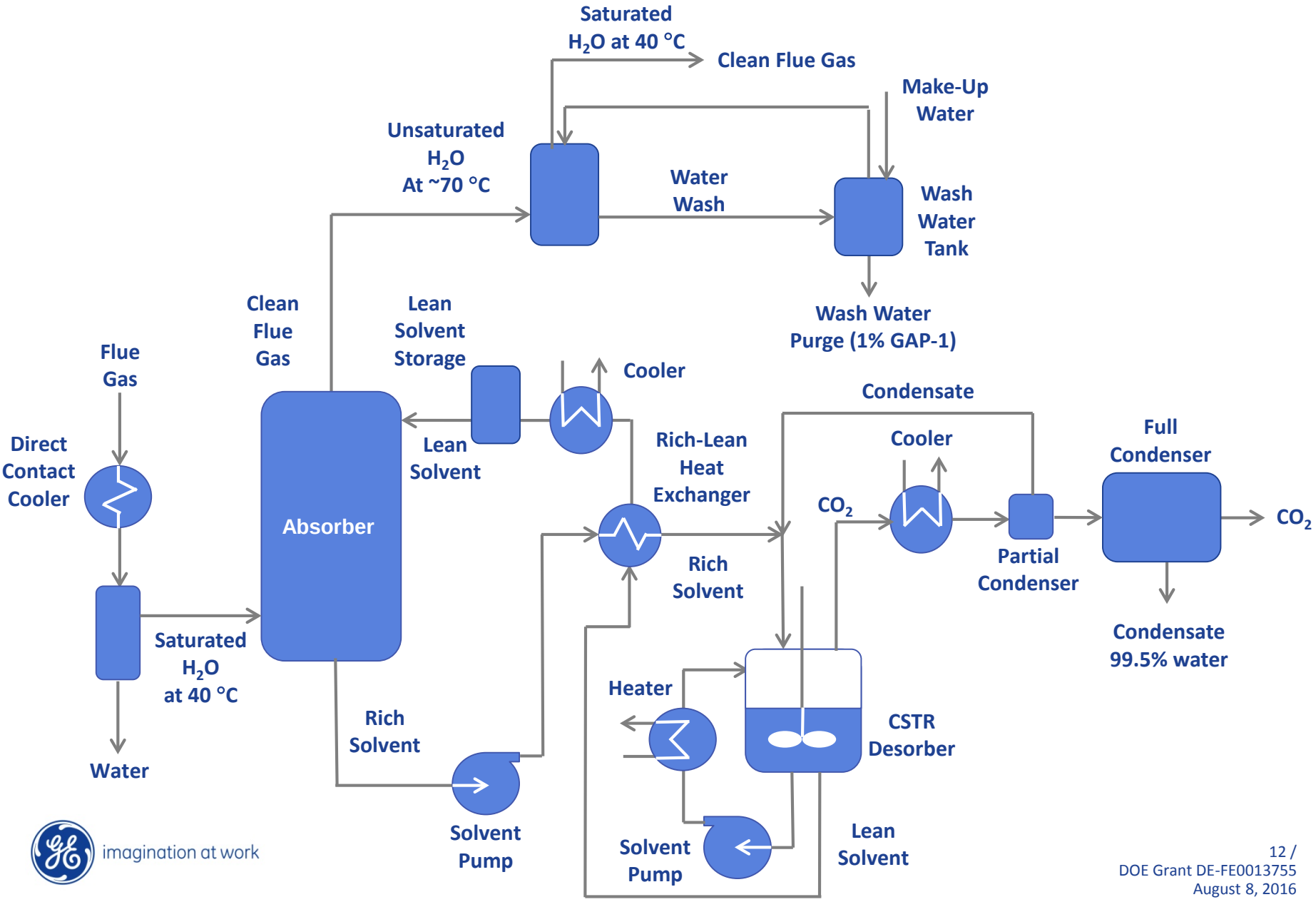
- ✓ Test matrix, sampling & analytical plan determined
- ✓ Mid-May: BOP startup, steam & flue gas available
- ✓ New bag house… reduce solvent loss from aerosol
- ✓ Steam commissioning completed with regenerator
- ✓ Steam commissioning with CSTR
- ✓ Solvent loaded
- o Test window: August through October… test both CSTR and steam stripper

Pilot-scale test skid



imagination at work

Original Process Concept



imagination at work

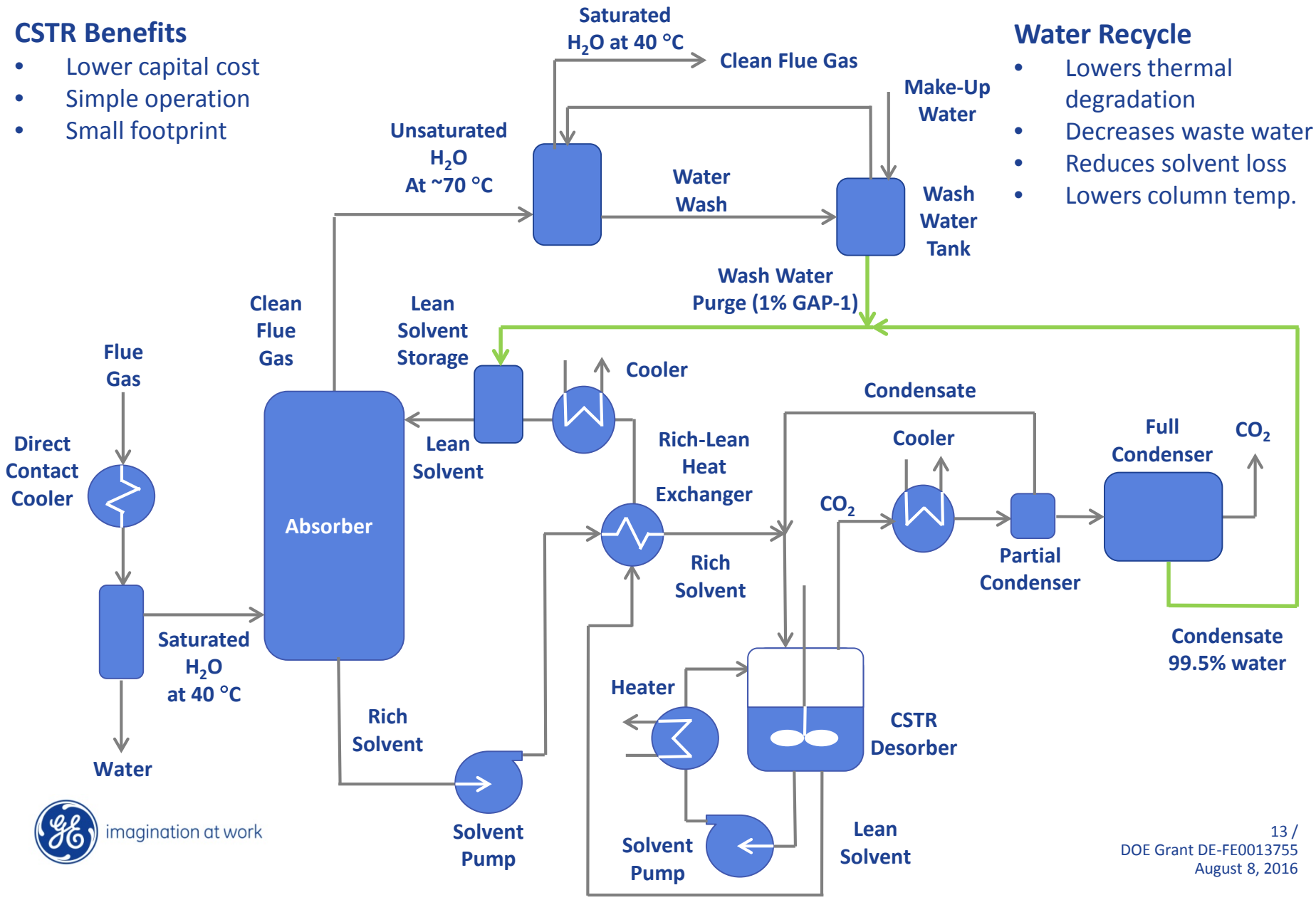
Process Design with CSTR and Water Recycle

CSTR Benefits

- Lower capital cost
- Simple operation
- Small footprint

Water Recycle

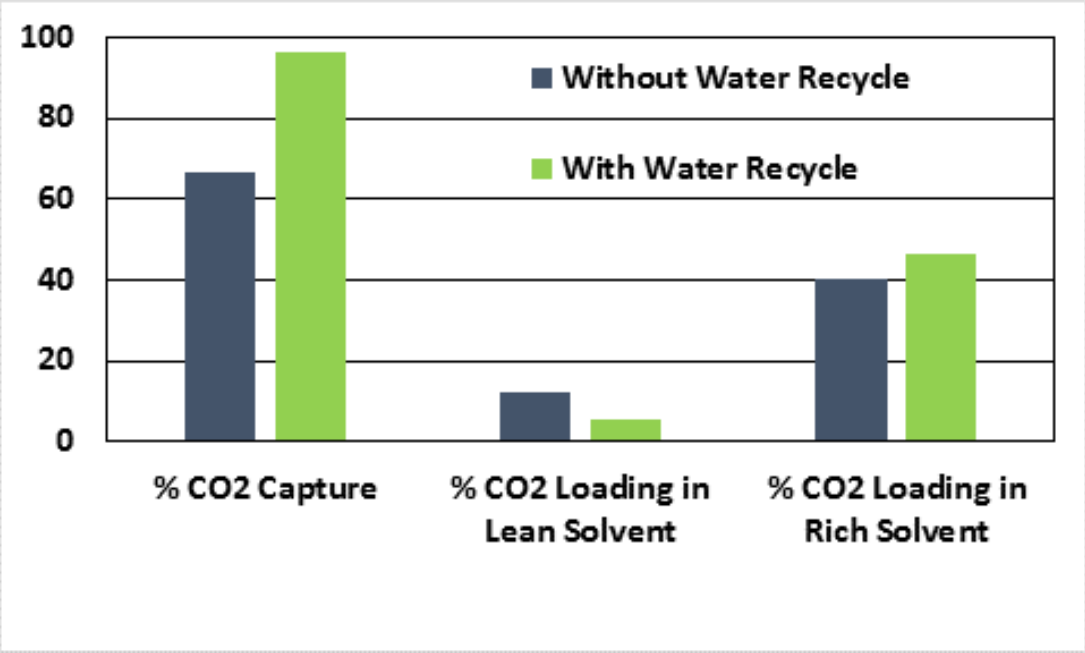
- Lowers thermal degradation
- Decreases waste water
- Reduces solvent loss
- Lowers column temp.



imagination at work

Predicted Performance

- Process model evaluation of system performance



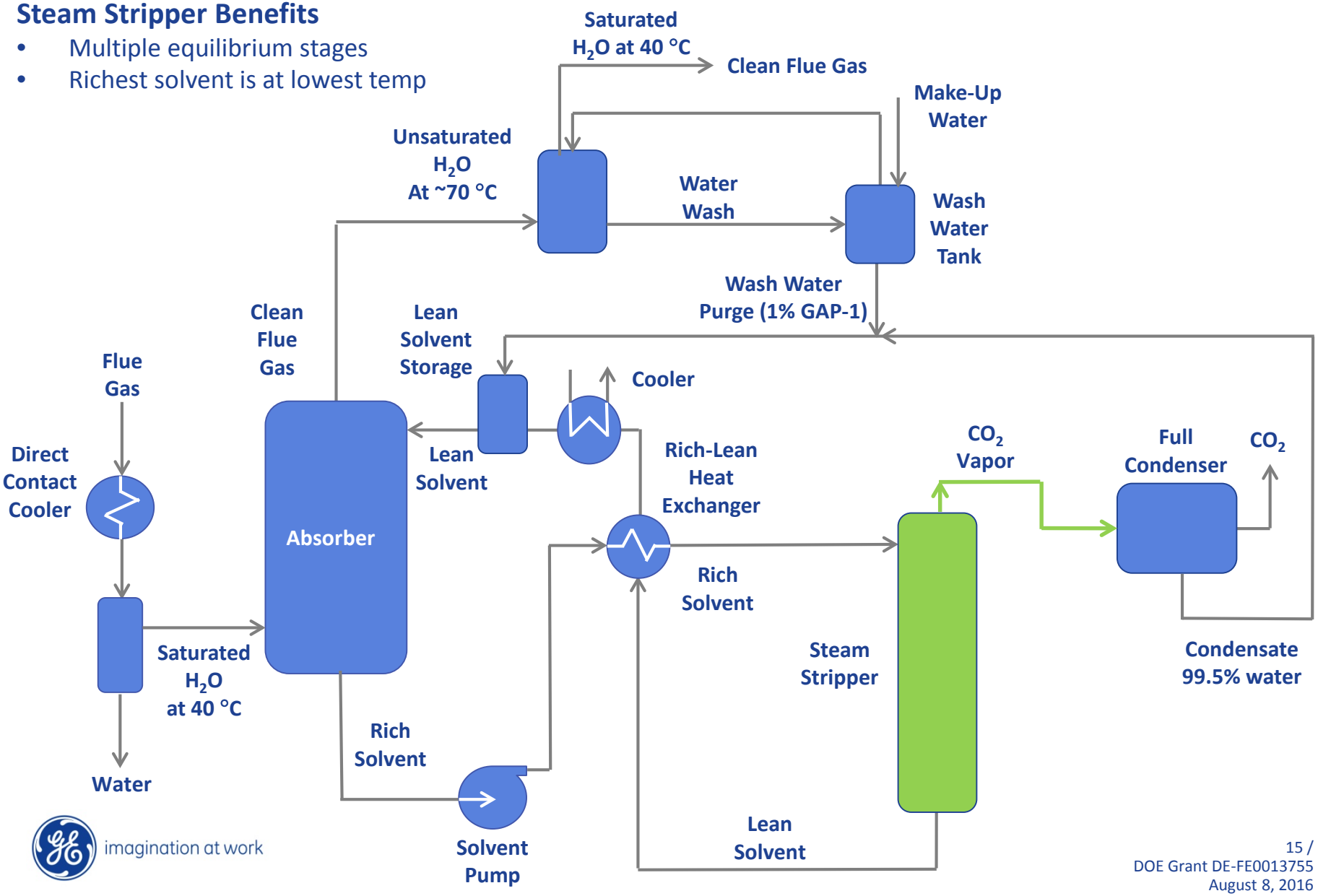
- Process conditions
  - Flue Gas CO_2 Concentration = 12.2%
  - Flue Gas Inlet Temp. = 43.3 °C
  - Flue Gas Flow Rate = 2270 kg/hr
  - Desorber Pressure = 1 bara
  - Cooling Water Temp. = 32 °C

- Water recycle enhances capture performance

Process Design with Steam Stripper

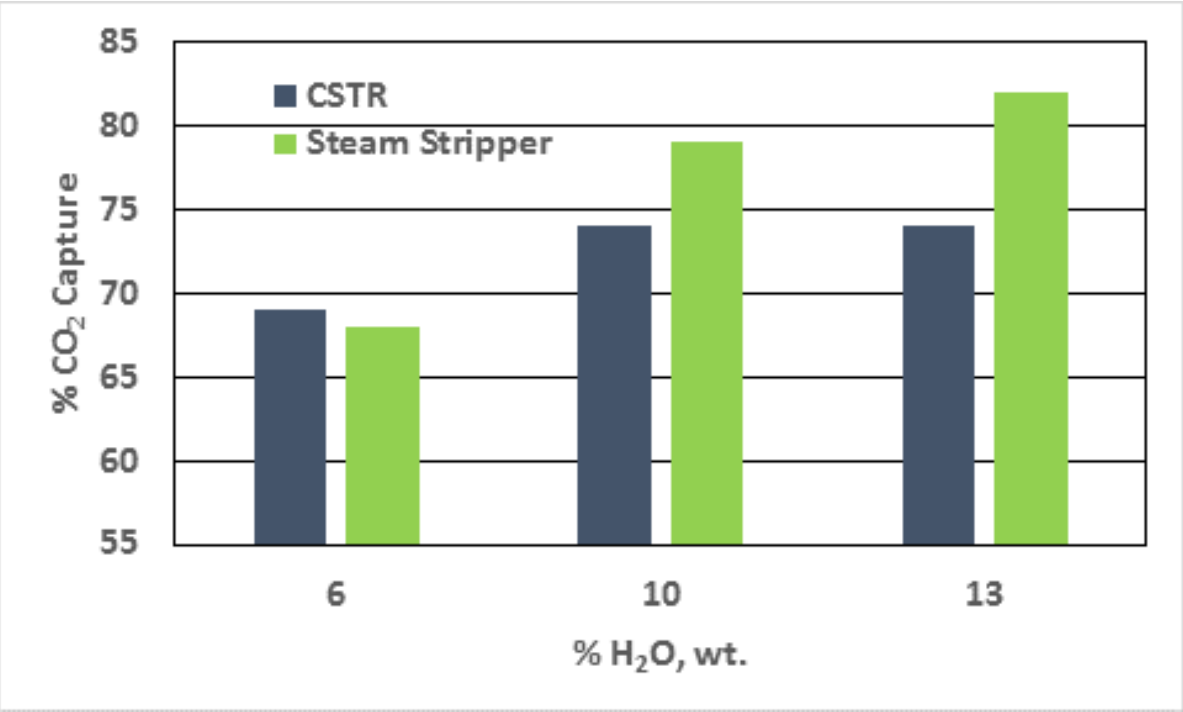
Steam Stripper Benefits

- Multiple equilibrium stages
- Richest solvent is at lowest temp



imagination at work

Steam Stripping at Bench-Scale



Process conditions

- $T_{reboiler}$ = 108 °C
- Flue Gas CO_2 Concentration = 12%
- Flue Gas O_2 Concentration = 5% O_2
- Flue Gas SO_2 Concentration = 1 ppm

imagination at work

Future Work

- 2016
  - Operate PSTU with CSTR desorber for 1.5 months (starting in August)
  - Operate PSTU with steam stripper for 1.5 months (starting in September)
  - Use data to update process models
  - Update Techno-Economic Analysis and EH&S Risk Assessment
- Beyond
  - Work with solvent manufacturers to lower solvent cost
  - NETL has funded GE to evaluate performing demo-scale (10 MW) test at TCM
  - Continue developing
    - Methods for reducing oxidative degradation
    - Solvent reclamation processes

Thanks

- Andrew O'Palko (program manager)
- Lynn Brickett
- GE GRC team members
- GE Power and Water
- The National Carbon Capture Center

Acknowledgment: This material is based upon work supported by the Department of Energy under Award Number DE-FE0013755.