EFFICIENT REGENERATION MODULE FOR CARBON CAPTURE SYSTEMS IN NGCC APPLICATIONS

DOE Contract: FE0032135

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SRI International

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Mixed-Salt Process (MSP)

Process Summary

- Uses inexpensive, industrially available material (potassium and ammonium salts)
- No solvent degradation
- Has the potential for easy permitting in many localities
- Uses known process engineering
- Accelerated development possible

Demonstrated Benefits (by testing and modeling)

- Enhanced CO_2 capture efficiency
- High CO_2-loading capacity
- High-pressure release of CO_2 (10-12 bar)
- Reduced energy consumption (~ 2.3 MJ/kg-CO_2 for coal based applications)

Expected Additional Benefits

- Flexible CO_2 capture possible
- > 95% capture possible
- Removes common acid pollutants and particulates

K_2CO_3–NH_3–CO_2–H_2O system

$CO_2(g) \leftrightarrow CO_2(aq)$

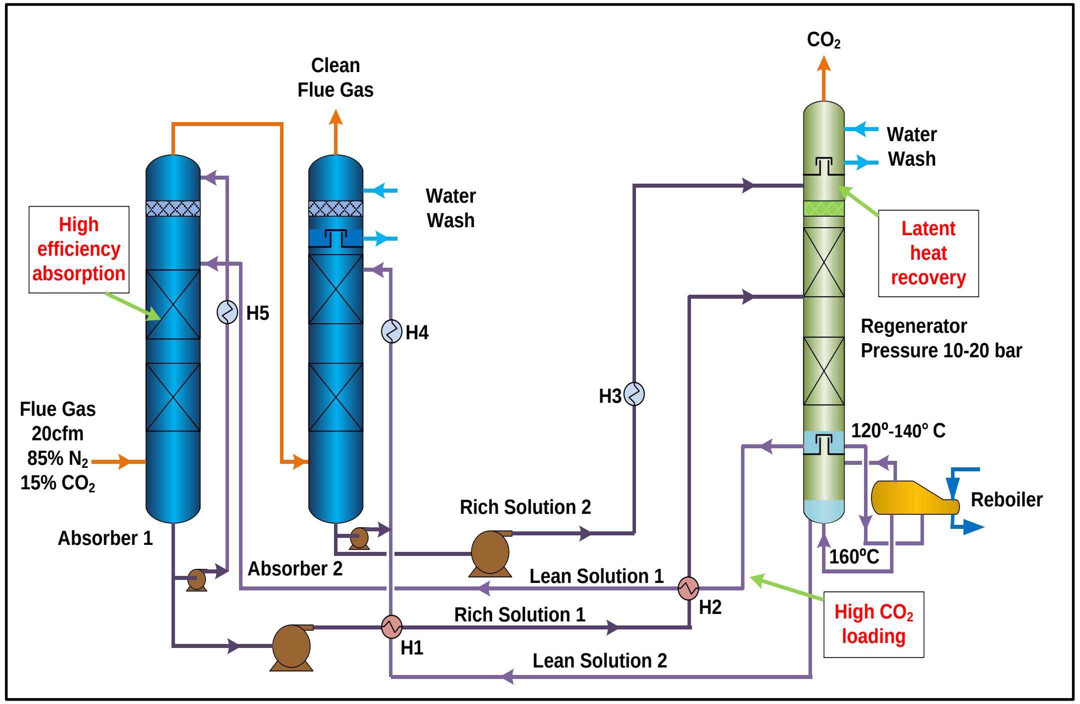
$NH_3(aq) + CO_2(aq) + H_2O(liq) \leftrightarrow (NH_4)HCO_3(aq)$

$(NH_4)_2CO_3 + CO_2(aq) + H_2O\ (liq) \leftrightarrow 2(NH_4)HCO_3(aq)$

$2NH_3(aq) + CO_2(aq) \leftrightarrow (NH_4)NH_2CO_2$

$(NH_4)NH_2CO_2(aq) + CO_2(aq) + 2\ H_2O(liq) \leftrightarrow 2(NH_4)HCO_3(aq)$

$K_2CO_3(aq) + CO_2(aq) + H_2O(liq) + Catalyst \leftrightarrow 2KHCO_3(aq) + Catalyst$



Simplified Process Flow Diagram

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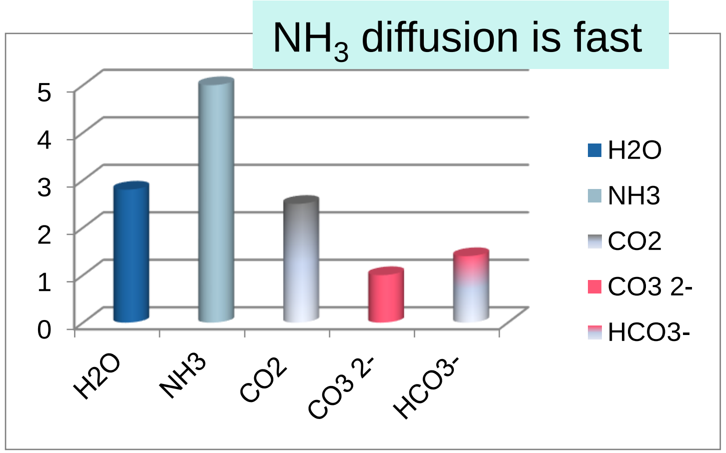
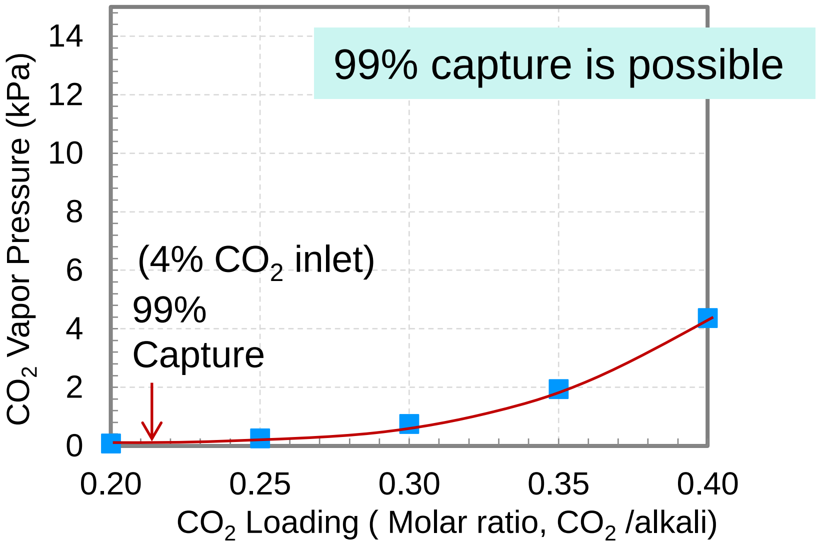
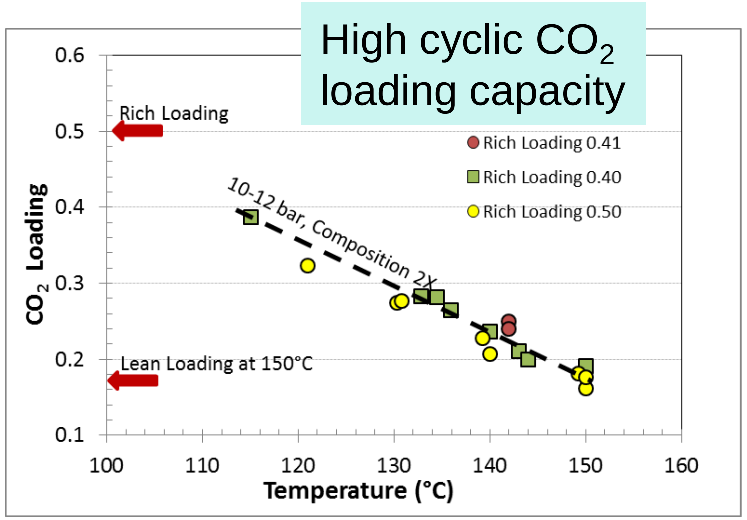
Selected Solvent Properties



Diffusion coefficient (m²/s) in water at 273 K



Vapor pressure of CO_2 as a function of CO_2 loading (7M at 20°C)



Attainable CO_2-lean loading as a function of temperature

Project Objective

+ The project objective is to design, fabricate, and test a highly efficient regeneration module capable of providing a deep-lean absorption solution required for capturing CO_2 from dilute sources such as natural gas (NG) power plants at 95% or better efficiency. Integrating this advanced regenerator module with the absorption modules of the Mixed Salt Process (MSP).
+ We plan to demonstrate significant progress toward a 20% reduction in cost of capture compared to the DOE reference Natural Gas Combined Cycle (NGCC) plant with carbon capture.

Project Scope

The project scope includes:

+ design and modeling of the advanced flash stripper;
+ modeling stripper integration to the MSP system;
+ fabrication of the stripper and auxiliaries;
+ installation and integration of the stripper to the SRI bench-scale system;
+ testing of the advanced stripper at SRI site using a simulated flue gas stream equivalent to about 10 kWe;
+ studying the strategies for producing very highly alkaline lean solvent with minimized emissions;
+ collecting critically important data for a detailed techno-economic analysis (TEA); and
+ updating the State Point Data Table and Technology Maturation Plan (TMP).

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Project Funding and Budget Period

	Budget Period: 1/14/2022 – 1/13/2024	
	Government Share	**Cost-Share**
Project Total	$1,499,759	$375,000*
Funding Source Percentage	80%	20%
* Cost-share provided by Baker Hughes		

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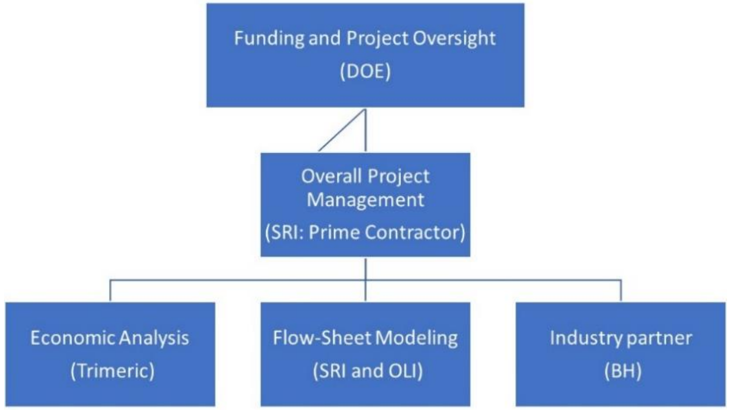
Project Team

Project Manager: Krista Hill, Zachary Roberts (former), NETL

Prime Contractor: SRI International

Project Team: US and International Partners



Work Organization

- SRI International
  - Technology developer
- Baker Hughes
  - Industrial cost-share partner
- OLI Systems
  - Process modeling
- Trimeric Corporation
  - Techno-economic analysis

NATIONAL ENERGY TECHNOLOGY LABORATORY

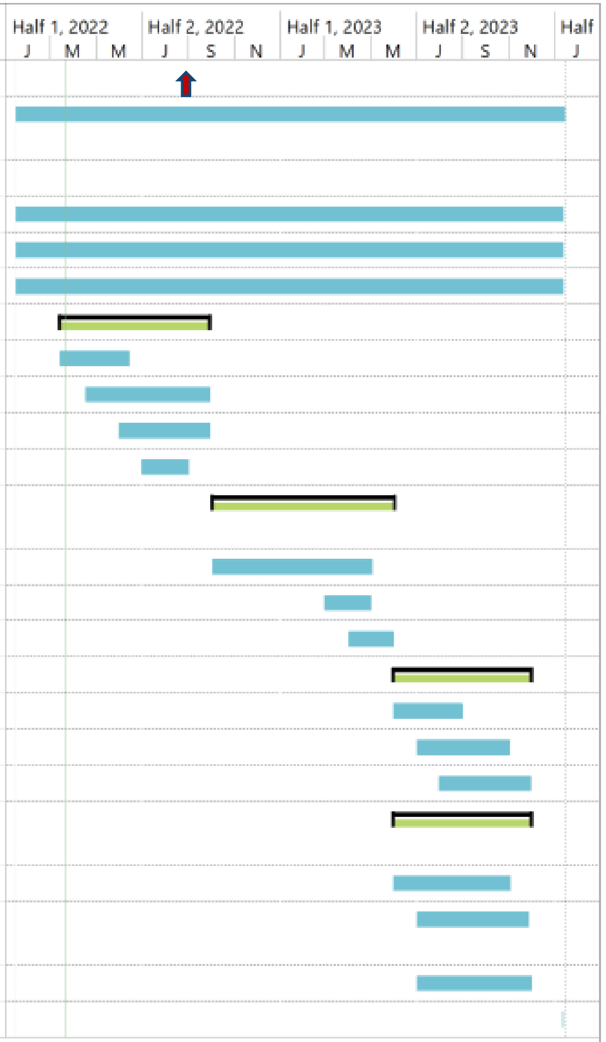
OLI systems, Inc.

Baker Hughes

TRIMERIC CORPORATION

Project Timeline

Task Name	Start	Finish
Highly Efficient Regeneration Module for Carbon Capture Systems in NGCC Applications	**Fri 1/14/22**	**Mon 1/15/24**
TASK 1.0 - Project Management (BP1)	**Fri 1/14/22**	**Fri 1/12/24**
Subtask 1.1 Project Mangement Plan	Fri 1/14/22	Fri 1/12/24
Subtask 1.2 Technology Maturation Plan	Fri 1/14/22	Fri 1/12/24
Task 2.0 - Advanced Stripper Design and Modeling	Mon 3/14/22	Thu 9/29/22
Subtask 2.1 - Advanced Stripper Design	Mon 3/14/22	Tue 6/14/22
Subtask 2.2 – Advanced Stripper Modeling	Mon 4/18/22	Thu 9/29/22
Subtask 2.3 – Integrated System Modeling	Wed 6/1/22	Thu 9/29/22
Task 3.0 – Process HAZOP Evaluation	Fri 7/1/22	Thu 9/1/22
Task 4.0 – Stripper Fabrication, Installation and Shakedown	Mon 10/3/22	Fri 6/2/23
Subtask 4.1 –Stripper Fabrication and Installation	Mon 10/3/22	Wed 5/3/23
Subtask 4.2 –Test Plan Development	Wed 3/1/23	Mon 5/1/23
Subtask 4.3 –Stripper Shake-Down Testing	Mon 4/3/23	Wed 5/31/23
Task 5.0 – Stripper Operation & Data Collection	Thu 6/1/23	Fri 12/1/23
Subtask 5.1 –Initial Steady-State and Dynamic Testi	Thu 6/1/23	Thu 8/31/23
Subtask 5.2 –Parametric Testing	Mon 7/3/23	Thu 11/2/23
Subtask 5.3 –Steam Use Measurements	Tue 8/1/23	Thu 11/30/23
Task 6.0 – Final System Modeling and Techno-Economic Analysis (TEA)	Thu 6/1/23	Fri 12/1/23
Subtask 6.1 –Modeling and Test Data Comparison	Thu 6/1/23	Fri 11/3/23
Subtask 6.2 –Optimized CC Unit Integration with the Power Pant and TEA	Mon 7/3/23	Mon 11/27/23
Subtask 6.3 –Technology Maturation Plan (TMP)	Mon 7/3/23	Fri 12/1/23
Final Report	Fri 1/12/24	Fri 1/12/24



Project kick-off meeting was on 4/1/2022.
We are currently on target to complete the Task 2 milestones on time.

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Large Bench-Scale System at SRI

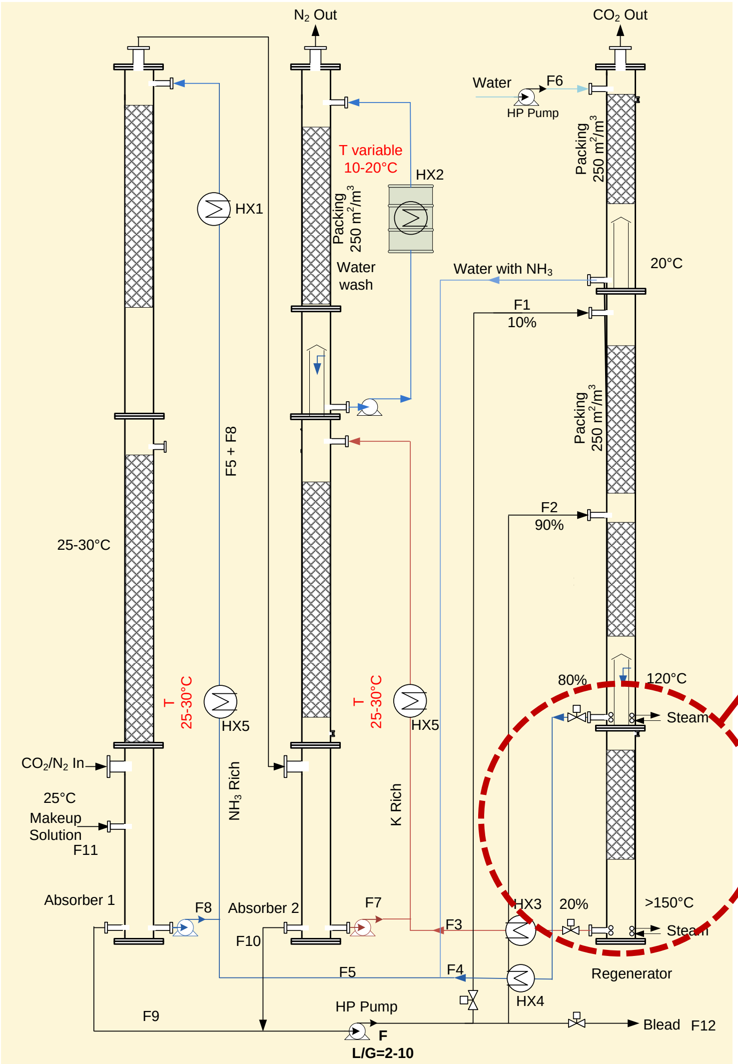
Analytical and Control Systems

Absorbers

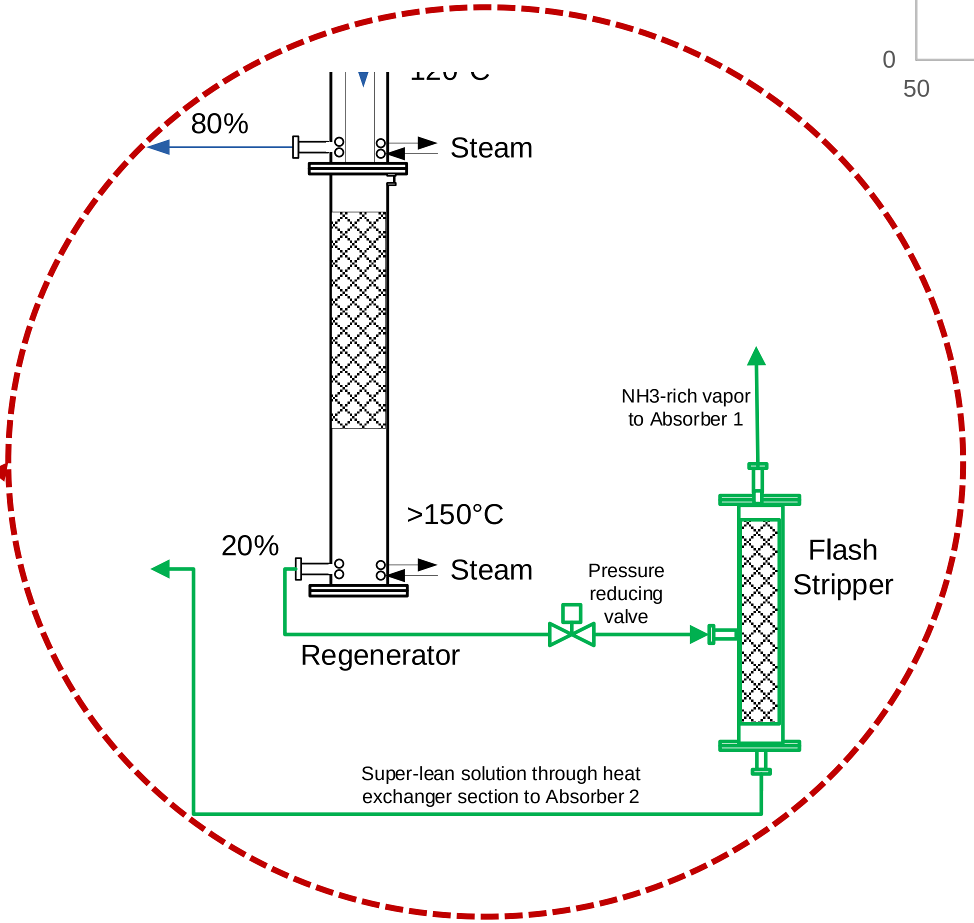
Regenerator

- This system was commissioned in May 2014 (DE-FE0012959)
- Currently being used in A-MSP project (FE0031597) and will be modified for the current project

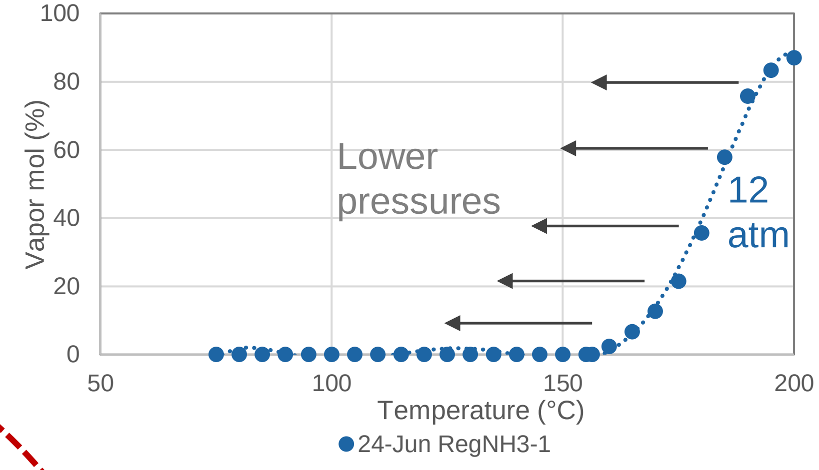
Planned System Modification



Existing System



Proposed Modification



Ammonia vapor pressure as a function of temperature

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Project Work Update

+ Task 1: Project Management and Planning
  - Subcontract and vendor agreements completed
  - Kickoff meeting was on April 2, 2022
  - PMP prepared
  - Preliminary TMP submitted
  - Preliminary EH&S report prepared
+ Task 2: Advanced Stripper Design and Modeling
  - Advanced stripper design is being finalized
  - Currently modeling the integrated system

Prelimi

Project Work Update (Continued)

1. Component modeling to support the design of the advanced stripper to generate an ultra-lean absorption solvent (<0.2 CO_2 loading).

2. Modeling of the advanced stripper integration with the existing large bench CO_2 capture system at SRI

3. Preliminary modeling of the CO_2 capture system integration to the reference NGCC power plant to produce heat and mass balance data

- Mixed-Salt Process simulation with coal flue gas scaled down to SRI bench scale
- First conversion of SRI bench-scale simulation from coal to natural gas flue gas
- Reduction in solvent flow rate to reflect lower CO_2 content of natural gas flue gas
- Optimization of heat exchanger sizing to reduce reboiler duty
- Increased the molarity in lean solution (6 to 8 M)
- Reduction in solvent flow rate to reflect higher molality of lean solution
- Addition of single-stage flash stripper to absorber 2 lean stream

Key parameters varied include - solvent recycle rate, alkaline concentration (6 to 8M), and flash stripper operating temperature and pressure

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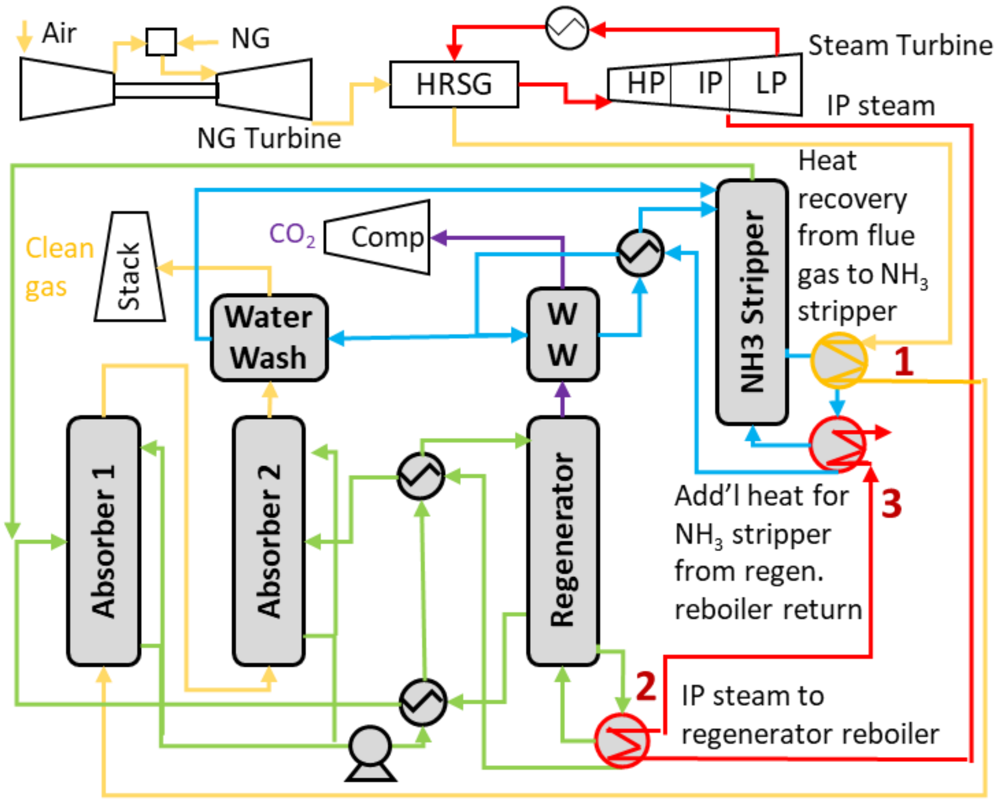
Preliminary Modeling: Integration of the CC System with Power Plant

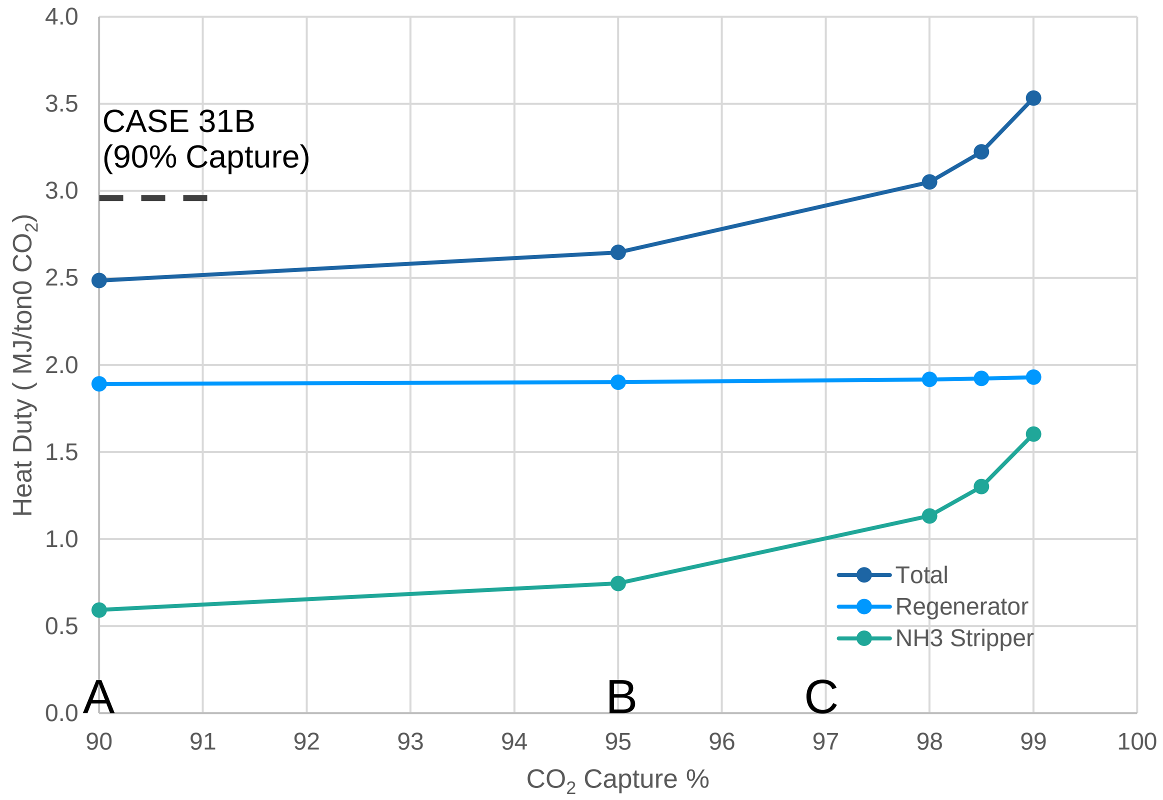


Performance Factors	Cansolv Baseline (Case B31B)	SRI MSP (90%)	SRI MSP (95%)
CO_2 capture, %	90	90.1	95
CO_2 purity, %	98.65	99.4	99.1
CO_2 pressure, atm	2	12	12
CO_2 compression power, MWe	17	10.7	TBD
Reboiler duty, MJ/Kg CO_2	2.9	2.5	~3.0
Steam temperature (°C) and pressure (MPa, abs) for reboiler	308°C; 0.51 MPa	308°C; 0.51 MPa	308°C; 0.51 MPa
Steam flow rate for reboiler, kg/h	259,2	183,3	TBD
Steam temperature (°C) and pressure (MPa, abs) for reclaimer	356°C and 4.28 MPa, abs (HP turbine)	No reclaimer necessary	No reclaimer necessary

Modeling will follow the DOE guidelines provided in- Performing a Techno-Economic Analysis for Power Generation Plants, National Energy Technology Laboratory, DOE/NETL-2015/1726, July 2015. https://netl.doe.gov/energy-analysis/details?id=711

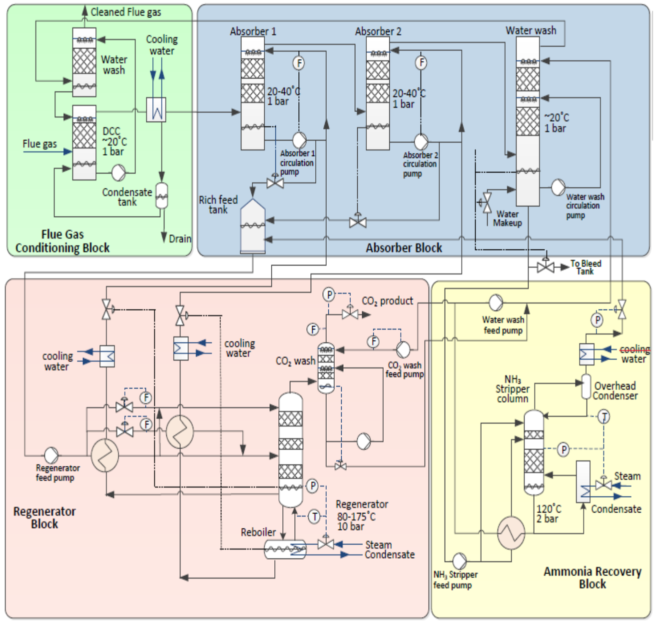
Sensitivity Analysis: CO_2 Capture from NGCC

Current MSP configuration was modeled



Heat duty for MSP with 90-99% CO_2 capture, based on simulations from OLI Systems.

A. Previous goal for CO_2 capture from PCC (90% Capture)
B. Current project goal for CO_2 capture from NGCC for the current project (>95% Capture)
C. Future goal for CO_2 capture from NGCC (>97% Capture)



Block flow diagram

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Project Milestones

We are on schedule to complete the project milestones

BP	Task/ Subtask No.	Milestone Description	Planned Completion
1	1	a. Updated PMP	Completed
		b. Completions of subawards	Completed
1	1	c. Kickoff Meeting	Completed
1	1	d. Preliminary Technology Maturation Plan	Completed
1	2.1-2.3	e. Completion of the advanced stripper design and modeling	9/29/22
1	4.1	f. Advanced stripper fabrication and integration to the large bench system	5/1/23
1	4.3	g. Completion of the advanced stripper shake-down testing	5/31/23
1	5.1 and 5.2	h. Completion of parametric testing; at least 40 runs	11/2//23
	5.3	i. Completion of steam use measurements	11/30/23
1	6.1	j. Completion of modeling of the full flow-sheet and comparison with test data	12/1/23
1	6.2	k. Techno-Economic Analysis (TEA) topical report submitted	12/1/23
1	6	l. Updated State-Point Data Table submitted	12/1/23
1	6.3	m. Technology Maturation Plan topical report submitted	12/1/23
1	1	Draft Final Report submitted	12/1/23

Project Risk Registry

Description of Risk	Probability (Low, Moderate, High)	Impact (Low, Moderate, High)	Risk Management Mitigation and Response Strategies
Technical Risks:			
Precipitation of solids in the absorber during preparing rich solutions for stripper testing	Low	High	Store rich solution in a separate tank overnight; design a standard operating procedure (SOP) to avoid shutdowns with rich solutions.
Residual ammonia in the exit gas stream	Moderate	Moderate	Increase water-wash column freshwater flow to capture ammonia vapor. The mini-pilot system at SRI has already demonstrated this capability.
Condensation of solids in regenerator gas exit lines during long-term operation	Moderate	Low	Ensure proper heat tracing of susceptible lines and control valves. Plan periodic inspections of suspect places and maintain the temperature above the condensation point. SRI has already modeled this in FE0031588.
Resource Risks:			
Delays in procurement of required components for assembling the new stripper	Low	Moderate	Plan ahead with vendors. Place orders early and have backup vendors.
Management, Planning, and Oversight Risks:			
Project team availability	Low	Moderate	Identify backup team members
Financial Risks:			
Cost overruns	Moderate	High	Work closely with the project team to execute the MSP modular system fabrication and installation. Assign a dedicated project administrator (PA), closely monitor expenditures, and report any variations to the DOE PM immediately. Complete exhaustive planning to avoid cost overruns and strictly adhere to the project scope.
EH&S Risks:			
Personal health and safety	Low	High	Prepare SOPs, train operators, and review safety procedures regularly, including use of personal protective equipment (PPE) when working directly with ammoniated solvent.
Accidental release/ spillage of solvent	Low	High	Pressurized equipment will be certified and stamped. All components of the modular system will be tested for functionality and leak tightness with water before introducing solvent to the system.
Residual ammonia in the exit gas stream	Moderate	Moderate	Increase water-wash column freshwater flow to capture ammonia vapor. The mini-pilot system at SRI has already demonstrated this capability.
External Factor Risks:			
Pandemic-related issues	Moderate	High	Create a flexible schedule

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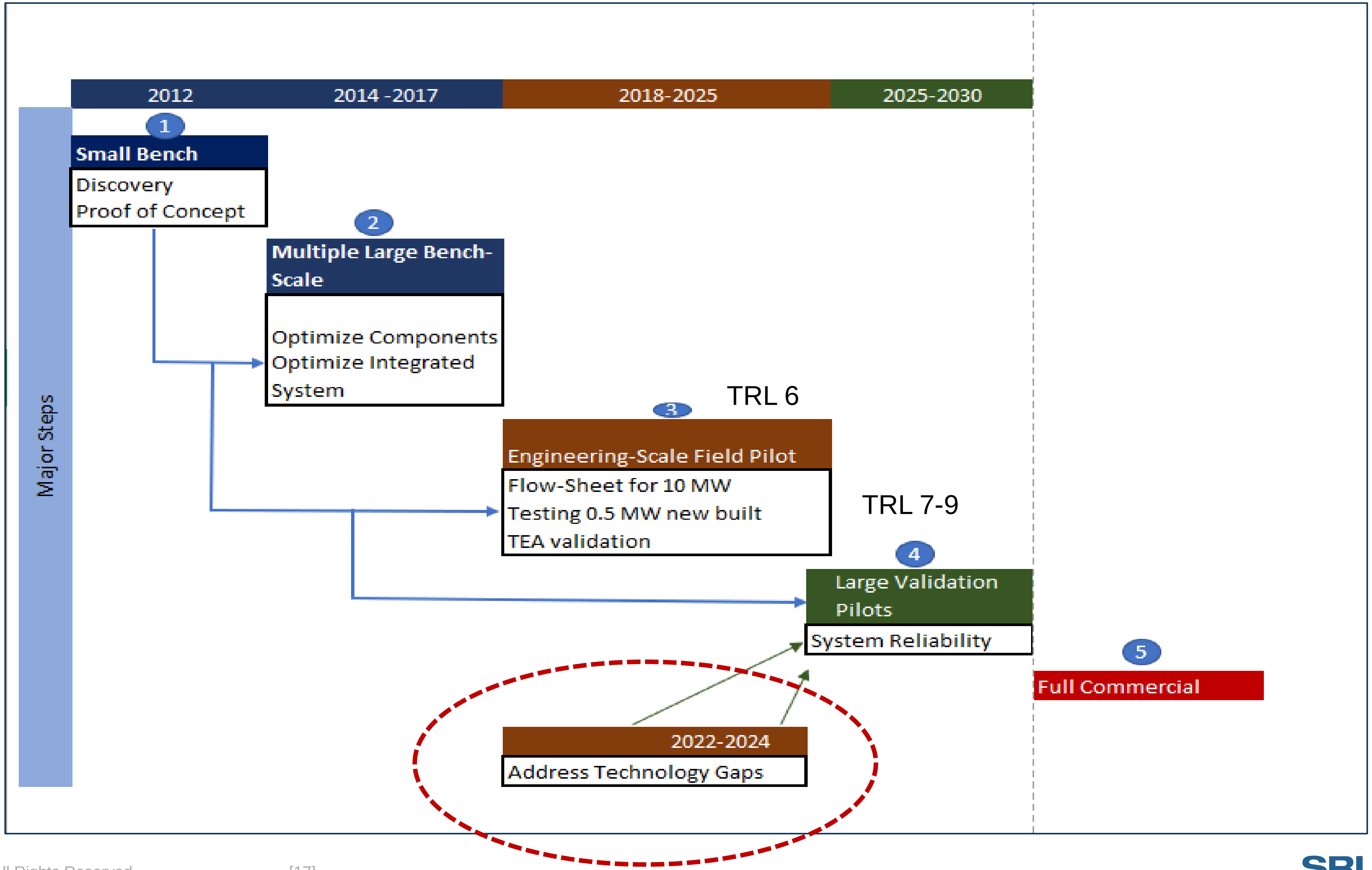
Overall MSP Maturation Plan



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- OLI Systems
- POLIMI
- Stanford University
- Aqueous Application Systems
- Baker Hughes
- IHI Corporation

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Thank you