# Engineering-scale Demonstration of the Mixed-Salt Process (MSP) for $CO_2$ Capture

2024 FECM/NETL Carbon Management Research Project Review Meeting

**PI: Indira Jayaweera, SRI**

**Presented by Elisabeth Perea, SRI**

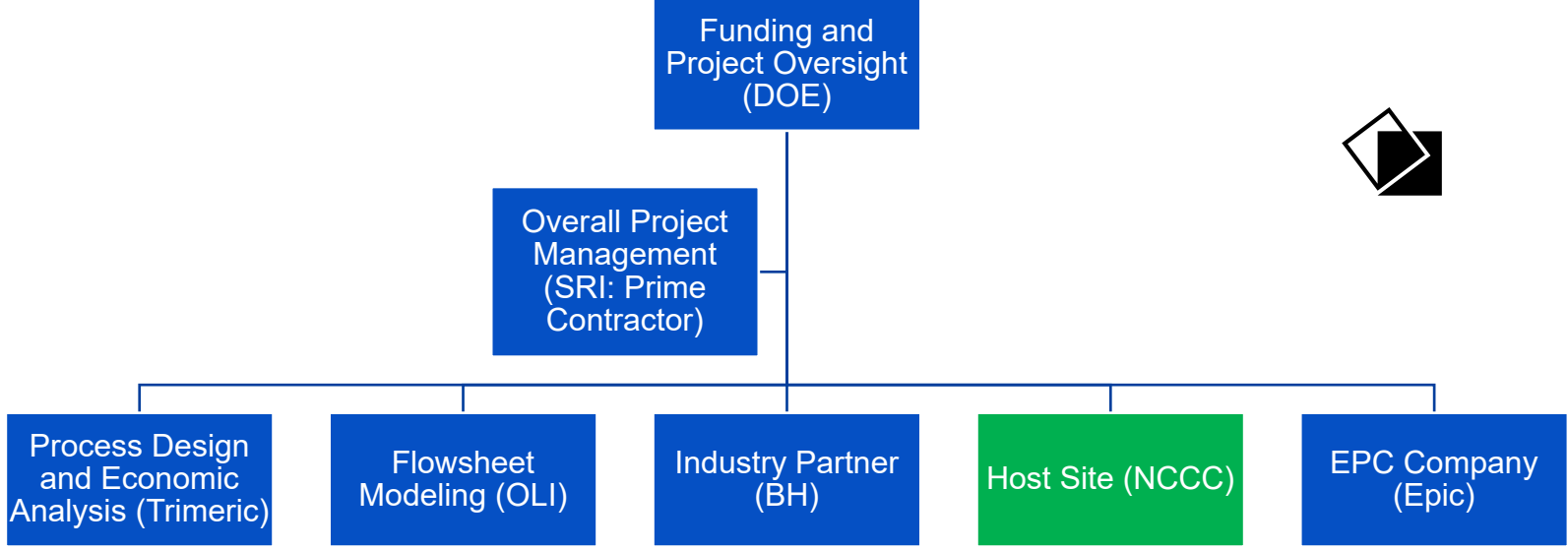
August 7, 2024 2:00-2:15 PM

**DOE Contract # FE0031588**

## Disclaimer:

This presentation includes an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

# Project Overview




**SRI**: Overall project management, procurement, skid testing and operation, data collection and decommissioning of the skid.

**NCCC**: Host-site; provides flue gas, utilities, and skid installation.

**Trimeric Corporation**: Preparation of the Process Design Package (PDP) for the pilot, support the modular fabrication effort and Techno-Economic Analysis (TEA).

**OLI Systems**: Optimization of the process flowsheet for the 0.5 $MW_e$ pilot, and modeling of 550 $MW_e$ (NETL Case B12B) for the power plant integration.

**EPIC Systems**: Modular MSP system fabricator; procurement, construction, and delivery of the modular system.

**Baker Hughes**: Cost-sharing industry partner

NATIONAL CARBON CAPTURE CENTER

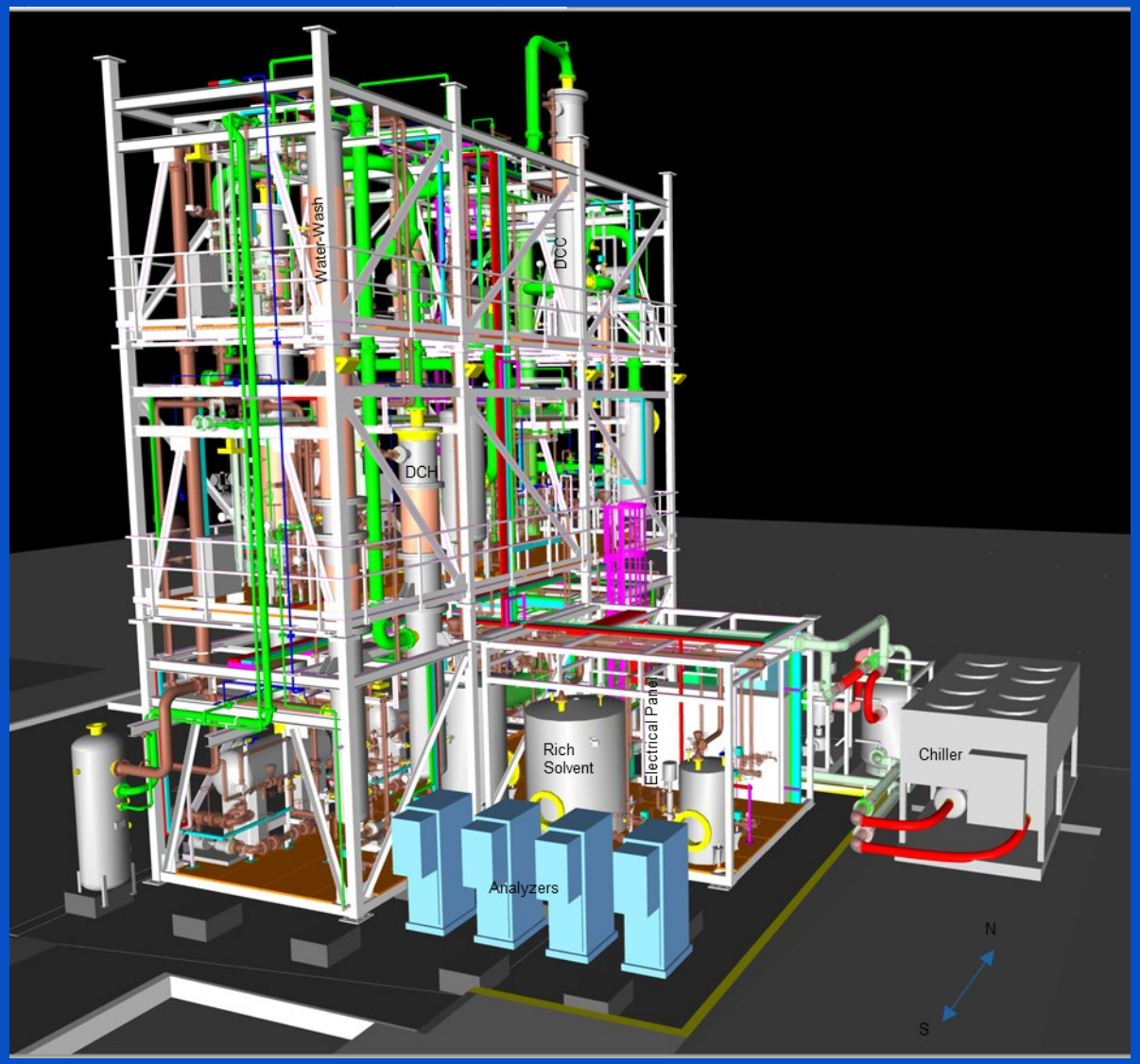
TRIMERIC CORPORATION

Baker Hughes

**Project Period (BP1 to BP5):**
07/01/2018 - 12/31/2025
Total: $21,949,080

**NCCC Project (BP4 and BP5):**
03/1/2022 -12/31/2025
**Project Cost:**
Govt. Share: $13,418,080
Cost Share: $3,710,643
Total: $17,128,723

# Current MSP Project Objectives




- Test at engineering scale (0.5 $MW_e$ equivalent)
- Demonstrate the MSP can capture $CO_2$ at 90%
- Regenerate $CO_2$ with 95% purity
- Long-term testing periods under dynamic and steady state conditions with a real flue gas stream
- Address concerns related to scale-up and integration of the technology to coal-based power plants
- Determine the pathway to reaching DOE targets for $CO_2$ capture costs

# Mixed-Salt Process (MSP) Technology Background

## 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

- Capture from low-concentration $CO_2$ sources
- > 95% capture possible
- Removes common acid pollutants and particulates

### $K_2CO_3$–$NH_3$–$CO_2$–$H_2O$ system

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

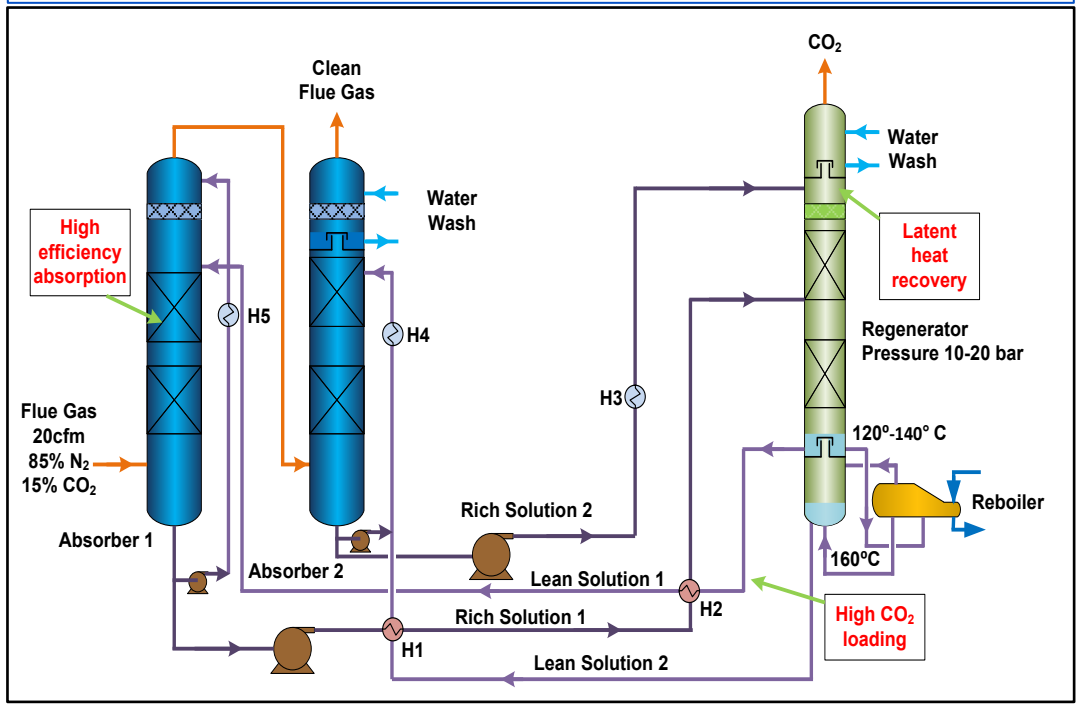
$$NH_3(aq) + CO_2(aq) + H_2O(liq) \leftrightarrow (NH_4)HCO_3(aq)$$

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

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

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

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

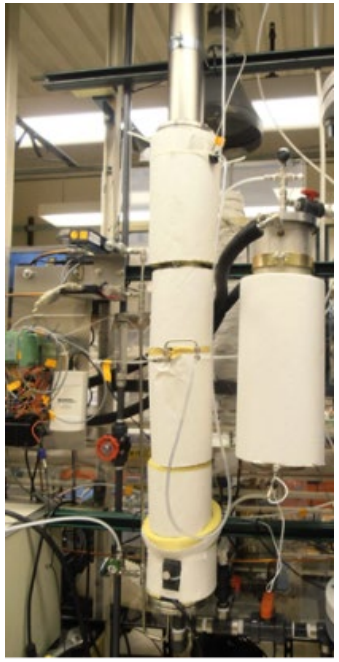



Simplified Process Flow Diagram

# Advanced Ammonia Technology Background

## Ammonia technology developed at SRI in 2004
## MSP technology development started at SRI in 2012

SRI, Menlo Park



Bench-scale Absorber

Regenerator

2012-2014

IHI Research Center, Yokohama, Japan (IHI)

Large Bench-scale

2016

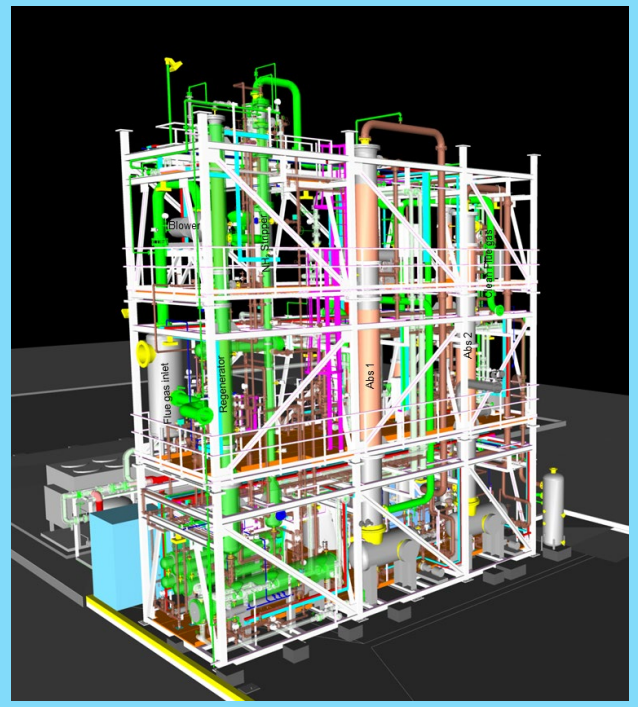
SRI, Menlo Park

Large Bench-scale

2015-2017

DOE Contract: DE FE0012959

**MSP Engineering Pilot**
**NCCC**



2018 - 2025

DOE Contract:DE-FE0031588

**SRI has patent coverage for the MSP in the US, Japan, and Europe**

SRI has entered into a **global exclusive licensing agreement** with Baker Hughes for MSP use for post-combustion $CO_2$ capture in 2021 (https://netl.doe.gov/node/10671), and this partnership will pave the pathway for early entry of the technology into the market.

# BP4 and BP5 Work Update and Schedule

| *Activity* | *Start Date* | *End Date* | *Task #* |
|---|---|---|---|
| **BP4** | | | |
| Bid Request Period | February 24, 2023 | April 7, 2023 | Subtask 8.1 |
| Bid Evaluations and Award | April 7, 2023 | May 12, 2023 | Subtask 8.1 |
| Contract Execution | May 15, 2023 | June 27, 2023 | Subtask 8.2 |
| Engineering & Procurement | June 28, 2023 | August 9, 2024 | Subtask 8.1-8.2 |
| Skid(s) Fabrication | November 6, 2023 | August 9, 2024 | Subtask 8.3 |
| Skid Prep & Delivery | August 19, 2024 | September 4, 2024 | Subtask 8.3 |
| On-site Installation | September 4, 2024 | October 31, 2024 | Subtask 9.2 |
| Shakedown & Pre-Commissioning | November 15, 2024 | December 31, 2024 | Subtask 9.3-9.4 |
| **BP5** | | | |
| Commissioning | January 1,2025 | February 14, 2025 | Task 11 |
| Pilot testing | February 18,2025 | August 31,2025 | Task 12 |
| Decommissioning | December 1, 2025 | December 31, 2025 | Task 13 |
| | | | |

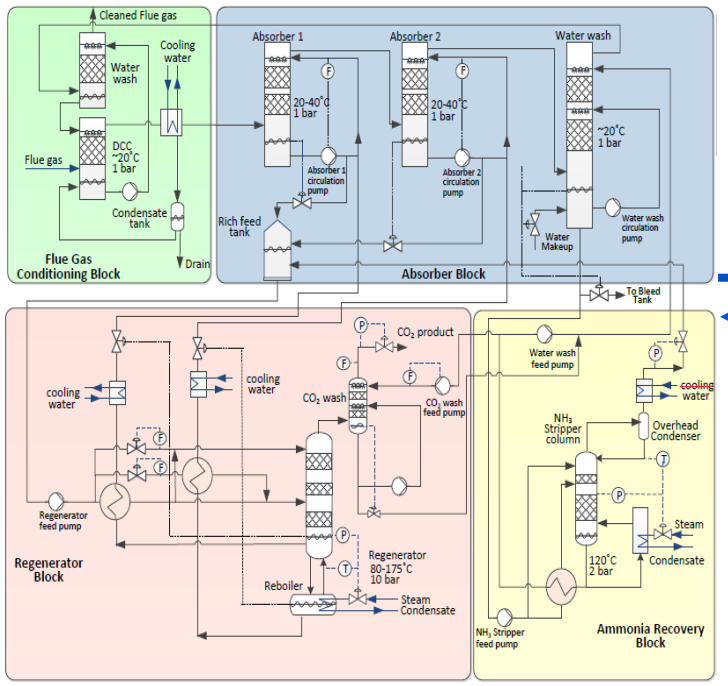
In Progress

- SRI received DOE GO decision for the “Modular System” testing at NCCC site on May 22, 2024.
- SRI received the NCTE to extend BP4 from 7-31-2024 to 12-31-2024.

# Engineering Scale Pilot Design

**OSBL: From NCCC**

Flue gas supply/return, process water, nitrogen, instrument air, electricity




**ISBL: SRI**

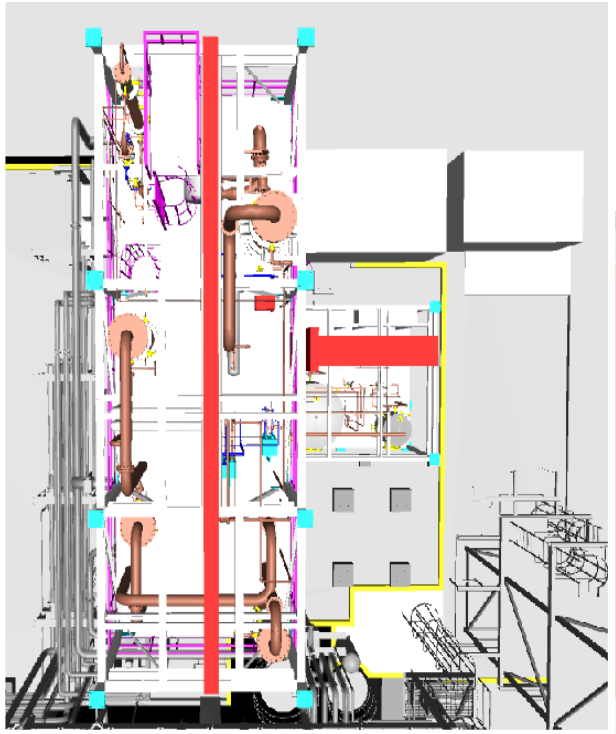
**Process Supporting Equipment**

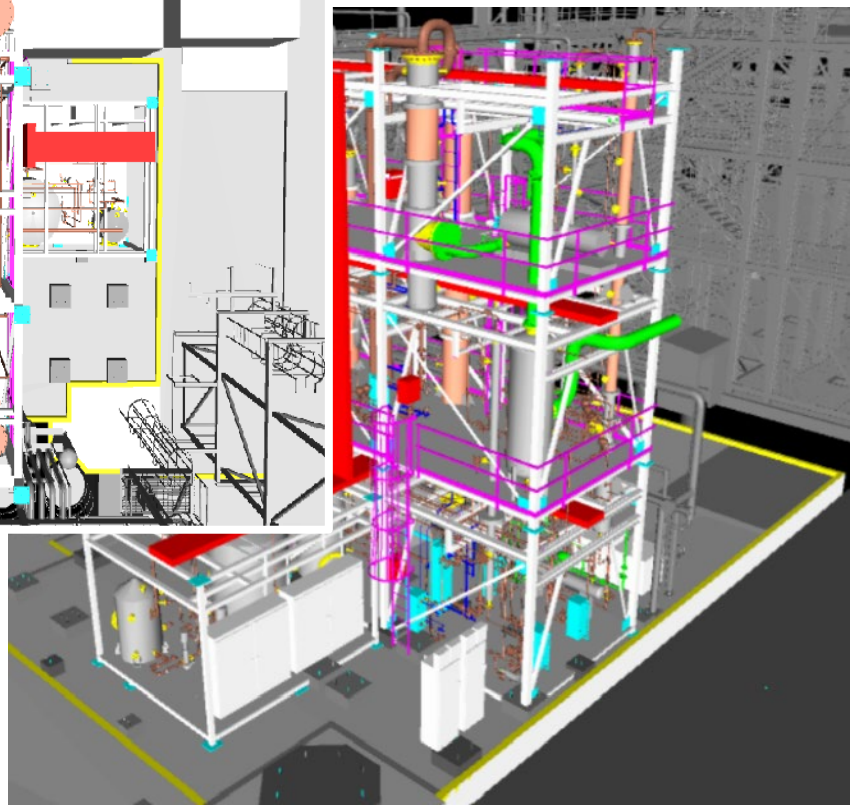
- Gas analyzers
- Vent header/knockout tank
- Solvent make-up ($NH_3$)
- Vent gas conditioning makeup($H_2SO_4$)
- Chilled water (rental chiller)

**Process Skid**

- Flue gas and vent gas conditioning
- $CO_2$ absorption and water wash
- Solvent regeneration, $CO_2$ product wash, and solvent heat exchange
- Ammonia stripping and recovery

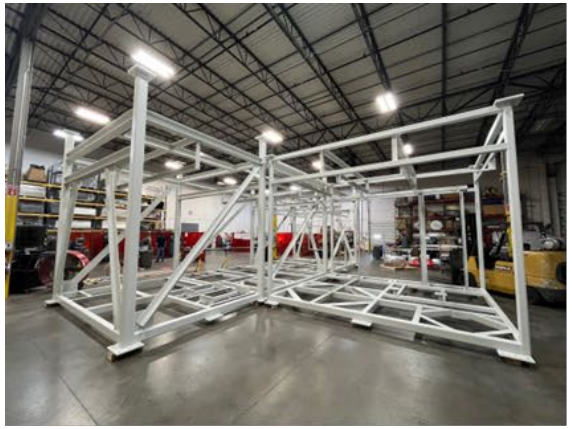
System Layout at NCCC Bay 2
(~10 TPD $CO_2$ Capture)





# Skid Progress

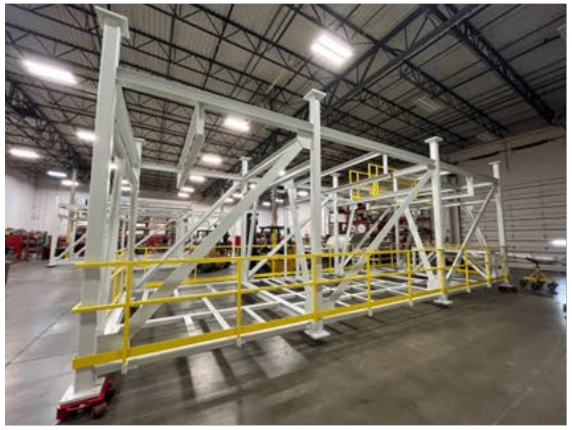
## May 2024



Blower

Large bore SS piping

Large bore CS piping



Frames (4-skids)

Tanks

Various SS values and piping

# Skid Progress

## June 2024




Level 1


Levels 2- 3


Level 3

# Skid Progress

## July 2024

Skids 1 and 4 (from the S-W corner)

Completed Skid 2

# Lessons Learned

- The details of connections between the site and process should be clearly defined at project onset to avoid having to fill gaps later
  - Flue gas, steam lines, auxiliary equipment
- Close collaboration between all parties (host site, EPC, technology developer) is essential to resolve issues quickly
- Leaving room initially for future changes/additions to the system design will minimize the impact of change orders
  - Extra electrical capacity to power add-on equipment
  - Extra I/O ports to accommodate added sensors

# Test Plan

| Parameter to vary | Possible Range of Variation | Metric(s) |
|---|---|---|
| **Flue gas flow rate** | Flow rate through T101: 75-100% of design capacity | Overall $CO_2$ capture rate, Energy consumption |
| **Regenerator (T-310) temperature** | 160° to 175°C | Overall $CO_2$ capture rate, $CO_2$ desorption, Steam flow rate, Energy consumption |
| **Rich solvent flow from rich tank (TK-300) to regenerator (T-310)** | Flow rate through P-300: 75-100% of design capacity | Overall $CO_2$ capture Rate, L/G Ratio, Energy consumption |
| **Recycle flow rate in Absorbers 1 and Absorber 2 (T-210 and T-220)** | Flow rate through P-210: 75-100% of design capacity<br>Flow rate through P-220: 75-100% of design capacity | $CO_2$ capture rates in Absorber 1 and Absorber 2 |
| **Regenerator steam flow rate** | 0-100% of design capacity | Overall $CO_2$ capture rate, $CO_2$ desorption, Energy consumption |
| **NH3 stripper (T-510) reboiler temperature** | E-550 75-100% of full power | Ammonia stripping efficiency, Energy consumption |
| **Water wash column (T-230) recycle rate** | Flow rate through P-230: 75-100% of design capacity | Ammonia removal efficiency |
| **$CO_2$ wash column (T-410) recycle rate** | Flow rate through P-420: 75-100% of design capacity | $CO_2$ purity |
| **$H_2SO_4$ feed rate** | 1 to 1.5 lb/hr | ppmv contaminant removal from the clean flue gas |

**Parametric testing:**

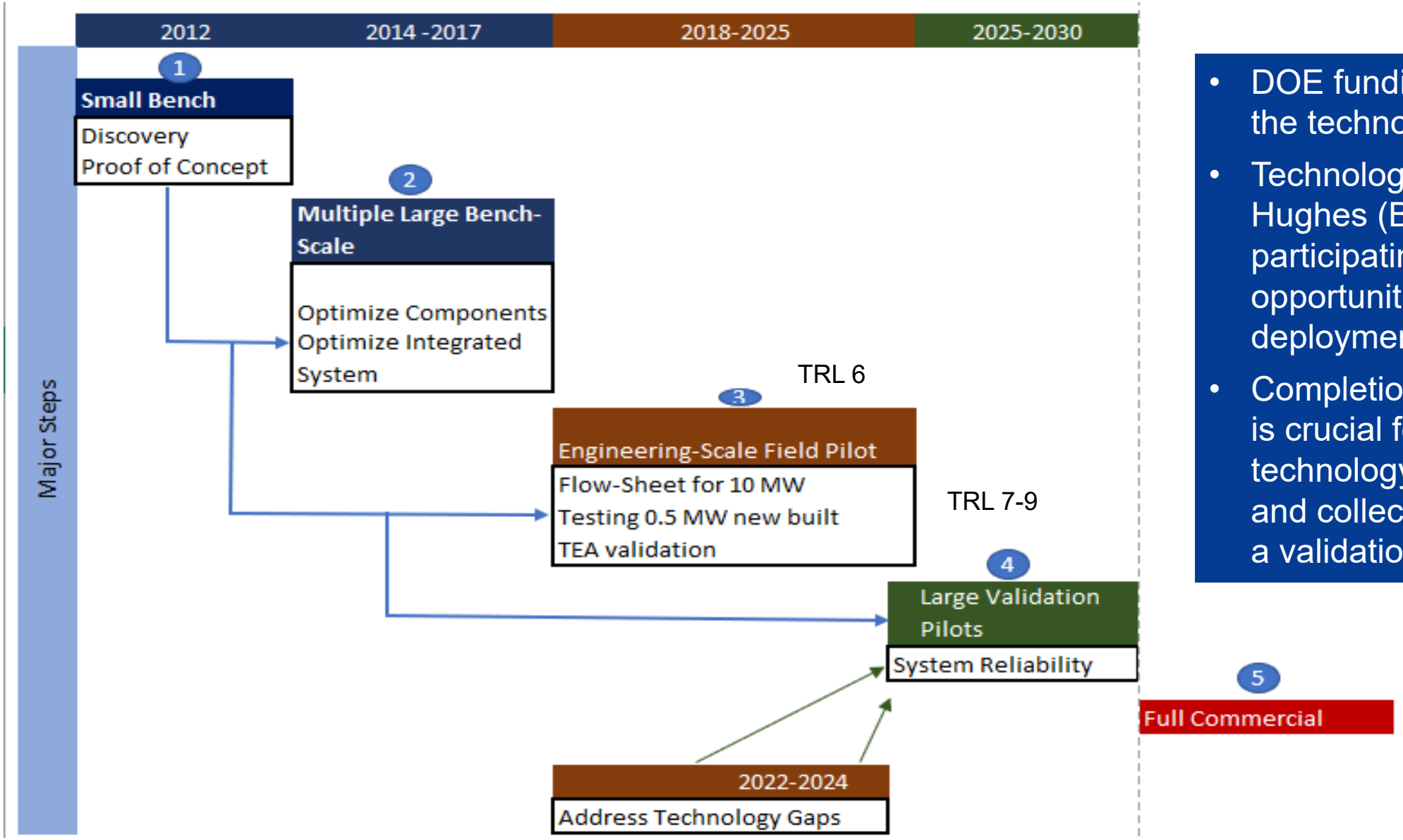
- Test the sensitivities of key parameters on the performance.
- Performance is assessed by measuring the response variables for each run:
  - $CO_2$ Capture Efficiency (%)
  - Reboiler Duty (kJ/kg $CO_2$)
  - Ammonia Emissions (ppm)

**Dynamic testing: Investigate the system's response and performance under transient and ramp operations**

- Cold and warm starts
- Step changes in conditions such as flue gas composition and flow rate

| | Range | Baseline |
|---|---|---|
| Inlet $CO_2$ | 4 to 12.9% | 12.9% |
| Capture Efficiency (%) | TBD | 90% |
| L/G | 1.4 to 2.5 | 1.88 |

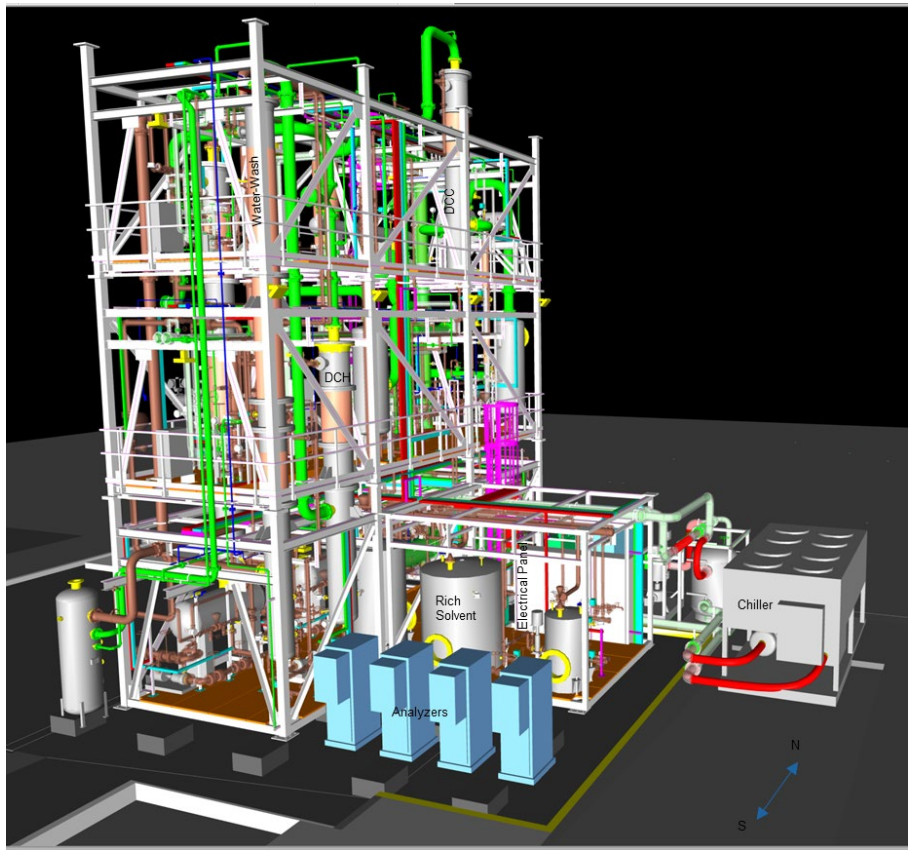
# Technology Maturation Plan




- DOE funding is critical for getting the technology to market
- Technology licensee Baker Hughes (BH) is actively participating in finding opportunities for technology deployment
- Completion of the current project is crucial for demonstrating the technology's competitiveness and collecting data for designing a validation pilot

# Summary

- Expected delivery of skid to NCCC in 1 month
- Mixed Salt Skid operations will commence in Fall 2024 with full test plan to be carried out in 2025




Design becoming reality!

# Acknowledgements


- Krista Hill, Andrew Jones, Jose Figueroa, Dan Hancu, Lynn Brickett, and others at NETL
- NCCC team
- Epic Systems team
- Trimeric team
- OLI Systems team
- BH team
- SRI team led by Dr. Indira Jayaweera

# Thank you!

**Contact:**

**Dr. Indira Jayaweera**

indira.jayaweera@sri.com

1-650-859-4042