SRI International

2018 NETL CO_2 Capture Technology Project Review Meeting

Engineering-scale Demonstration of Mixed-Salt Process (MSP) for CO_2 Capture (FE0031588)

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SRI International

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Technology Background

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)

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

Regenerator operation at 120° – 160°C at 10-20 atm

- Produces high-pressure CO_2 stream

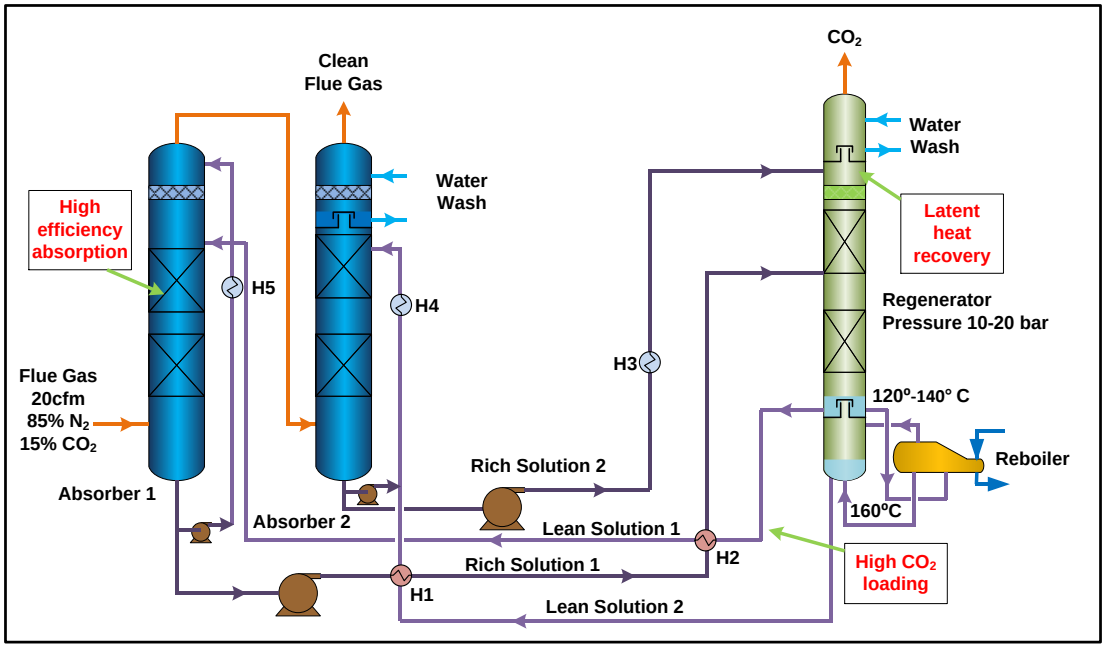
K_2CO_3-NH_3-CO_2-H_2O system

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 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/or modeling)

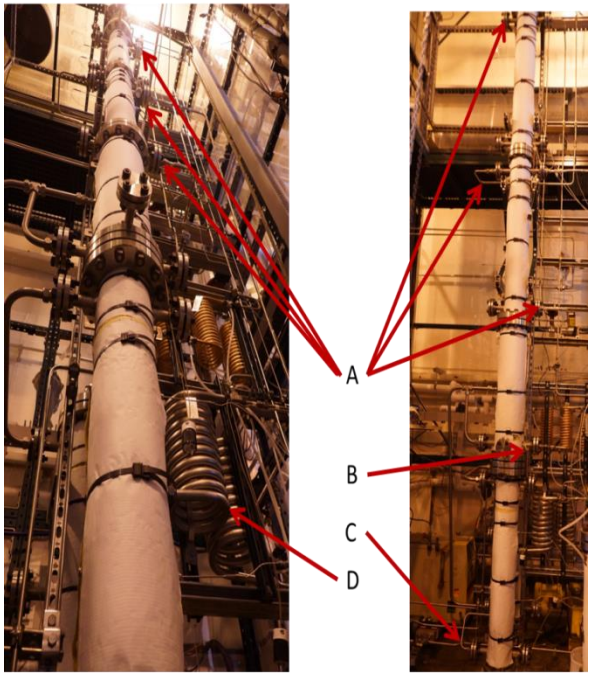
- Enhanced CO_2 capture efficiency
- High CO_2-loading capacity
- High-pressure release of CO_2 (10-20 bar)
- Reduced reboiler energy consumption (~ 2 MJ/kg-CO_2)
- Reduced auxiliary electricity loads

Recently Completed Project (FE0012959)

Large Bench-scale Mixed-salt System at SRI

0.25 t-CO_2/ day capacity - operational since January 2016

Absorbers



A : Rich solution inlet locations.
B : Discharge location for high NH3/K ratio solution
C : Discharge location for low NH3/K ratio solution
D: Heat exchangers (Cold rich ↔ Hot lean)

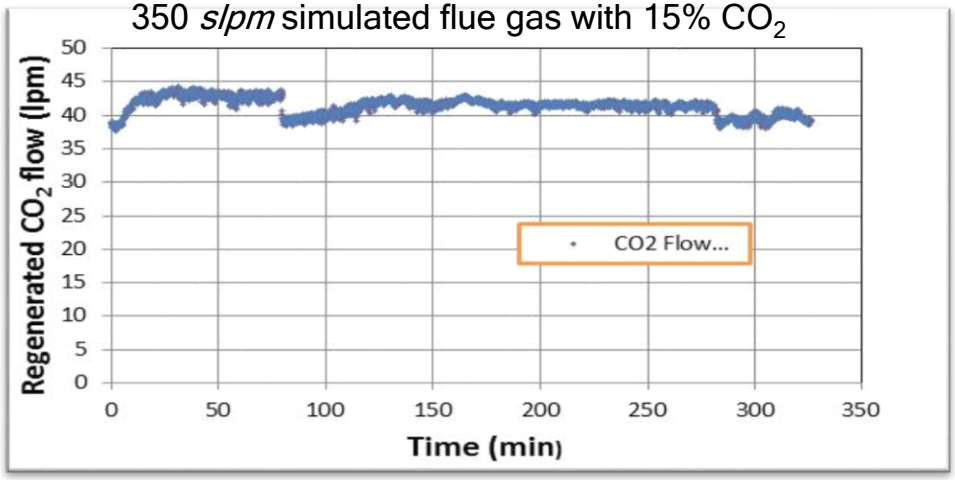
Regenerator pictures from different angles

System built under FE0012959

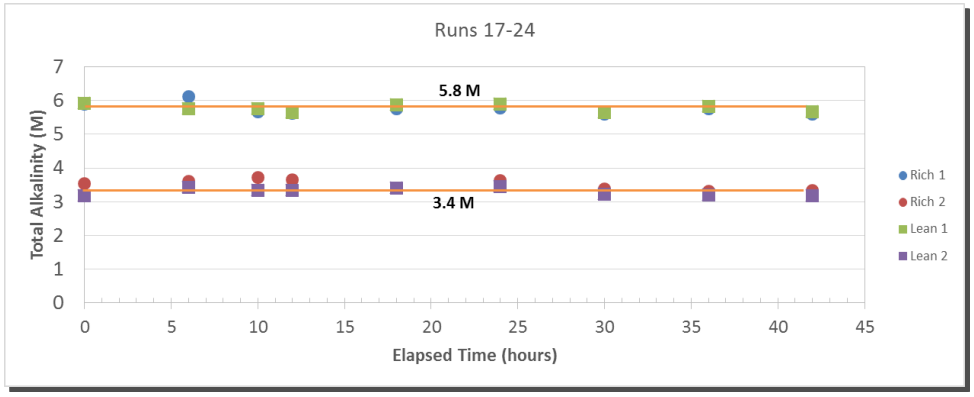
Continuous smooth operation of the integrated system over1.5 years of operation

Data from Integrated System Testing in 2016

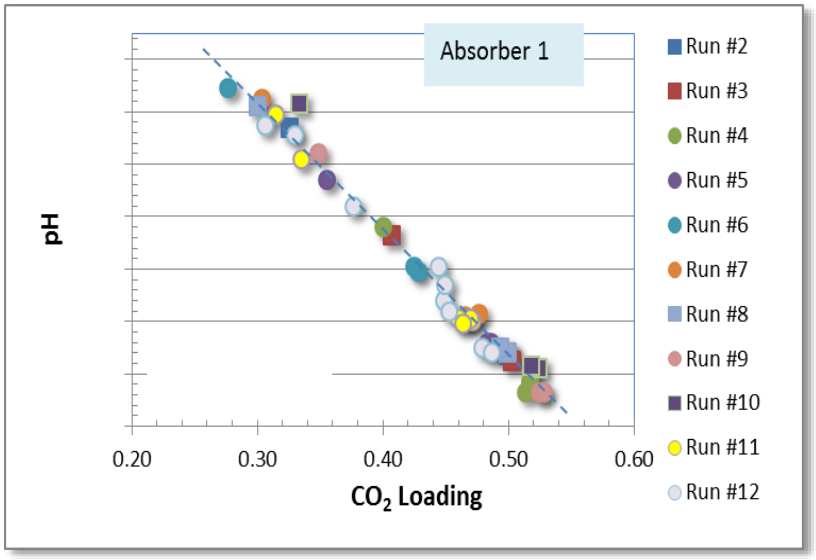
Excellent Performance



Observed 90% capture efficiency and regeneration with cyclic loading of ~0.7 mole of CO_2/mole of ammonia at 10 bar.



Alkalinity of rich and lean solutions circulating in the integrated system



Data showing relationship of the measured pH of rich and lean solutions from Absorber 1

Absorber: 20-35°C
Regenerator stage 1: 140°C
Regenerator stage 2: 160°C
L/G = 2 to 6 (kg/kg)
Solvent composition: 5 to 8 m

Results from FE0012959

Techno-Economic Data

Comparison Between Mixed-salt Technology and DOE Baseline Case

Case name	Case B12A w/o capture (report NETL 2015)	Case B12B Cansolv (report NETL 2015)	Case Mixed-Salt
Coal feed rate [kg/hr]	179193	224791	220576
CO2 removal	n/a	Cansolv	Mixed-Salt Technology
CO2 purification	n/a	no	no
Sulfur removal	FGD	FGD	FGD
Performance and Economic Summary			
CO2 capture	n/a	90.0%	90.0%
CO2 purity	n/a	>99%	>99%
H2 recovery	n/a	n/a	n/a
HHV plant efficiency	40.7%	32.5%	32.7%
COE w/o T&S [$/MWh]	82.3	133.2	117.5
COE w/ T&S [$/MWh]	82.3	142.8	127.0
Increase in COE comparing the case w/o capture with the case w/ CC&T&S	0%	88%	67%
Reference money value	Costs in $ June 2011	Costs in $ June 2011	Costs in $ June 2011

Reference :NETL, «Cost and Performance Baseline for Fossil Energy Plants Volume 1a: Bituminous Coal (PC) and Natural Gas to Electricity Revision 3,» pp. 137-166, 2015

Process Modeling: OLI, IHI, and POLIMI

Cyclic loading: 0.18 to 0.58; Reboiler duty: 2.0 (OLI); 2.3 MJ/kg-CO2 (POLIMI); 2.1 to 2.3 MJ/kg-CO2 (IHI-measured)

Ammonia emission < 10 ppm

Cost of CO_2 Capture at <$40/t CO2; Cost Of CO_2 avoided (excluding T&S) ~ $51/t CO2

Cost analysis was performed by POLIMI

Current Project (FE0031588)

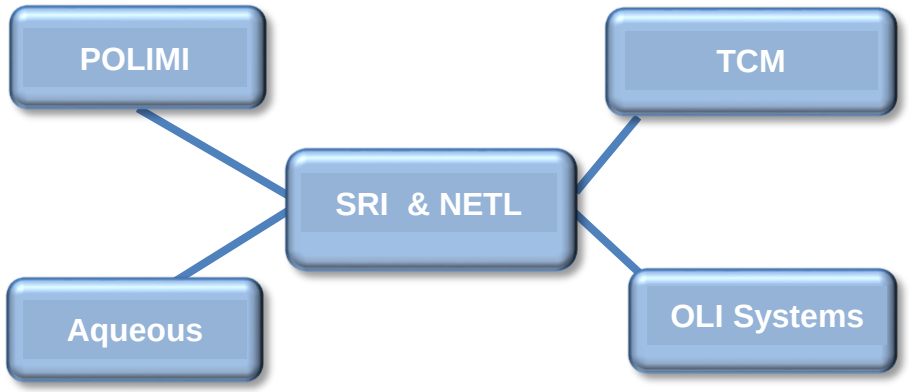
Project Budget, Team, and Work Organization

DE-FE0031588
Two Budget Period s (BP1 and BP2)
BP1: 7/12/2018 to 10/31/2018
BP1 DOE Funding: $566,135
TCM: In-kind cost-share

Project Manager: Mr. Andrew Jones, NETL

Prime Contractor: SRI International

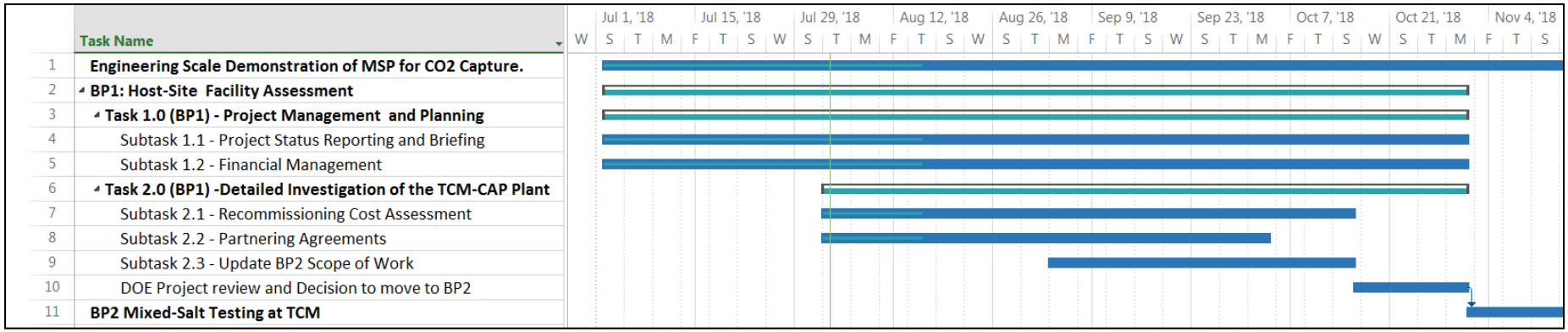
Project Team: US and International Partners



Work Organization

- SRI International
  - Technology provider
- Technology Center Mongstad (TCM), Norway
  - Host site and cost-share partner
- OLI Systems, USA
  - Process modeling (energy and mass balance)
- Aqueous Systems Aps, Denmark
  - Thermodynamic modeling
- POLIMI, Italy
  - Techno-economic analysis

BP1 Work Update



- Workshop at TCM on June 28, 29: Discussions on the program details, TCM requirements, TCM-CAP system P&IDs and modification requirements, and current status of the TCM-CAP system.
- TCM-CAP system inspection meeting at TCM (August 28, 29): Project progress evaluation and information exchange.

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BP2 Tasks

Task 1. Project Management

Task 2. CAP System Re-commissioning and Modification

Task 3. Dynamic Testing of MSP

Task 4. Steady-state Testing of MSP

Task 5. Process Economics, Technology Gap Analysis, and Technology Maturation Plan

Task 6. Environmental, Health & Safety Assessment

Task 7. Pilot Shutdown and Project Closure

The planned system inspection and modification period is about 12 - 18 months and the planned technology testing period is about 9 -12 months. BP2 Tasks will be finalized after completing the BP1 work.

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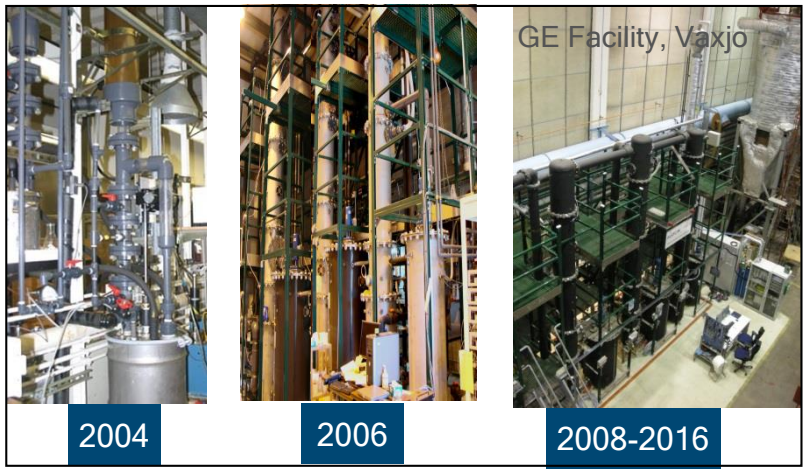
Technology Maturation: MSP Developments

Small bench to mini pilot to large pilot

Ammonia technology development started at SRI in 2004

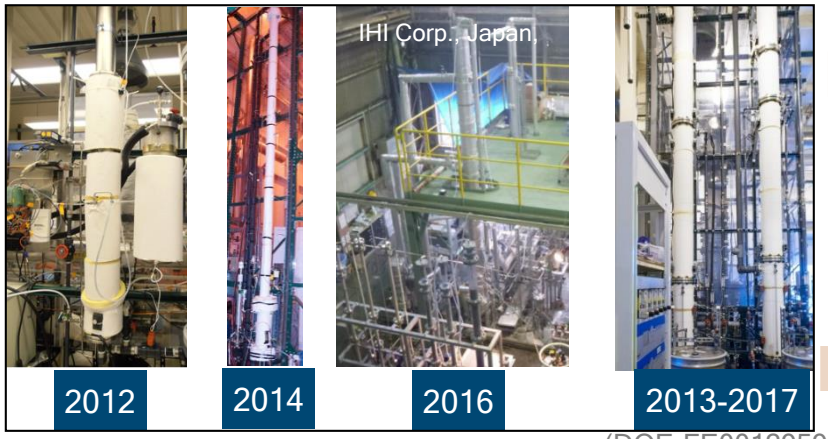
Chilled Ammonia Process (CAP)



CAP Validation at TCM

Step change

Mixed-salt Process (MSP)



(DOE-FE0012959)

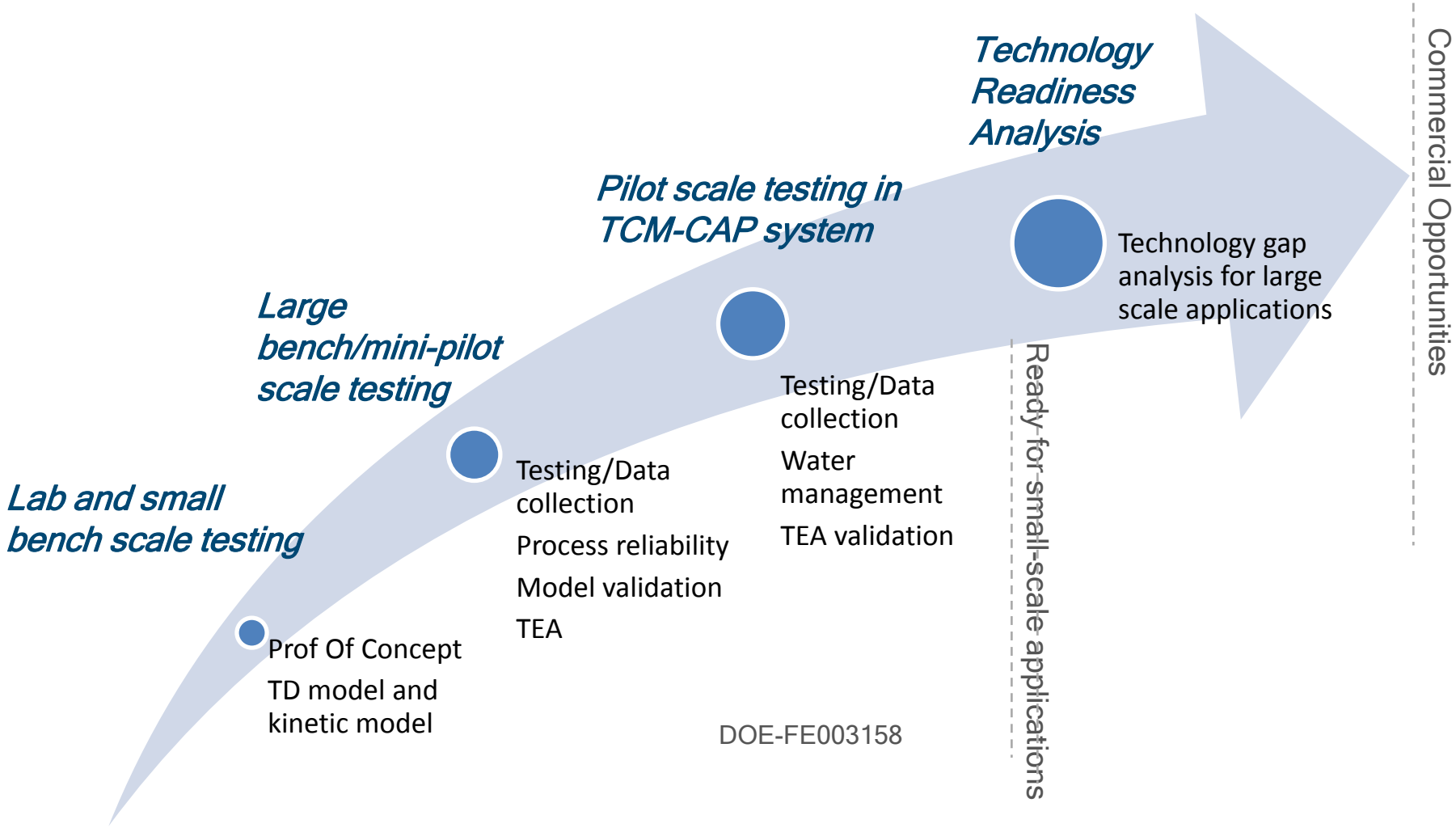
MSP Testing in TCM-CAP System (DOE-FE0031588)

Step change

Transformational Technology Development

Next Generation MSP

Technology Maturation: Testing MSP at TCM and Beyond



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

Acknowledgements

NETL (DOE)

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

SRI Team

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Host Site

- TCM (Bjørn-Erik Haugan, Jorunn Brigsten, Thilak Narayanadoss, Gerard Lombardo, and Kjetil Hantveit)

Other Collaborators and Contributors

- OLI Systems (Prodip Kondu and Andre Anderko)
- POLIMI (Gianluca Valenti and others)
- Stanford University (Adam Brant and Charles Kang)
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Thank You

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