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First computer mouse

Created “Siri” for i-phone

Engineering-Scale Demonstration of the Mixed-Salt Process (MSP) for CO_2 Capture

DOE Contract: DE-FE0031588

Presented by: Indira Jayaweera, Sr. Staff Scientist and Sr. Program Manager

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NATIONAL ENERGY TECHNOLOGY LABORATORY

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  - Founded by Stanford University in 1946
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- Mission : To change the world by making people safer, healthier, and more productive!

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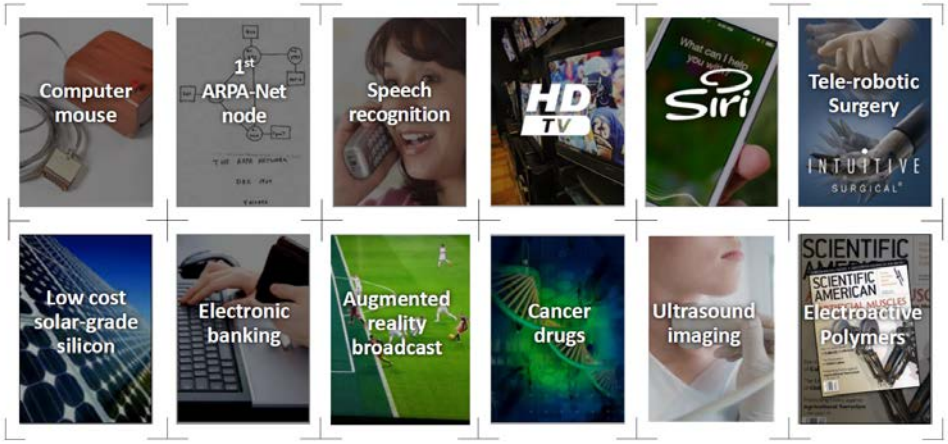

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SRI Ventures is the commercialization arm of SRI International. We have created and launched more than 70 ventures with a total market capitalization of over $20 billion. Over 33% of our companies have had successful exits.

In 2017, we launched 7 startups and they raised over $60 million.

In 2018, we launched 7 successfully-funded startups

Portfolio Companies

Project Background and Technology

CAP Plant at Technology Center Mongstad (TCM)

MSP engineering demonstration at TCM is a critical step in the road map to scale-up

Source: https://www.norskpetroleum.no/wp-content/uploads/TCM_Mongstad_foto_Helge_Hansen_Statoil_1440_480-1440x480-c-default.jpg

Project Objectives

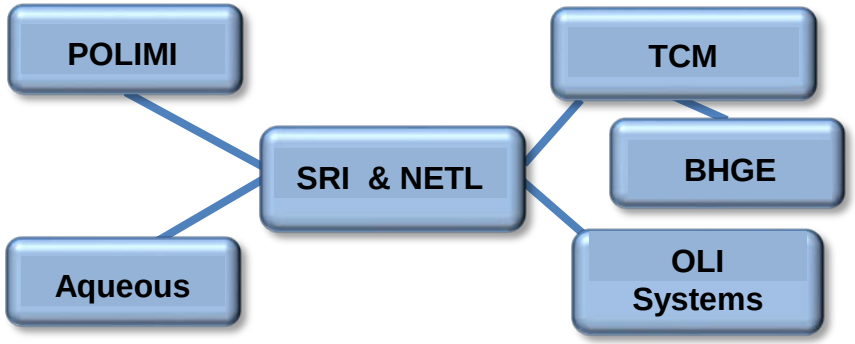
(DOE Contract: FE0031588)

- Perform integrated MSP testing at engineering scale for long-term periods under dynamic and continuous steady-state conditions with a real flue gas stream to address concerns relating to scale-up and integration of the technology to coal-based power plants;
- Operate the MSP with advanced heat integration to improve the process efficiencies;
- Study the solvent and water management strategies; and
- Collect critically important data for a detailed techno-economic analysis (TEA) and for further process advancements to reach the DOE's goal of \$30/tonne of CO_2 by 2030.

Key Focus:
(1) Process optimization, energy efficiency, chemical consumption and low emissions
(2) Dynamic and steady-state operations

Project Team

DOE Project Manager: Andrew Jones
Prime Contractor: SRI International
Project Team: US and International Partners
Project Value: ~ $22 M
(DOE funding:$13 M and TCM in-kind cost-share: $9 M)
Period of Performance: 7/1/18 to 7/31/21



- TASK 1.0 (BP1,BP2 & BP3) - Project Management and Execution
- Task 2 (BP1) – Detailed investigation of required changes to the TCM CAP Plant to run MSP
- TASK 3.0 (BP2) - Re-commissioning of the CAP Pilot at TCM
- TASK 4.0 (BP2) - System Modification, Modeling and Initial Testing
- TASK 5.0 (BP3) - Dynamic and Steady-state Testing of MSP
- TASK 6.0 (BP3) - Process Economics, Technology Gaps and Technology Maturation
- TASK 7.0 (BP3) - Environmental, Health and Safety (EH&S) Assessment
- TASK 8.0 (BP3) – Pilot plant shutdown and Project Closure

Work Organization

SRI International
- Technology provider

Technology Center Mongstad (TCM), Norway
- Host site and cost-share partner

Baker Hughes, a GE company (BHGE), Norway
- Process HAZOP

OLI Systems, USA
- Process modeling

Aqueous Systems Aps, Denmark
- Thermodynamic modeling

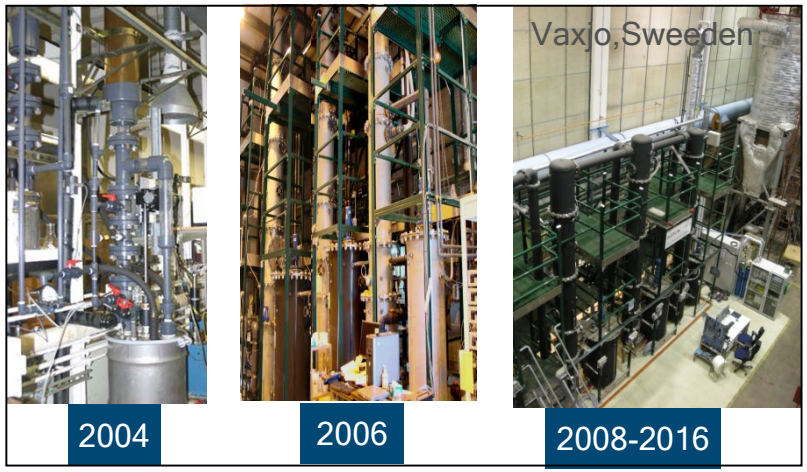
POLIMI, Italy
- Techno-economic analysis

MSP Developments

Small bench to mini-pilot to large pilot

Ammonia technology development started at SRI in 2004

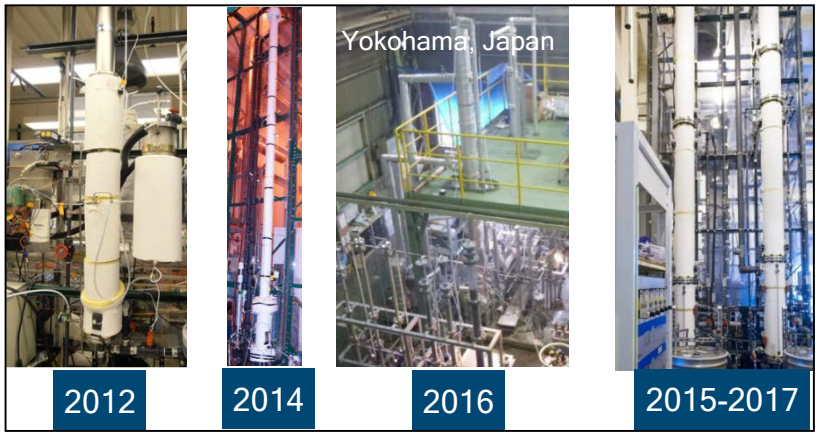
Chilled Ammonia Process (CAP)



CAP Validation at TCM

Step change

Mixed-Salt Process (MSP)



MSP Testing at TCM
DE-FE0031588

MSP scale-up development was funded by DOE under DE-FE0012959
MSP proof of concept development was funded by IHI, Japan

Mixed-Salt Process (MSP)

How it works:

Selected composition of potassium carbonate and ammonium salts

- Overall heat of reaction 35 to 60 kJ/mol (tunable)
- Excellent solvent physical properties

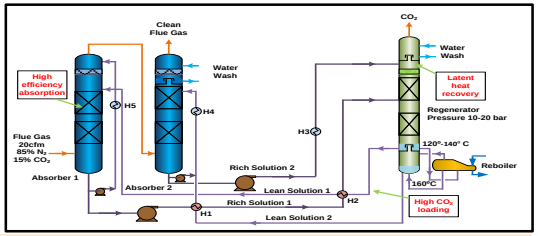
Absorber operation at 20° - 40° C at 1 atm with 30-40 wt.% mixture of salts

Regenerator operation at 120° - 160° C at 10-15 atm

- Produce high-pressure CO_2 stream

K_2CO_3–NH_3–CO_2–H_2O system

High CO_2 cycling capacity



Process Highlights:

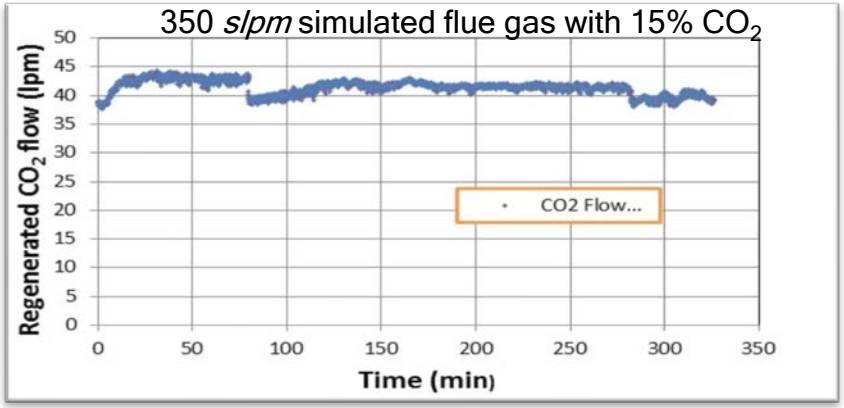
- Reduced ammonia emissions
- Enhanced efficiency
- Reduced reboiler duty
- Reduced CO_2 compression energy

A SIGNIFICANT PARASITIC POWER REDUCTION COMPARED TO MEA !

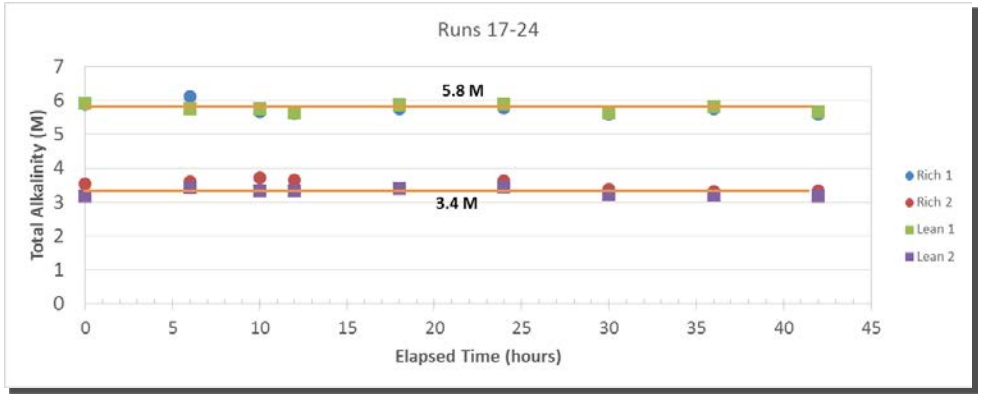
MSP Mini-pilot at SRI

Examples of Steady-State and Dynamic Testing of the Large Bench (mini-pilot)

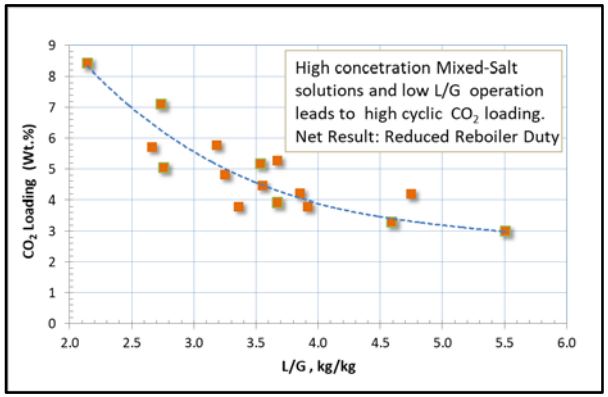
Results from FE0012959



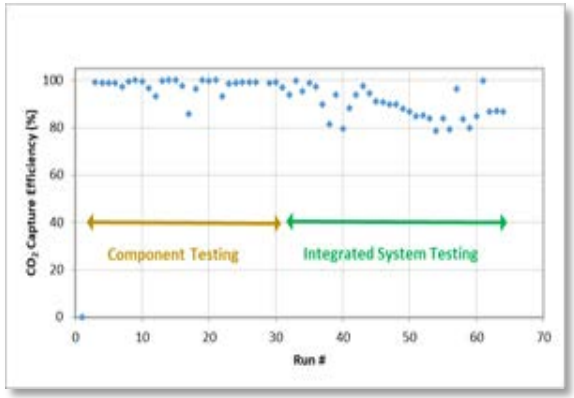
Observed 90% capture efficiency and regeneration with cyclic loading of ~0.7 mole of CO_2/mole of ammonia



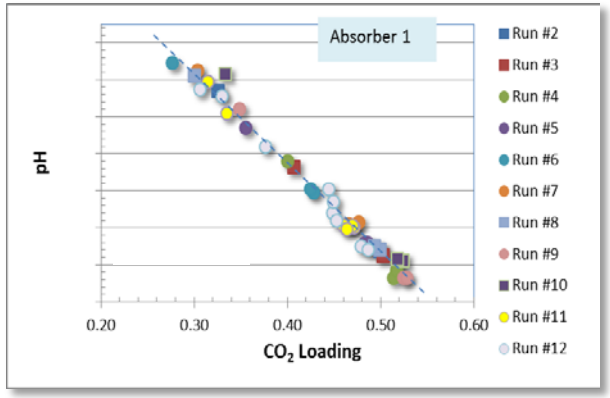
Alkalinity of rich and lean solutions circulating in the integrated system



Observed CO_2 loading as a function of L/G



CO_2 capture efficiency in parametric test runs



Observed pH as a function of CO_2 loading

Absorber: 20-35°C; Regenerator : 140°C; Reboiler: 160°C;L/G = 2 to 6 (kg/kg); Solvent composition: 5 to 8 m

MSP Summary and Benefits

Process Summary

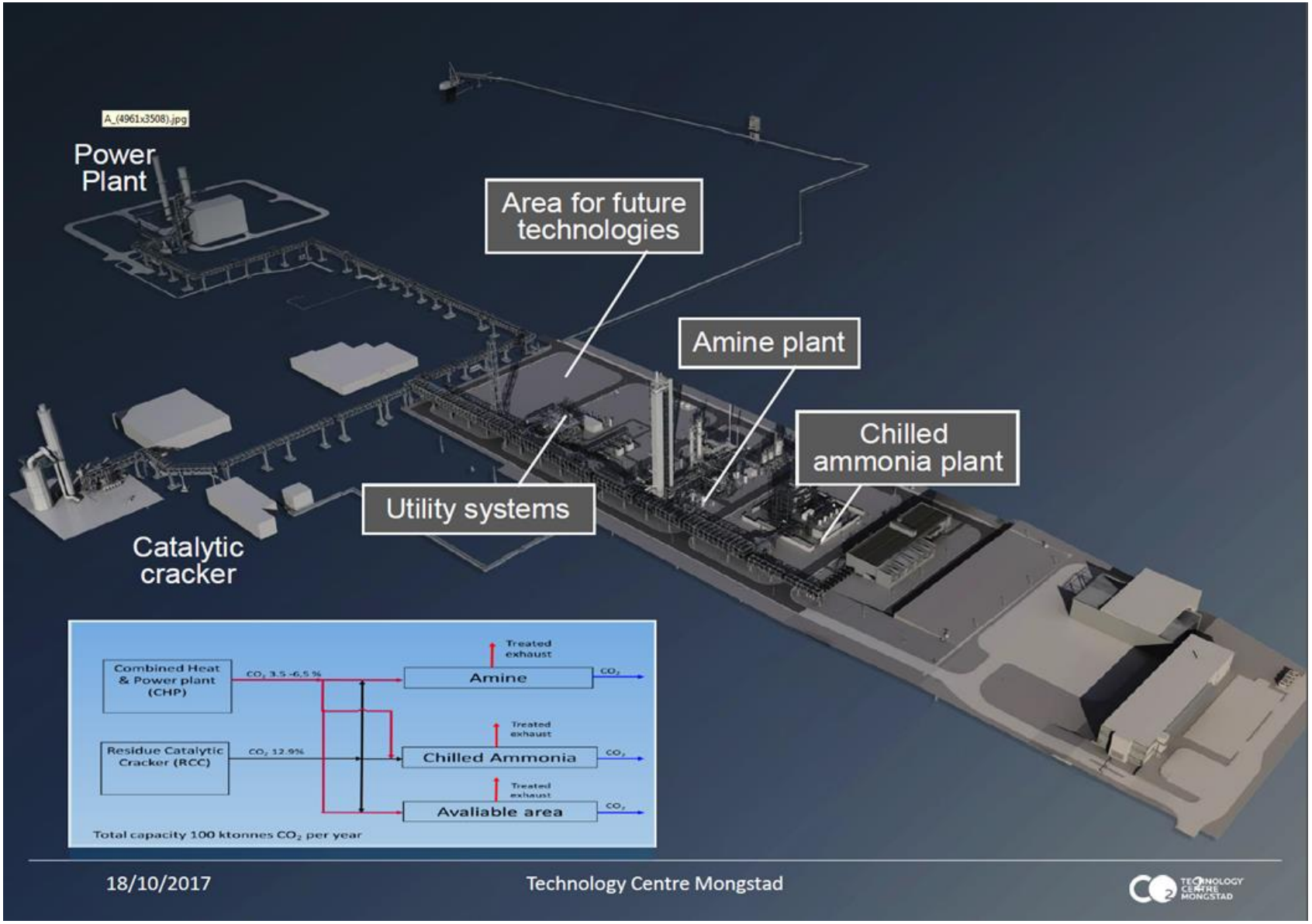
- Uses inexpensive, industrially available material (potassium and ammonium salts)
- No chemical degradation
- Has the potential for easy permitting in many localities
- Uses known process engineering
- Accelerated development possible

Demonstrated Benefits (By testing and modeling)

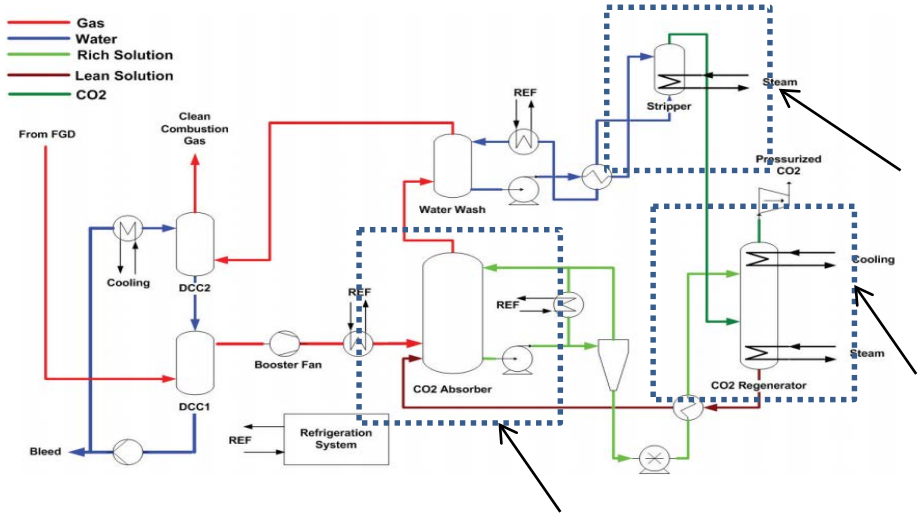
- Enhanced CO_2 capture efficiency
- High CO_2-loading capacity
- High-pressure release of CO_2 (10-15 bar)
- Reduced energy consumption (~ 2 MJ/kg-CO_2)
- Reduced auxiliary electricity loads

Project Update

Plant View of TCM

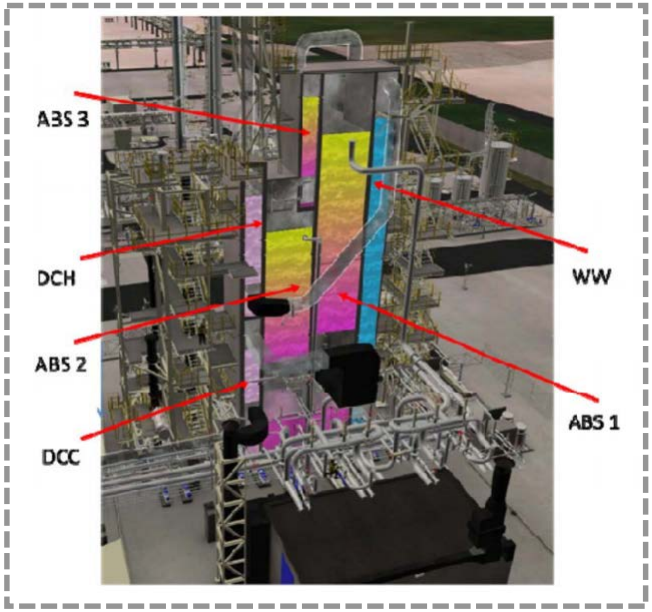


Existing CAP Infrastructure at TCM



Process flow diagram of the as-built CAP system

Source: Energy Procedia 114 (2017) 5593 – 5615



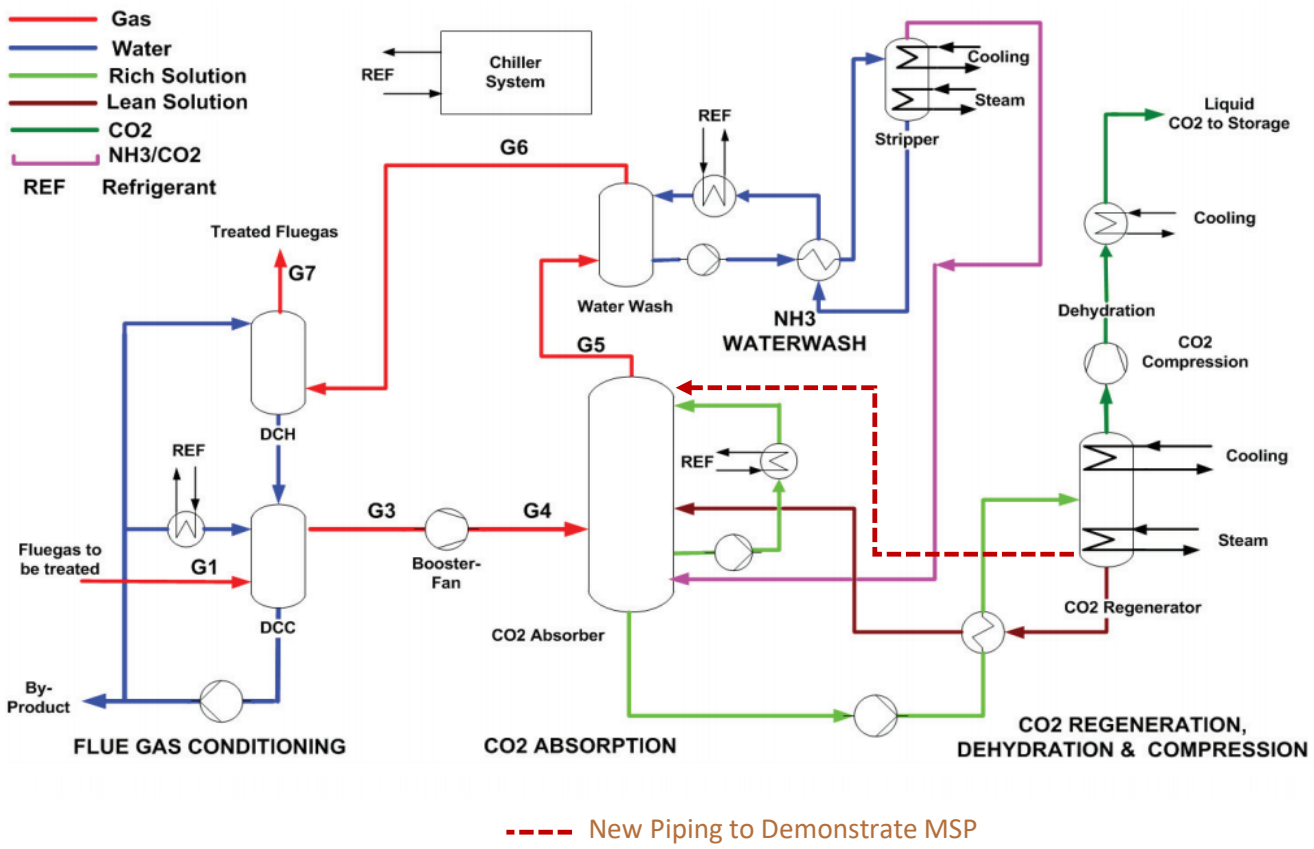
Absorber Block

Regenerator and Ammonia Recovery Blocks

Source: Energy Procedia 51 (2014) 31 – 39

CAP System Modification

MSP testing will be in non-solid mode



Non-Solid Mode Operation Flow Scheme

Key Modifications:

Absorber rearrangement (piping, valves etc.)

New lean transfer line from regenerator to absorber (piping, valves etc.)

Project Timeline

For system recommission, modification and testing

Completed or Ongoing Activities:

Contract Negotiation Phase 1 ✓

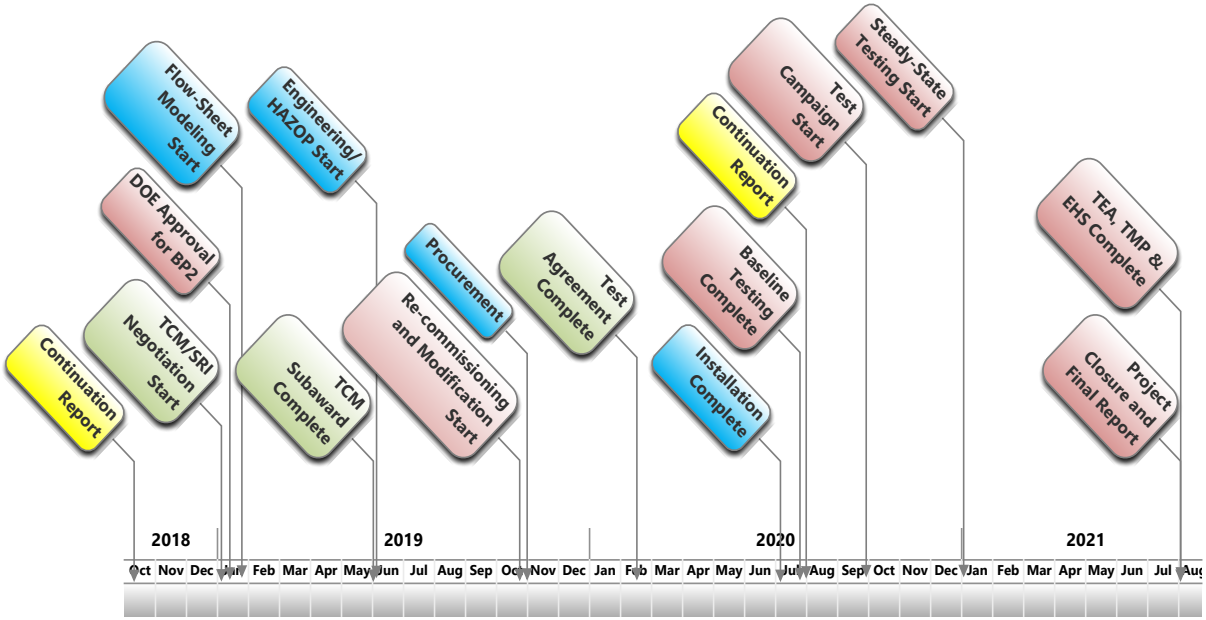
Prep work for recommission – system investigation ✓

Contract Negotiation Phase 2 ✓

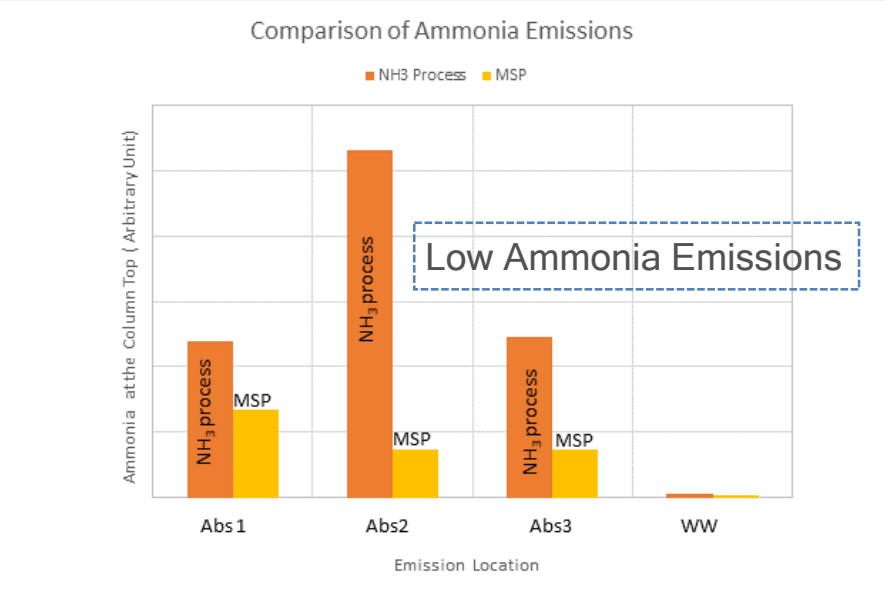
Prep Work and Engineering for Modification (in progress)

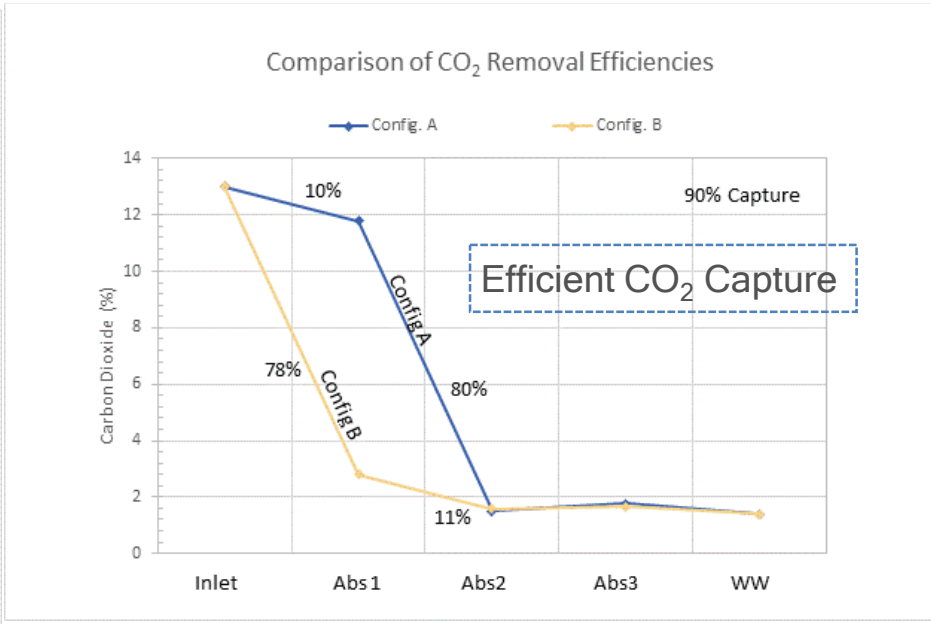
Flow-sheet modeling ✓

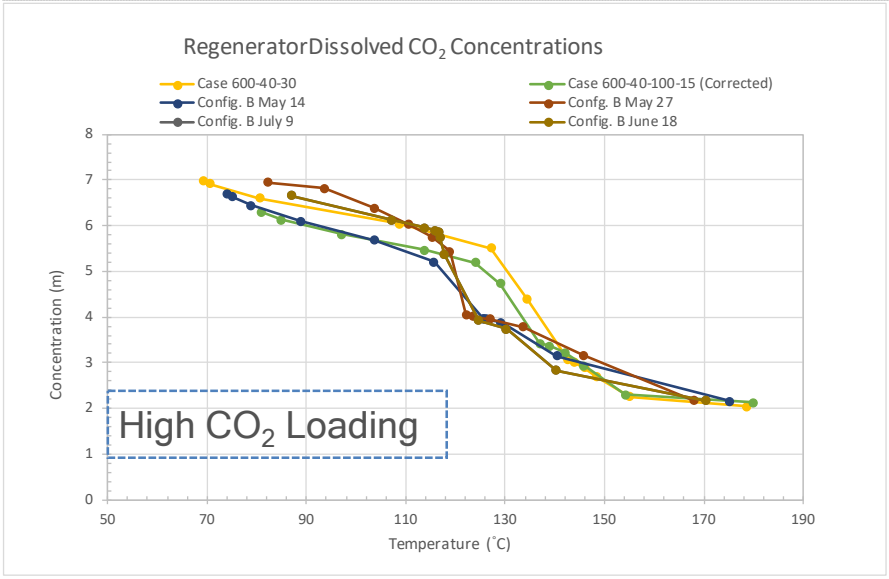
HAZOP (in preparation)

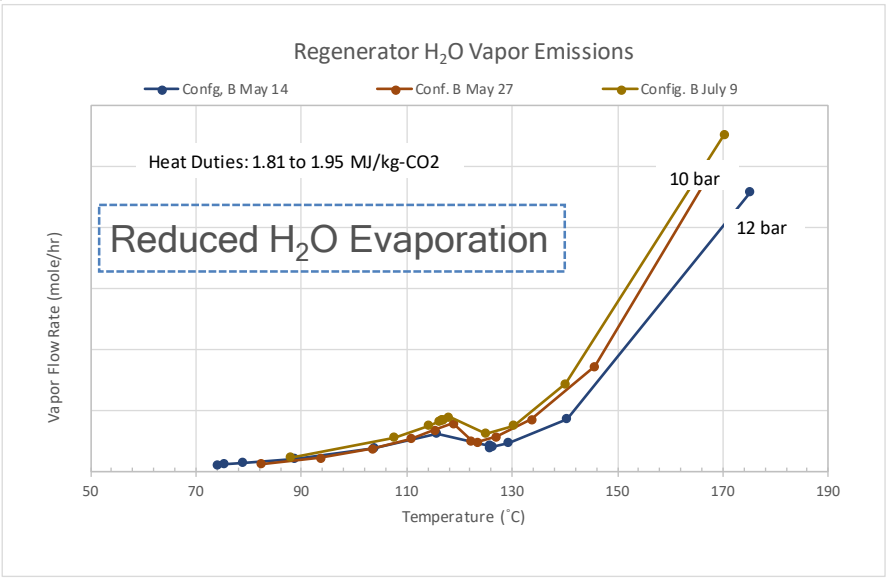


Selected Results from Flowsheet Modeling



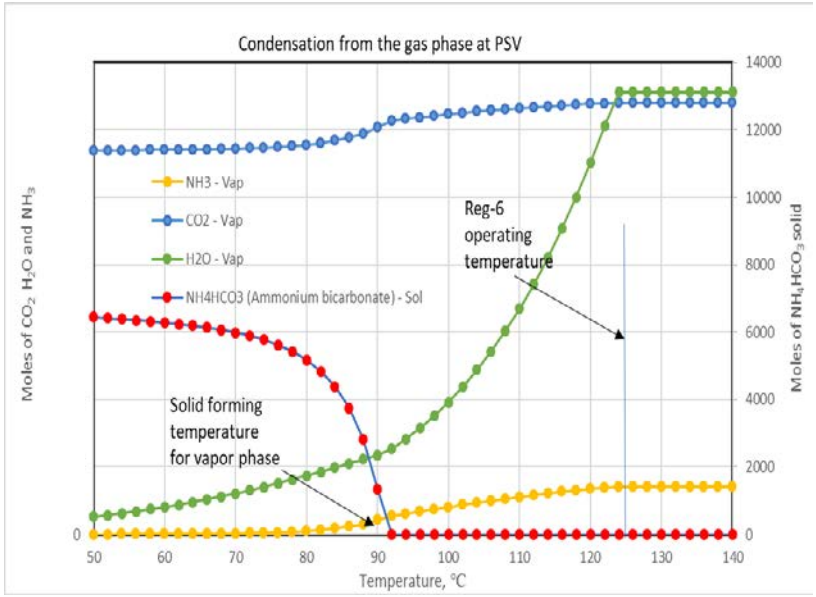




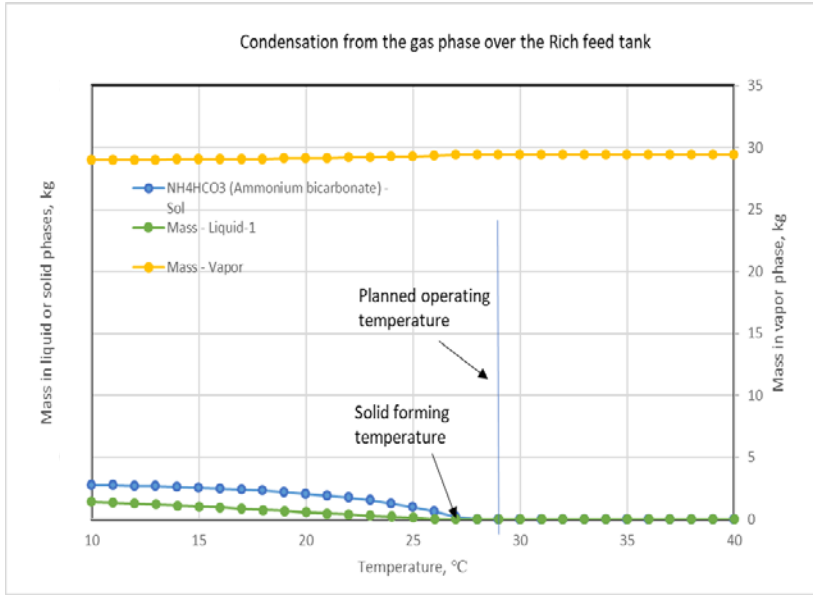


Selected Results from VLE Modeling

E.g., Crystallization risk avoidance by modeling the speciation of the vapor condensation



Solid formation behavior rich solution stream assuming a N_2 headspace such as in a PSV

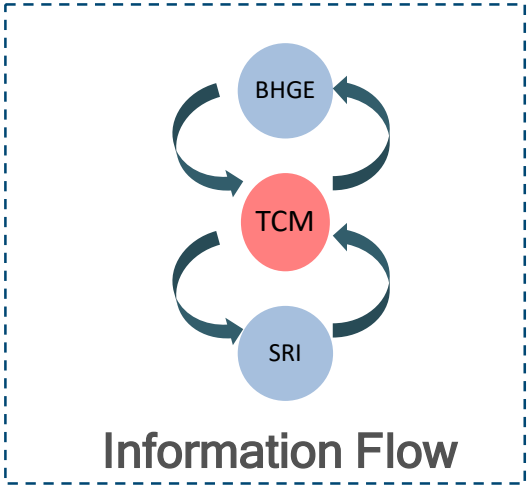


Solid formation temperature for the headspace gas in the Rich Feed tank

Current Tasks (HAZOP related)

Subtasks 3.2 & 4.1

- Document exchange and skype meetings
- Document review
- 2 Day HAZOP (starting 9/10/2019)
- Definitize the modification
- TCM board approval



Next Tasks

Subtasks 3.1 & 4.2

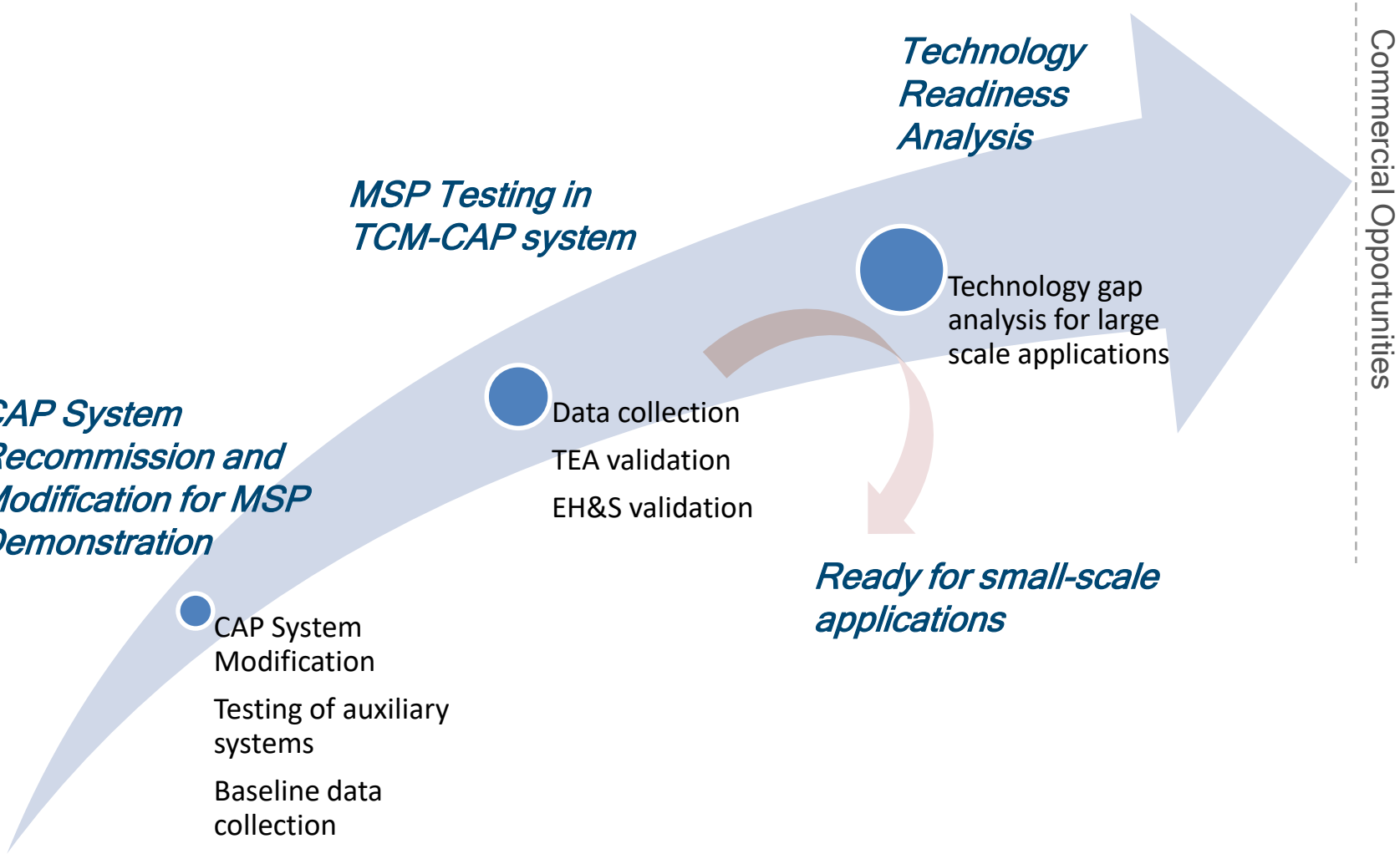
- CAP system recommissioning
- CAP system modification (procurement and fabrication)

Selected Project Milestones

BP	Task/ Subtask No.	Milestone Description	Planned Completion	Actual Completion	Verification Method
1	1	a. Updated PMP submitted	8/3/2018	8/3/2018	PMP file
1	1	b. Kickoff / BP1 Review Meeting convened	10/3/2018	10/2/2018	Presentation file
1	2	c. Work scope and firm cost estimate for the Chilled Ammonia Plant (CAP) recommissioning submitted	9/30/2018	10/12/2018	BP2 Continuation Application
1	1	e. Technology Maturation Plan	9/30/2018	9/26/2018	Topical Report
2	1	f. Updated PMP submitted	12/31/2018	12/18/2018	PMP file
2	3.1	g. Completion of CAP system recommissioning.	11/27/2019		RPPR quarterly
2	1	h. Test Site Agreement with TCM	11/27/2019		Agreement documents
2	4.5	i. Completion and submission of the test plans for both dynamic and steady state testing.	5/30/2020		RPPR quarterly
2	4.4	j-ii. Completion of CAP system modification.	5/30/2020		RPPR quarterly
2	4.4	j-iii. Completion of initial testing. Systems operability with regenerator at 10 bar and ammonia recovery [from the sour stripper] at >50% demonstrated.	5/30/2020		RPPR quarterly
3	5.1-5.2	l. Completion of dynamic testing and data analysis.	12/31/2020		RPPR quarterly
3	5.4-5.5	m. Completion of the steady-state testing and data analysis.	5/30/2021		RPPR quarterly
3	6.1	n. Techno-Economic Analysis topical report submitted	7/31/2021		Topical Report and summary in Final Report

Note: Project milestones g to m will be updated after the HAZOP

Pathway Toward Testing MSP at TCM and Beyond



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

Acknowledgements

Teams for Mixed-Salt Related Activities

NETL (DOE)

- Andrew Jones, Steven Mascaro, Jose Figueroa, Lynn Brickett, John Litynski and other NETL staff members

SRI Team

- Indira Jayaweera, Palitha Jayaweera, Elisabeth Perea, Regina Elmore, William Olsen, Chris Lantman, Kelli Connolly, Lisa Wottrich and Rene Harmount

Host Site

- TCM (Bjørn-Erik Haugan, Jorunn Brigsten, Kjetil Hantveit, Gerard Lombardo, Muhammad Ismail Shah, Stien Olav Nesse, Ronny Andvik and others)

HAZOP Team Partner

- BHGE (Gianluca Difederico, Olaf Stallmann, Erik Ullrich, Chris Schneider, Peter Strunz, Karsten Woitasky, and Michael Balfe)

Other Collaborators and Contributors

- OLI Systems (Ron Springer, Prodip Kondu and Andre Anderko)
- POLIMI (Davide Bonalumi, Stefano Lillia and Gianluca Valenti)
- Stanford University (Adam Brant and Charles Kang)
- Aqueous (Kaj Thomsen)
- IHI Corporation (Shiko Nakamura, Okuno Shinya, Kubota Nabuhiko, and others)

Disclaimer

Thank You!

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