Development of a Novel Gas Pressurized Stripping (GPS)-Based Technology for CO_2 Capture from Post-Combustion Flue Gases
DE-FE0007567

Carbon Capture Scientific, LLC.
CONSOL Energy Inc.
Nexant Inc.
Western Kentucky University

Presented by Shiaoguo (Scott) Chen

DOE Carbon Capture Technology Meeting, July 10, 2012, Pittsburgh, PA

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About Carbon Capture Scientific, LLC

- Early stage company located in Pittsburgh, PA
- Two patent pending CO_2 capture technologies
- Bench-scale development funded by the Department of Energy / National Energy Technology Laboratory
- Chemical Engineers/Scientists with strong expertise in process design, simulation and optimization
- Technology development based on transition from thermodynamic analysis, to process simulation, to bench scale prototyping

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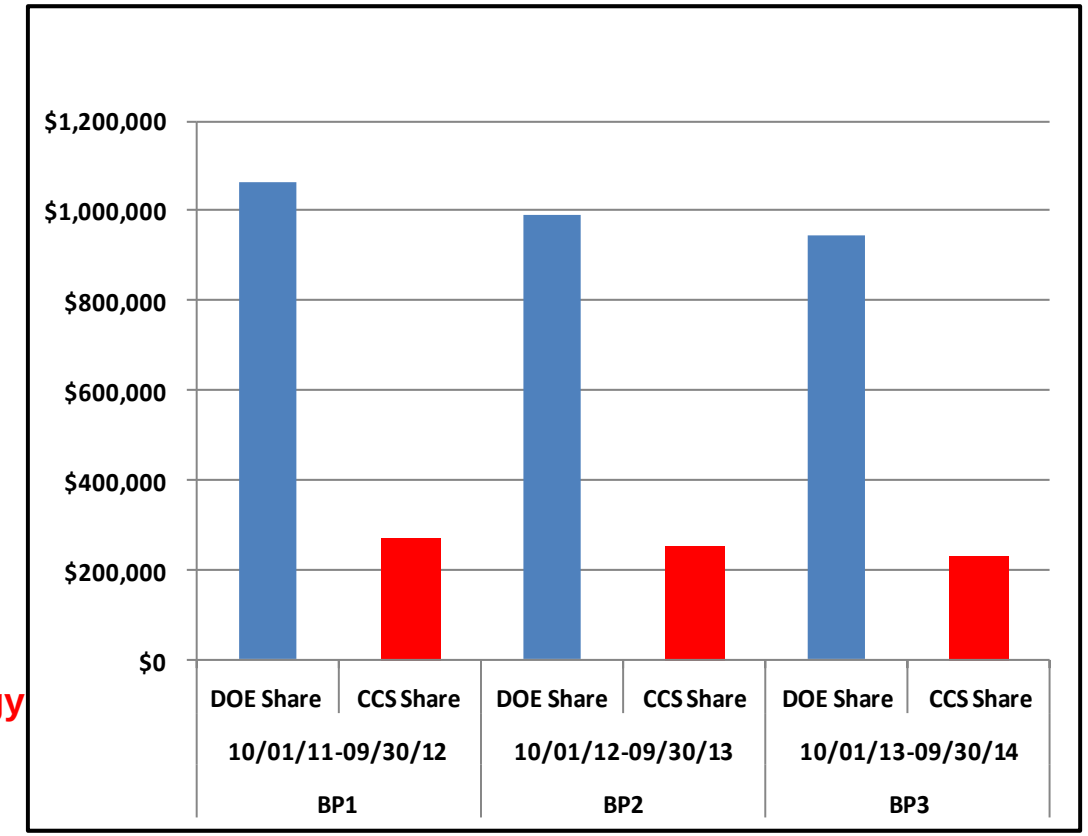
Project Budget

	Budget, $
DOE	2,999,756
CCS	751,178*
Total	3,750,934

*including cost share from CONSOL Energy and Western Kentucky University



(Cost share is ~20%)

DOE funding and cost share on a yearly basis

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Project Team and Focus

DOE/NETL

- Timothy Fout, NETL project manager

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- Computer simulation to optimize GPS based process for existing power plants
- Bench-scale experiments to obtain process design data for GPS based process

CONSOL Energy Inc.

- Work with CCS to acquire phase equilibrium and related process design data

Nexant Inc.

- Conduct techno-economic analyses for the GPS based technology

Western Kentucky University (WKU)

- Consult on thermal and oxidative properties; Corrosion effects and physical property measurements

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Project Objectives

- Conduct computer simulations to maximize the benefit of the GPS technology for existing power plants
- Perform bench-scale tests of individual process units to obtain necessary process design data for the pilot scale
- Carry out experimental investigation of selected solvents to minimize the economic risk of the GPS technology
- Conduct techno-economic analyses for GPS based process to identify improvement potentials

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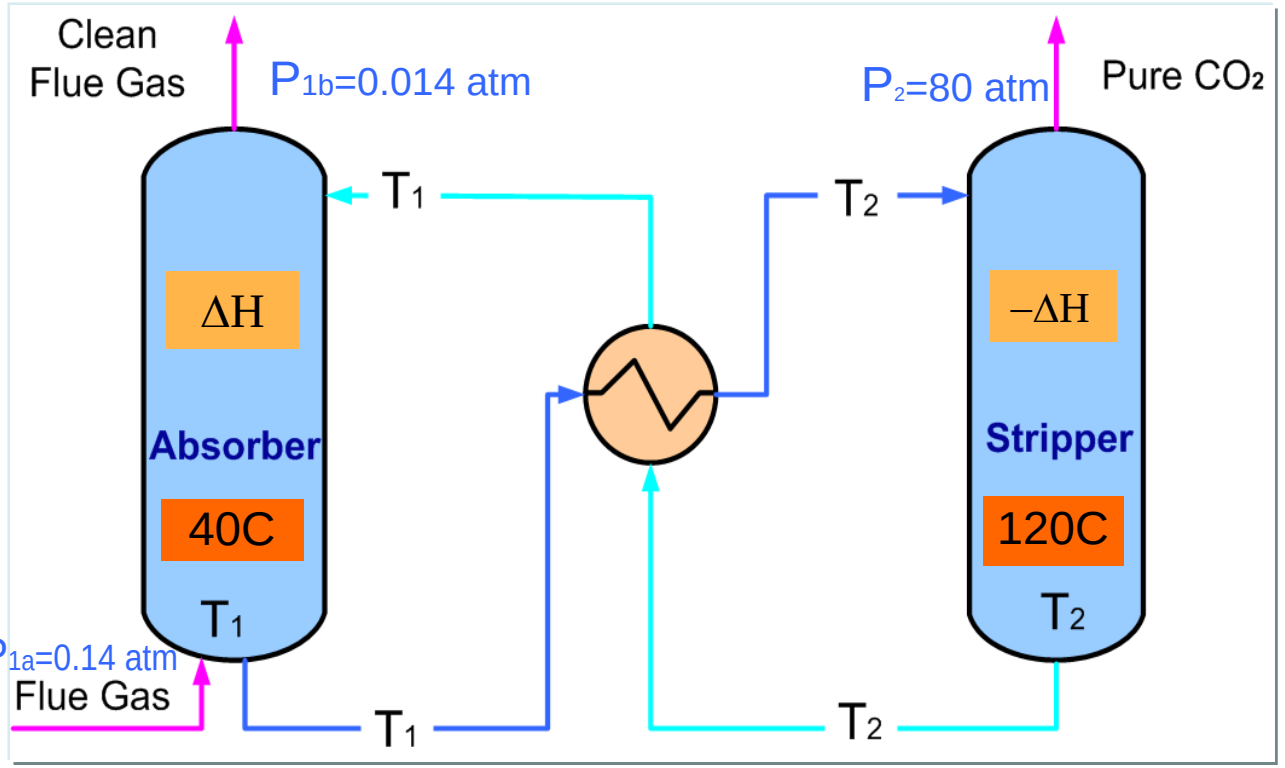
An Integrated Process for CO_2 Capture and Compression

CO_2 Capture/ Regeneration:

$$M + CO_2 \Leftrightarrow N - \Delta H$$

$$K = \left(\frac{\gamma_N x_N}{\gamma_M x_M}\right)\frac{1}{P_{CO2}}$$



Ignore all the driving force for heat and mass transfer

***van't Hoff Equation*:**

$$\frac{dlnK}{dT} \approx \frac{-dlnP_{CO2}}{dT} = \frac{-\Delta H}{RT^2}$$

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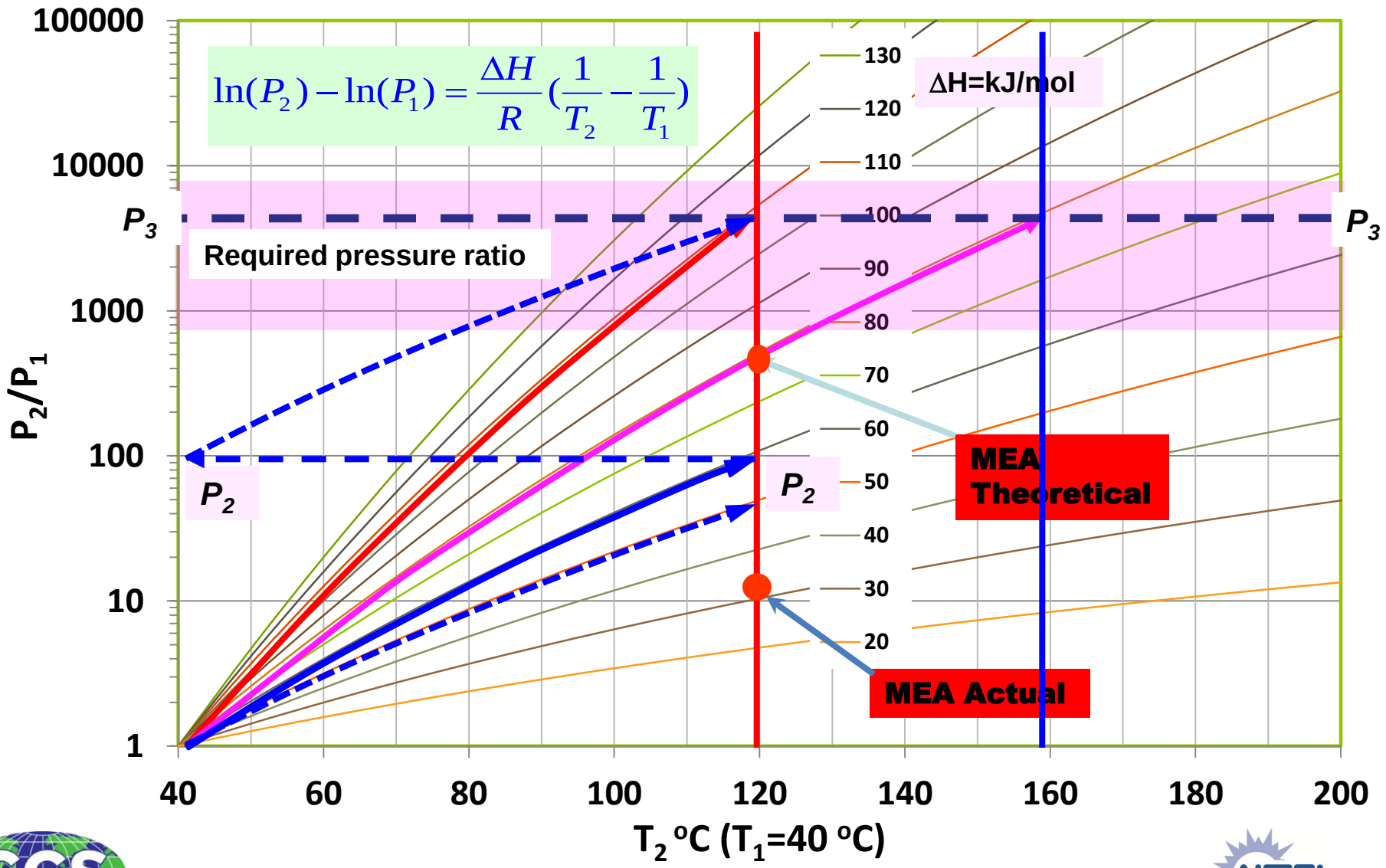
Thermodynamics of the Integrated CO_2 Capture Process



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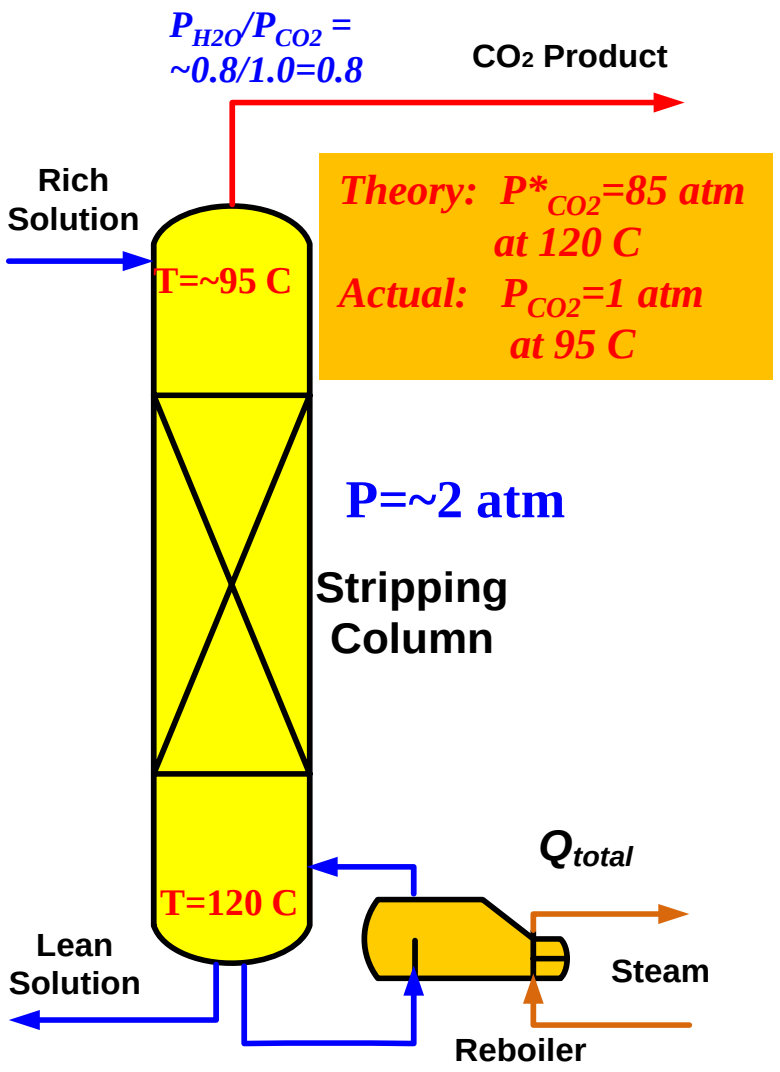
Issues with Conventional Strippers

- *Water vapor is used as stripping gas,* thus operating pressure is limited by the vapor pressure of the lean solution at the reboiler temperature
- *Water vapor is also used as a heat carrier* which leads to a temperature gradient along the column
- *Low operating pressure* results in a high ratio of P_{H2O}/P_{CO2} at the top of the stripper

Consequences:

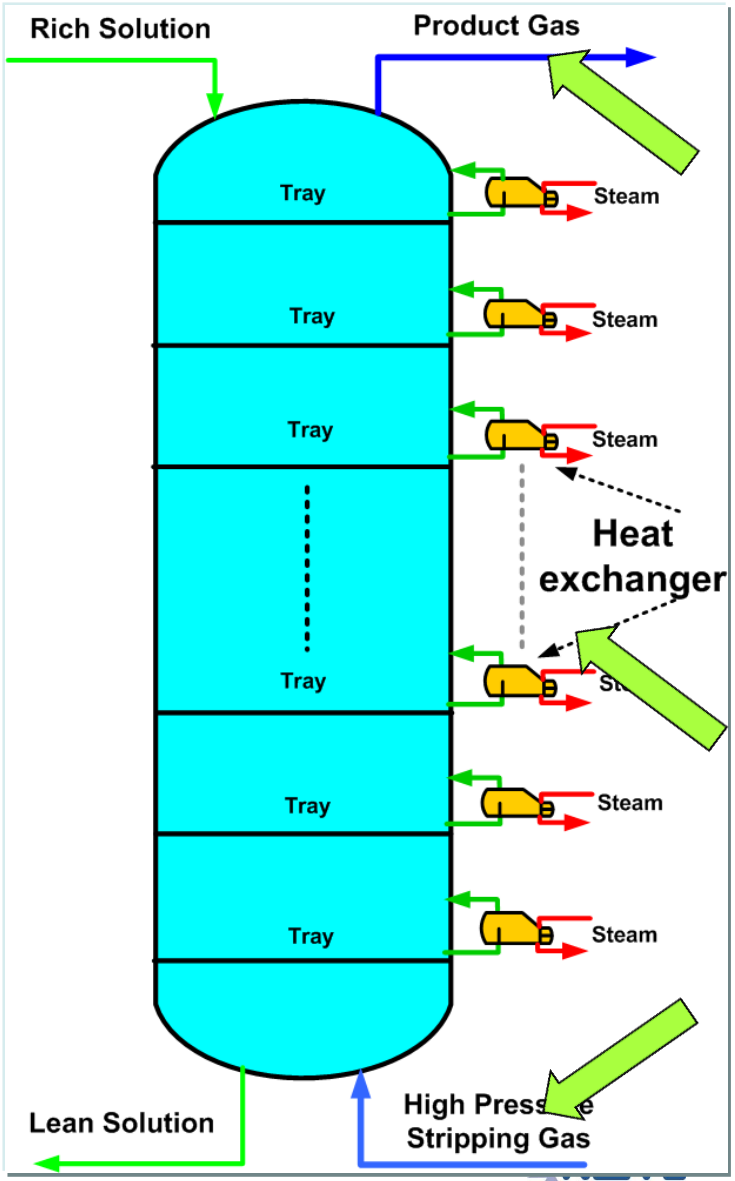
–Low thermal efficiency

–High compression work



The Novel Gas Pressurized Stripping (GPS) Column

- **Adding a high pressure stripping gas stream into the column**
  - ✓ Eliminating water as stripping gas
  - ✓ Enables high operating pressure
- **Adding side heaters to provide heat**
  - ✓ Eliminates the necessity of using water vapor as heat carrier
  - ✓ Reduces temperature gradient in the stripper
- **Product gas is a mixture of stripping gas and CO_2 along with water vapor**
  - ✓ Increased CO_2 partial pressure
  - ✓ Requires a separation unit



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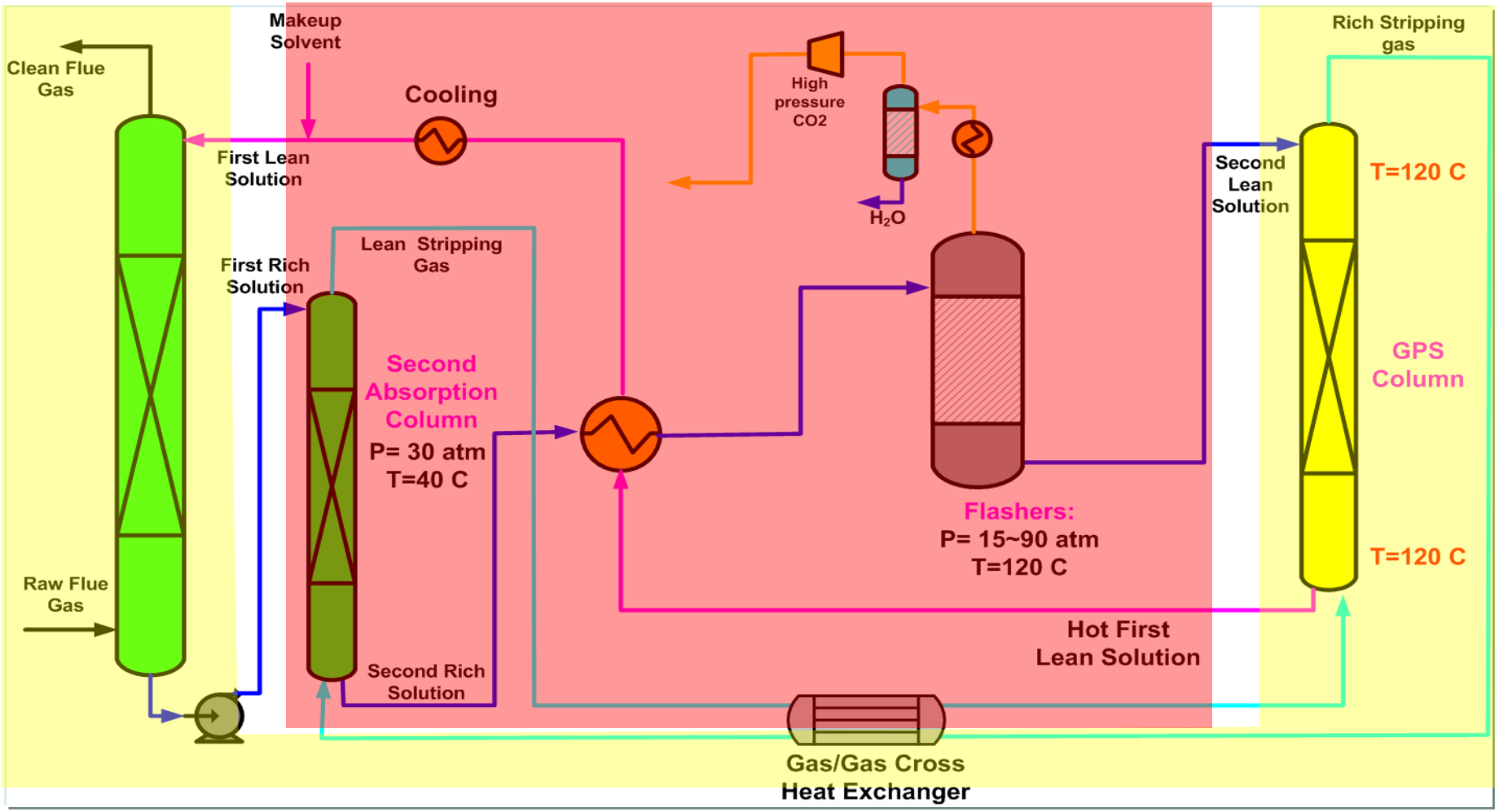
GPS Column Based Process---One Solvent GPS Process



Advantages of the GPS Based Processes

- Uses commercial off-the-shelf technology
  - All major equipment are common with conventional absorption/stripping processes
  - suitable for large scale applications such as power plants
- High operating pressure
  - Low stripping heat
- Minimal or no need for mechanical CO_2 compression
  - Uses thermal compression
  - High thermal efficiency (low exergy loss)
- Flexible
  - Many common units with the conventional absorption/stripping processes
  - Can be repeatedly used depending on the needs

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Project Schedule: Oct.1, 2011 – Sept.30, 2014

Tasks	Task Duration												Task Focus	Performer			
	1-12 BP1				13-24 BP2				24-36 BP3					CCS	CONSOL	Nexant	WKU
Task 1. Project planning & management													N/A	X			
Task 2. GPS column study and its optimization				A									Process	X			
Task 3. Optimization of GPS process for existing plant								C					Process	X			
Task 4. Optimization of flashers													Process	X			
Task 5. Phase equilibrium data measurement													Solvent	X	X		
Task 6. First absorption column testing													Process	X	X		
Task 7. GPS column design/ fabrication and testing								D					Process	X	X		
Task 8. Second absorption column testing											E		Process	X	X		
Task 9. Stability of solvent at high loading and high T				B									Solvent	X			X
Task 10. Corrosion test at high loading and high T													Solvent	X			X
Task 11. Physical properties measurement													Solvent	X	X		X
Task 12. Survey of EH&S of GPS process													Solvent	X			
Task 13. Preliminary techno-economic analysis													Economics			X	
Task 14. Revision of techno-economic analysis													Economics			X	
Task 15. Updated techno-economic analysis											F		Economics			X	

Project Milestones and Success Criteria

Milestones

A	GPS column study and optimization to achieve thermal efficiency of 60% or greater
B	Solvent loss due to degradation of solvent is less than 3 kg/ ton CO_2
C	Overall energy performance column and solvent less than or equal to 0.22 kwh/kg CO_2
D	GPS column efficiency experimental measured at 50% or greater
E	Overall energy performance of system less than or equal to 0.20 kwh/kgCO_2
F	Increase in capital equipment costs of less than or equal to 20% over existing process

Success Criteria

Category	Risk	Target
Solvent Loss	High operating T leads to solvent loss	Loss of < 3 kg / ton CO_2
Equipment Capital Cost	High operating P and T result in large increase in capital cost	Increase of < 20% relative to conventional process
Energy Consumption	Still require significant amount of mechanical compression of CO_2	Consumption of < 0.22 kWh/kgCO_2

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Tasks for BP 1: *Simulation & Experiments*

Task #	Description	Simulation / Experiment	Comments
2	GPS column study and its optimization	Simulation	In process / on schedule/ meet milestone
5	Phase equilibrium data measurement	Experiment	In process / on schedule
6	First absorption column testing	Experiment	In process / on schedule
9	Stability of solvent at high loading and high T	Experiment	In process / on schedule / meet milestone
13	Preliminary techno-economic analysis	Simulation	In process / on schedule / design document generated

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Task 2. GPS Column Study and Optimization

A report entitled:

"Preliminary Simulation of GPS Based Process: Used as Input for Preliminary Techno-economic Analysis"

Has been submitted to Nexant

Items	Conventional MEA	GPS Process
Reaction Heat KJ/kgCO_2	1870	1472
Stripping Heat KJ/kgCO_2	690	156
Stripping Column Total Heat KJ/kgCO_2	2560	1628
Minimum Heat Required KJ/kgCO_2	989	1277
Stripping Column Efficiency (%)	39	78**

** Milestone is 60% efficiency for GPS column

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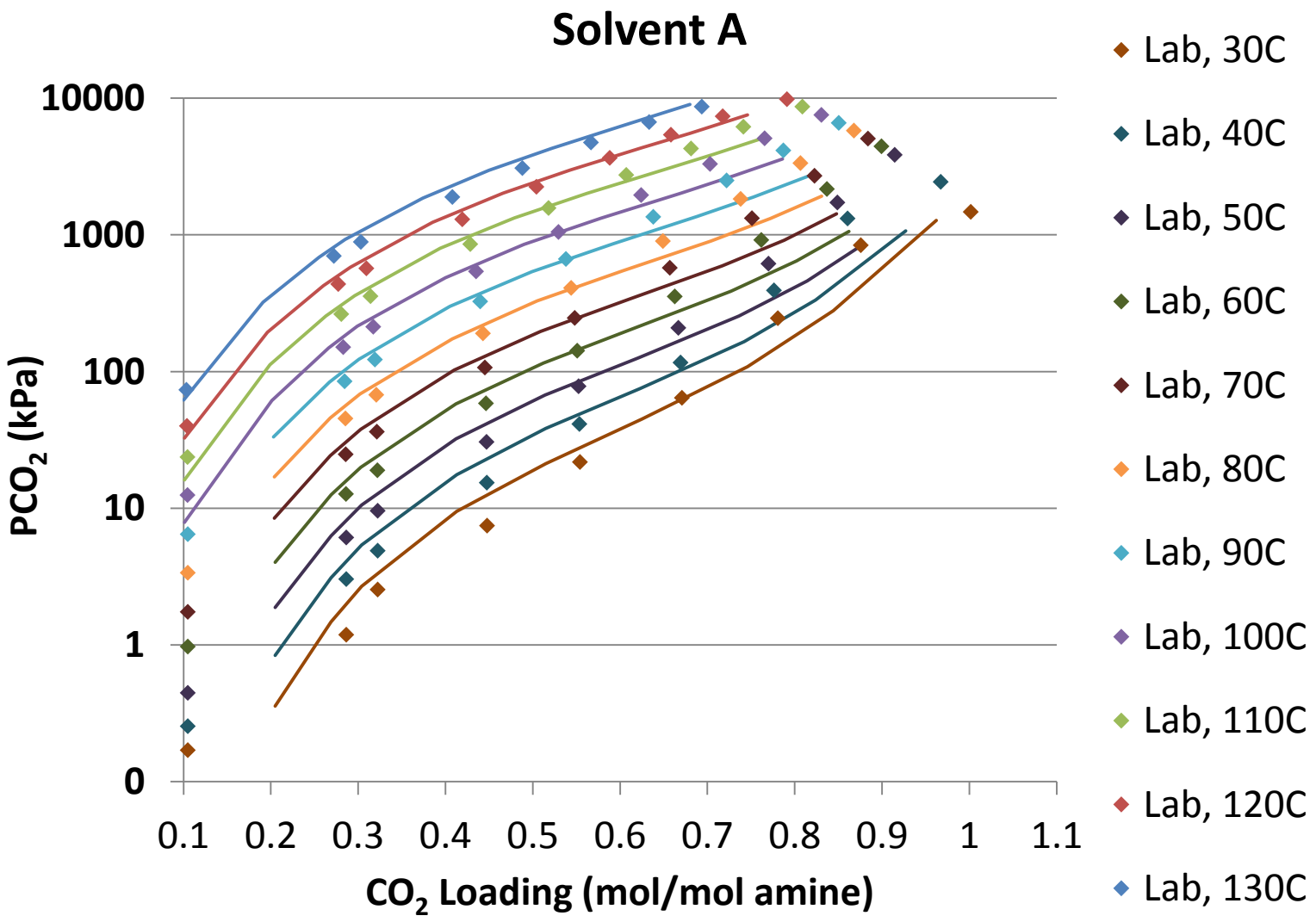
Task 5: Phase equilibrium data measurement



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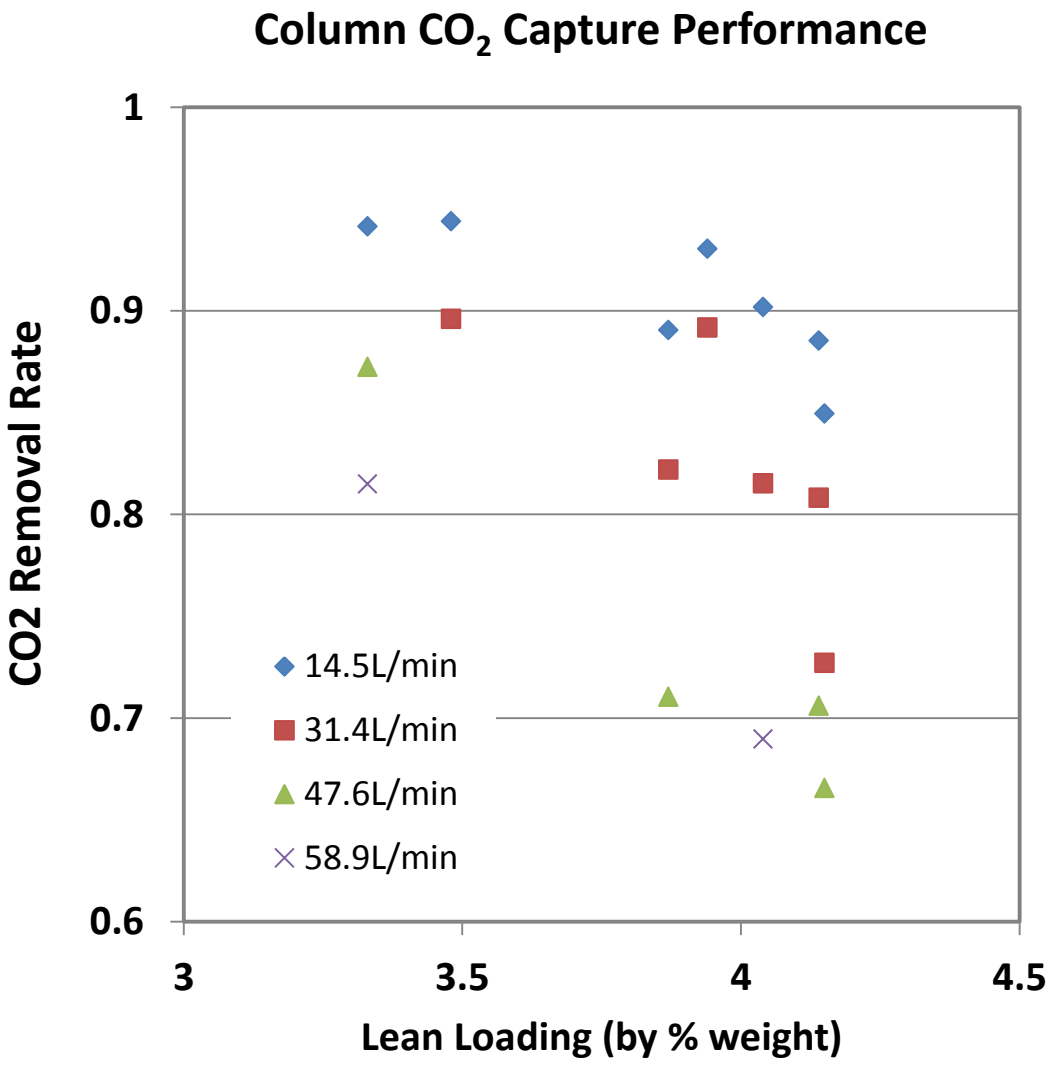
Task 6: First Absorption Column Testing



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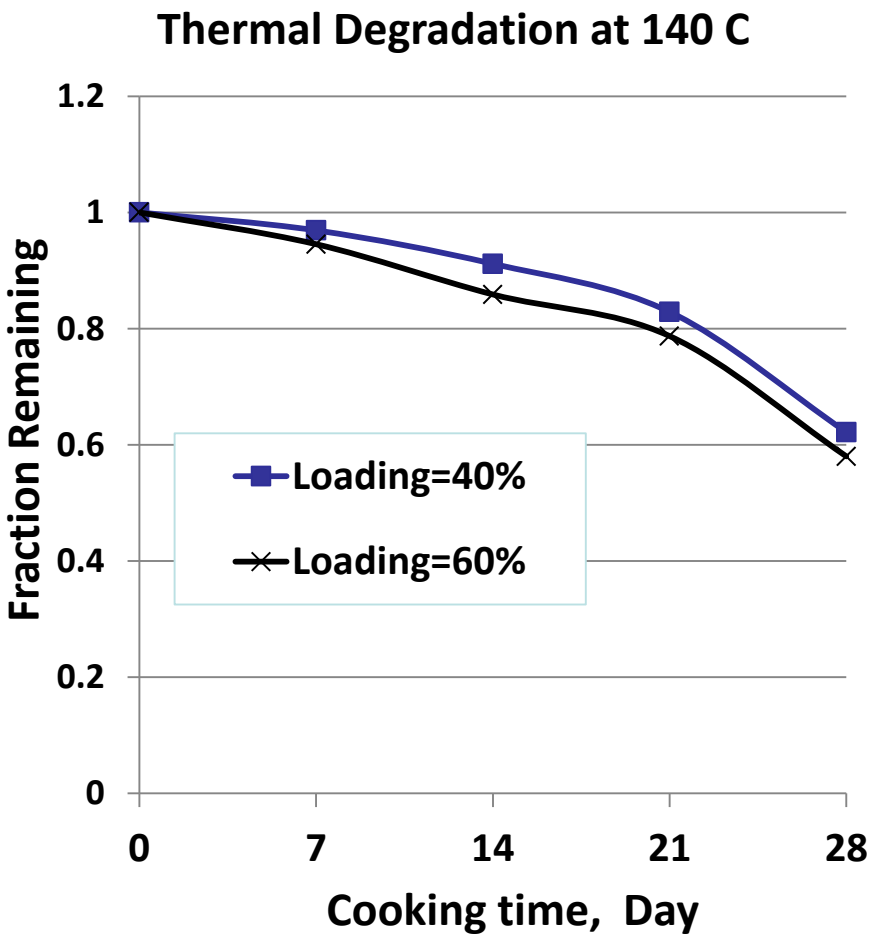
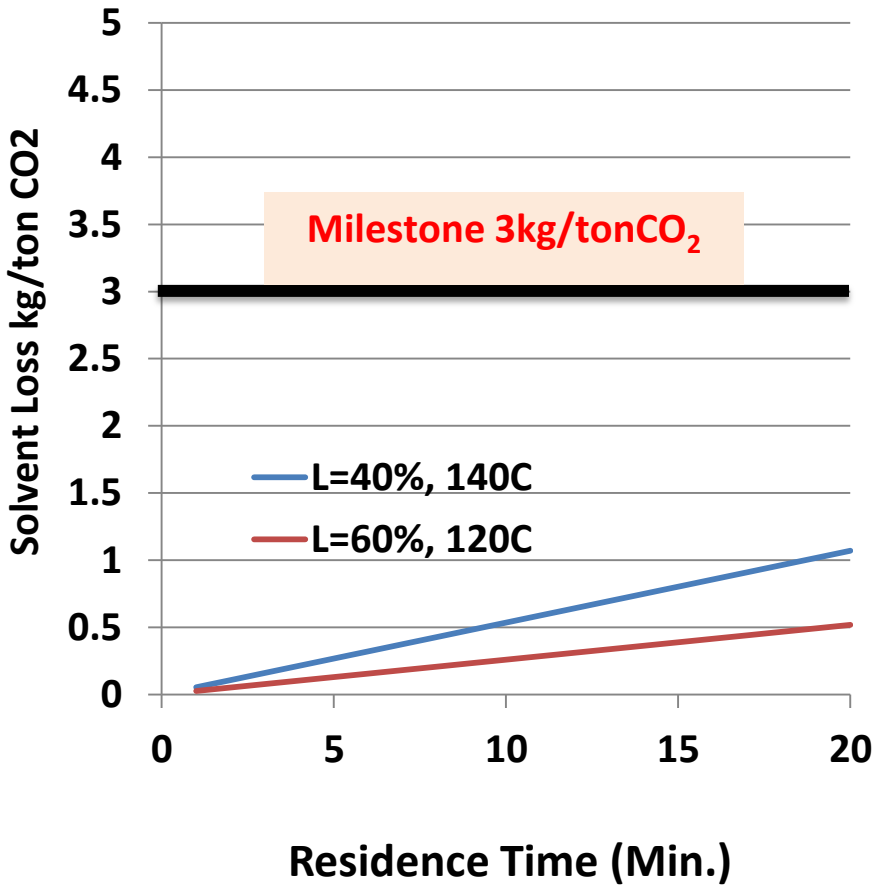
Task 9: Stability of solvent at high loading and high T





Task 13. Preliminary techno-economic analysis

- *"Gas Pressurized Stripping for CO_2 Capture from Post-Combustion Flue Gas – Preliminary Technology Feasibility Study Basis" has been finalized*
- *Techno-economic analyses are in progress*

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Summary of Progress to Date

- Company infrastructure in place, personnel hired and performing tasks
- All experimental testing for BP1 underway and proceeding as planned
- Two milestones for Budget Period 1 have been achieved
  - *GPS column Efficiency of 60%: actual 85%*
  - *Solvent loss 3kg/tonCO_2: actual <1kg/tonCO_2*
- *Financial expenses are all within budget*

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Future Work

Perform Tasks in BP2

Task	Description	Simulation / Experiment
3	Optimization of GPS process for existing plant	Simulation
7	GPS column design/ fabrication and testing	Experiment
10	Corrosion test at high loading and high T	Experiment
14	Revision of techno-economic analysis	Simulation

Prepare for Pilot Scale Tests

- Process design data for GPS based technology

Looking for EOR Opportunities

- GPS technology uses off-the-shelf equipment
- Interested in partnering opportunities

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Acknowledgements

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