A Process with Decoupled Absorber Kinetics and Solvent Regeneration through Membrane Dewatering and In-Column Heat Transfer

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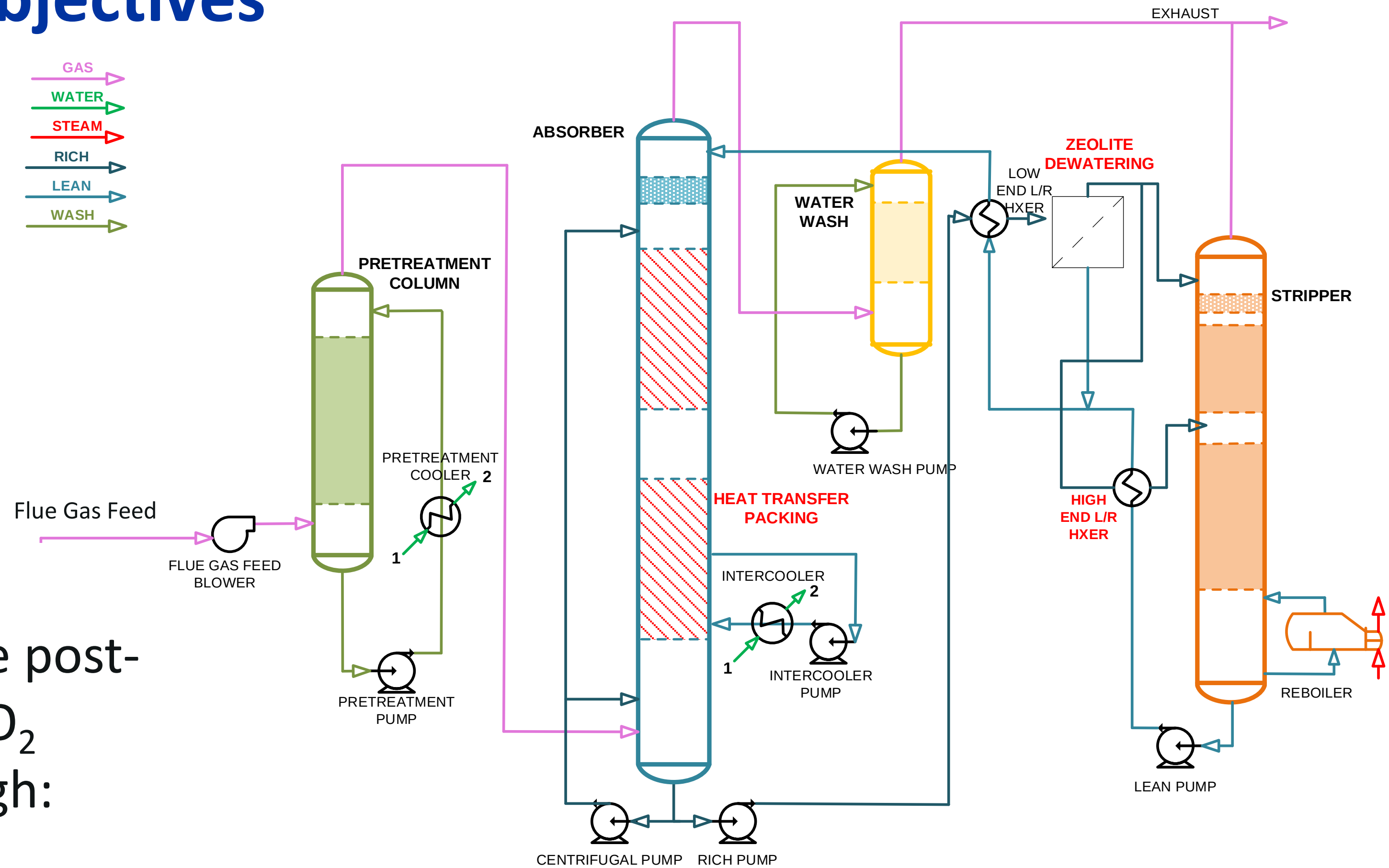
Project Objectives



Transformative post-combustion CO_2 capture through:

1. Applying 3-D printed two-channel structured packing material to control the absorber temperature profile
2. Implementing a zeolite membrane dewatering unit capable of >15% dewatering of the carbon-rich solvent prior to the stripper
3. Use of two-phase flow heat transfer prior to the stripper providing a secondary point of vapor generation

Project Team & Funding

	DOE-NETL	Cost Share	
Total:	$2,986,182	$748,068	$3,734,250
Percent Share:	80%	20%	100%

Project Dates	BP1	BP2
Start:	5/1/2018	11/1/2019
End:	10/31/2019	4/30/2021

Project Manager
DOE/NETL
David Lang

UKy-CAER
Project Management
Bench Scale Analysis
Zeolite Development

UK Center for Applied Energy Research

Media and Process Technology Inc.

Lawrence Livermore National Laboratory

Trimeric

SMG

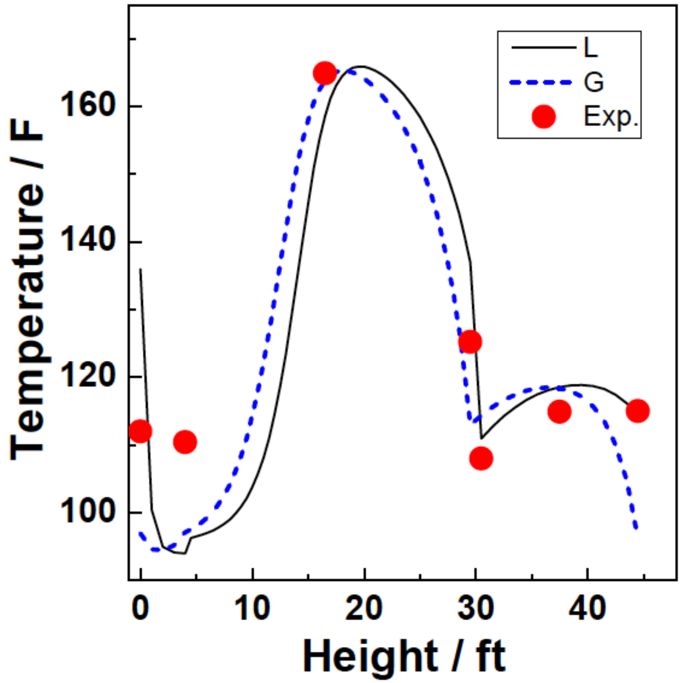
Lawrence Livermore National Laboratory (LLNL)
Packing Material

Media & Process Technology (MPT)
Membrane Module

Trimeric
Techno-Economic Analysis

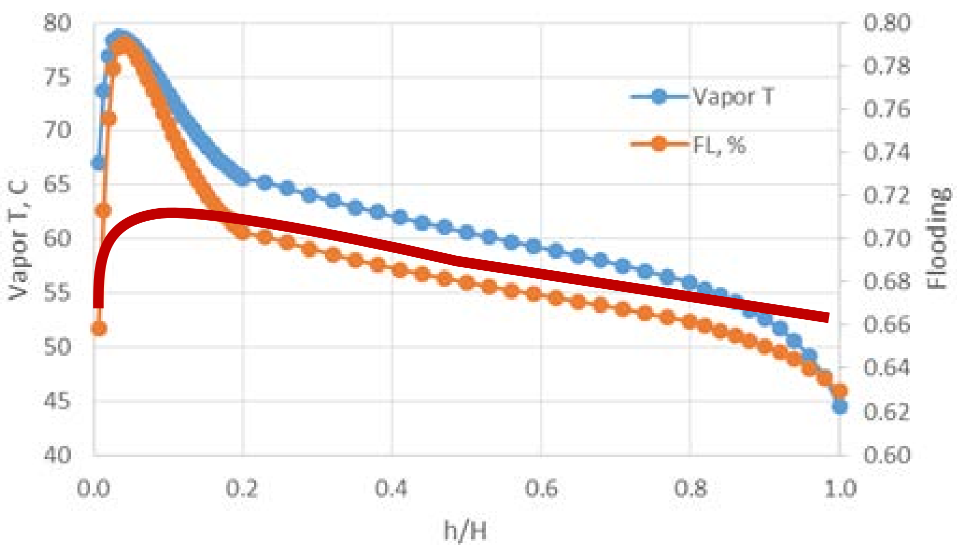
Smith Management Group (SMG)
Environmental Health & Safety

Background: Absorber Temperature Profile



A "temperature bulge" is present near the middle of the column.

Higher temperature will impede additional absorption of CO_2.



Absorber height can be reduced if the internal temperature is managed.

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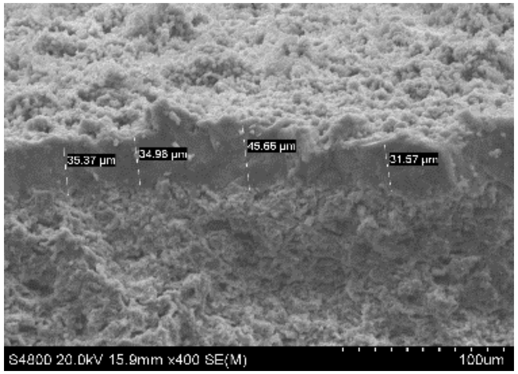
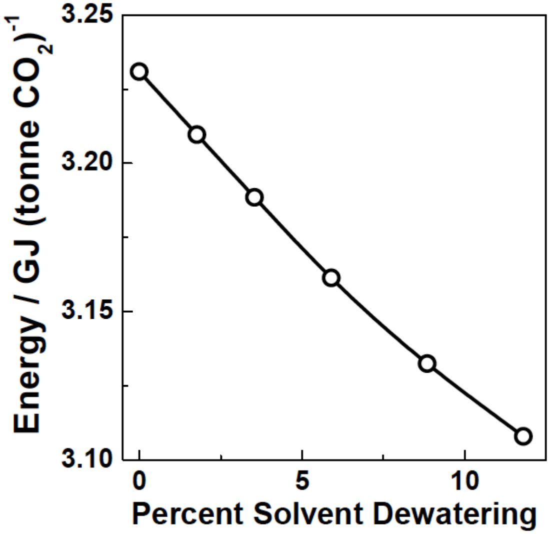
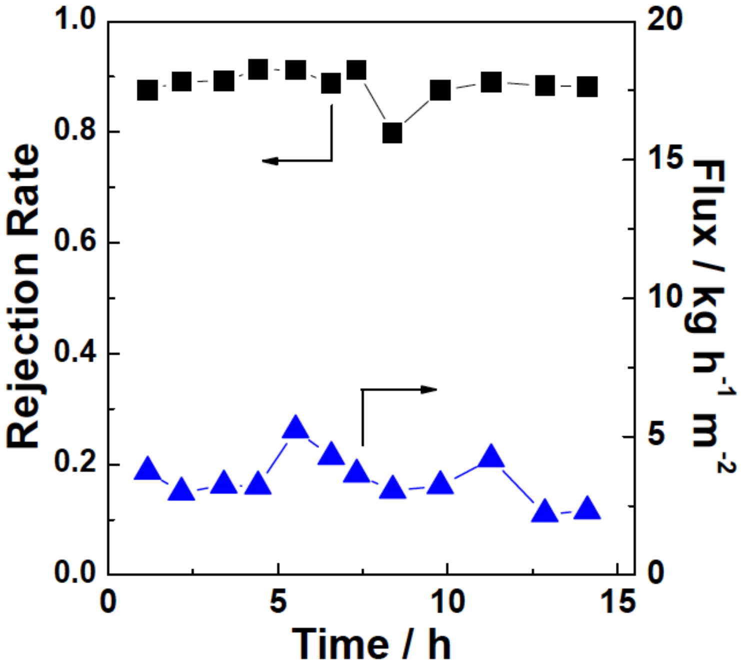
Background: Zeolite Membrane Modules

- Work previously conducted on catalytic zeolite (T) and dewatering (Y)
- Focus on membrane synthesis and modular configurations

Commercially used for water separations

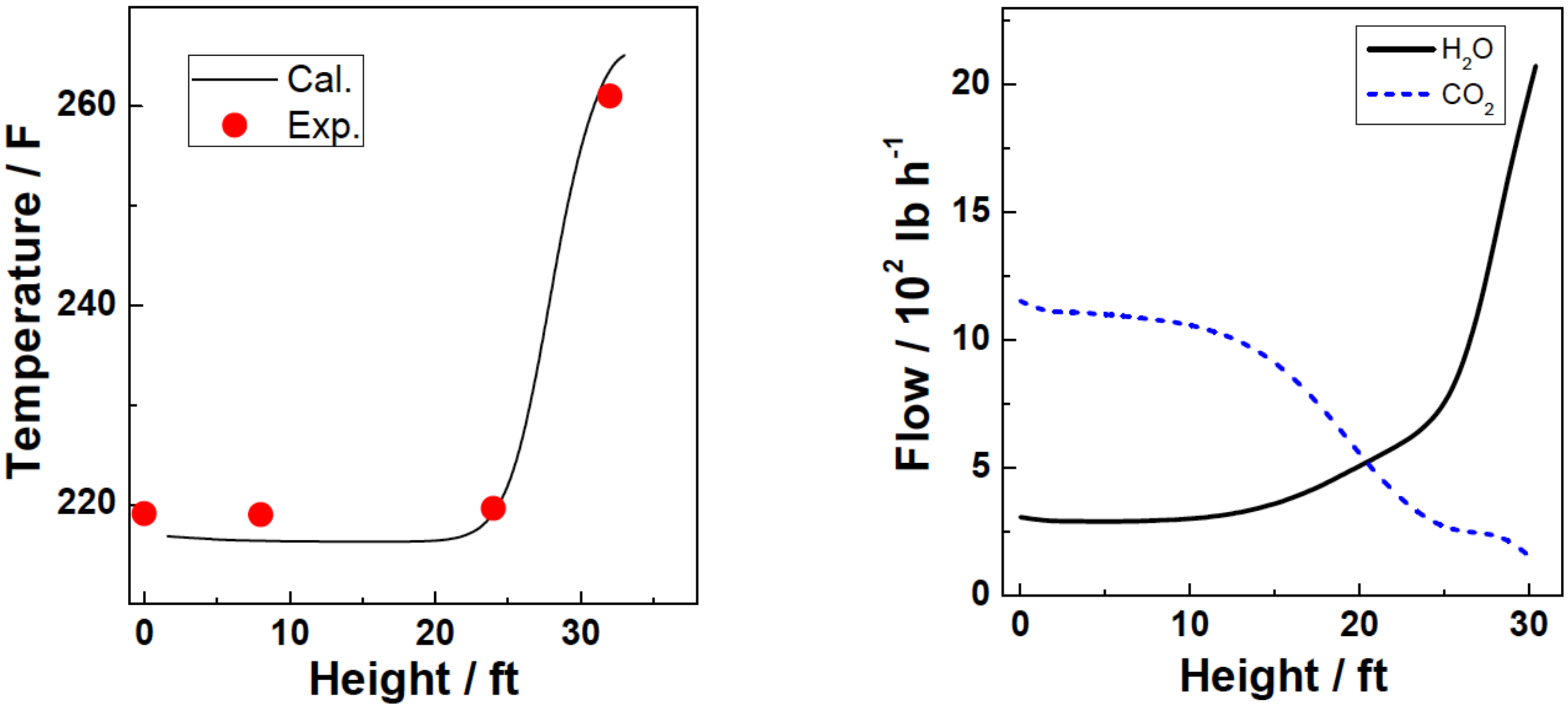






Dewatering of the process solvent can reduce the energy of regeneration

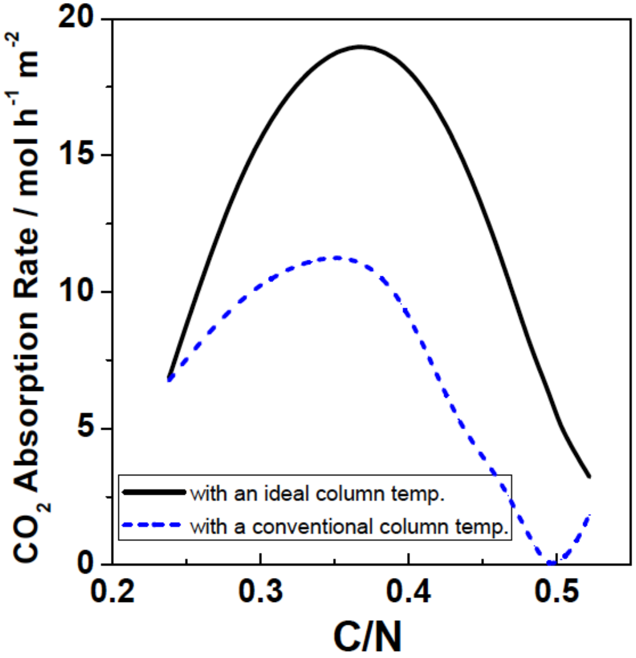
Background: Advanced Stripping & Secondary Vapor Generation Point



Temperature (left) and flow (right) conditions inside a stripping column. Temperature profiles in the column can cause significant energy to be expended to vaporize water (lower CO_2/H_2O ratio).

Project Approach

- Use of heat transfer packing material in the absorber to flatten the temperature profile and increase the CO_2 absorption rate
- Zeolite membrane dewatering of the process solvent to lower the energy cost of regeneration
- Split feed to stripper to provide a secondary vapor generation point



Predicted Plant Efficiency, COE, and CO_2 Capture Cost

TOTAL (STEAM TURBINE) POWER, kWe	740,717
AUXILIARY LOAD SUMMARY, kWe	
Coal Handling & Conveying	510
Pulverizers	3,850
Sorbent Handling & Reagent Preparation	1,260
Ash Handling	740
Primary Air Fans	1,810
Forced Draft Fans	2,770
Induced Draft Fans	10,700
SCR	70
Baghouse	100
Wet FGD	4,150
CO_2 Capture System Auxiliaries	13,681
CO_2 Compression	33,469
Miscellaneous Balance of Plant[2,3]	2,000
Steam Turbine Auxiliaries	400
Condensate Pumps	832
Circulating Water Pump	7,894
Ground Water Pumps	707
Cooling Tower Fans	4,087
Transformer Losses	2,569
TOTAL AUXILIARIES, kWe	91,599
NET POWER, kWe	649,118
Net Plant Efficiency (HHV)	33.55%
Net Plant Heat Rate (Btu/kWhr HHV)	10,169
Consumables	
As-Received Coal Feed (lb/hr)	565,820
Limestone Sorbent Feed (lb/hr)	57,835

	Case B12A	Case B12B	This Proposal
		90%	90%
COE ($/MWh, 2011$)	82.3	142.8	115.4
CO_2 TS&M Costs	0	9.6	8.2
Fuel Costs	24.6	30.9	29.6
Variable Costs	9.1	14.9	11.3
Fixed Costs	9.6	15.2	12.1
Capital Costs	39	72.2	54.1
COE (2011$/MWh) (excluding T&S)		133.2	107.2
CO_2 Captured, lb/MWh		1927	1632
Cost of CO_2 Captured ($/tonne CO_2)		66.6	44.8
Cost of CO_2 Captured ($/tonne CO_2) (excluding T&S)		58.2	33.6
Incremental COE		73.5%	40.3%
Reduction of Incremental COE from Case 12			45.2%
Reduction of COE from Case 12			19.2%

>19% COE reduction when compared to Case 12

Project Task Schedule & Success Criteria

Task	Title	Year 1	Year 2	Year 3
1	Project Management and Planning			
2	3-D Printed Packing Material for Absorber			
3	Zeolite Dewatering Module Development and Fabrication			
4	30 L/min CO2 Capture Bench Unit Evaluation			
5	Test Plan Development			
6	Evaluation of Proposed Technique at 0.1 MWth Post Combustion CO2 Capture Facility			
7	High Packing Density and Performance Zeolite Y Membranes			
8	Composite Zeolite and Alternative Dewatering Membrane			
9	Techno-Economic Analysis			
10	Topical Report Preparation and Submission			

Decision Point	Success Criteria
Budget Period 1	1. Peak Absorber Temperature Reduced by >10 °C Confirmed 2. Zeolite Y Membranes with Fluxes >10 $kg/m^2/h$ at Reject. Rates >90% 3. Dewatering Zeolite Y Module Design Complete with >200 m^2/m^3 4. Test Plan Complete for 0.1 MWth Capture Unit
Budget Period 2	1. Stripper Heat Int. >10% Energy Savings on 0.1 MWth Capture Unit 2. Long-Term Energy Savings of >15% from 1000-hour Process Study 3. Dewatering Membrane Packing Density Increase to >400 m^2/m^3 4. Aspen Model for Entire Integrated System 5. TEA Complete for Integrated Process 6. EH&S Assessment Complete for Integrated Process 7. Updated State Point Data Table for Membrane 8. Technology Gap Analysis Complete

Unique Facility: Small & Large Bench Units

30 L/min CO_2 Capture Unit

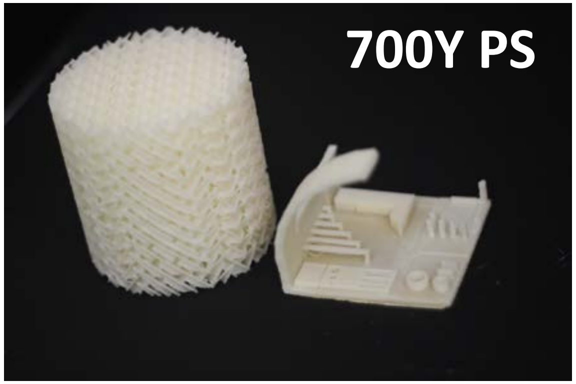
0.1 MWth CO_2 Capture Unit

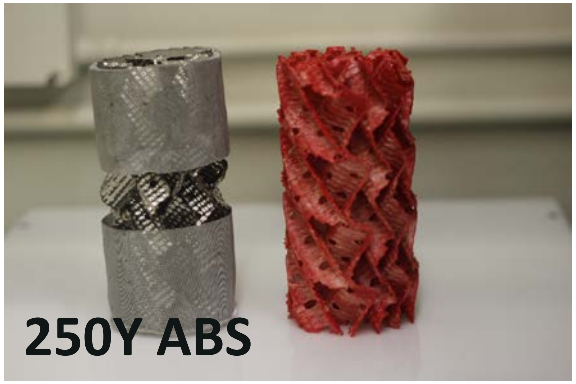
Project Risk Management

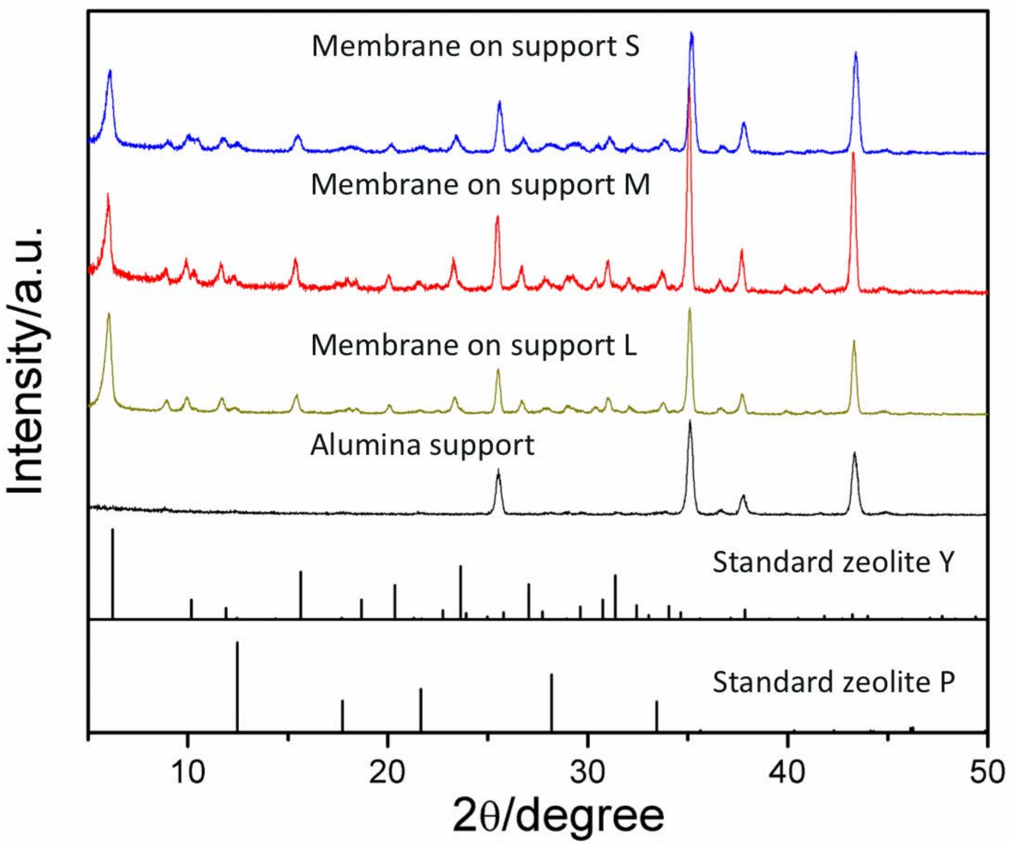
Risk Assessment, Management Mitigation and Response Strategies.				
Description of Risk	TRL	Probability	Impact	Risk Management Mitigation and Response Strategies
Technical Risks				
Dewatering Membrane Flux too Low	3	M	M	• Relocate the membrane to high-temperature site • Increase the rejected pressure • Alternative zeolite-type such as T-zeolite
Liquid/Gas Contact Impeded by Packing Heat Transfer Structure	3	L	M	• Modify the geometry • Surface treatment
Printing Material not Compatible for Application (poor heat transfer efficiency)	3	L	H	• Redesign internal surface with turbulence generator • Change metal material
Current Large CCS Strippers Configuration not Adequate for Split Feed	4	L	M	Modifications will be made to current vessel, or new vessel will be obtained

Progress and Current Status

Stability testing in CAER solvent completed on acrylonitrile butadiene styrene (ABS), polystyrene (PS), and high-density polyethylene (HDPE). Example packing materials have been printed by LLNL (on right).



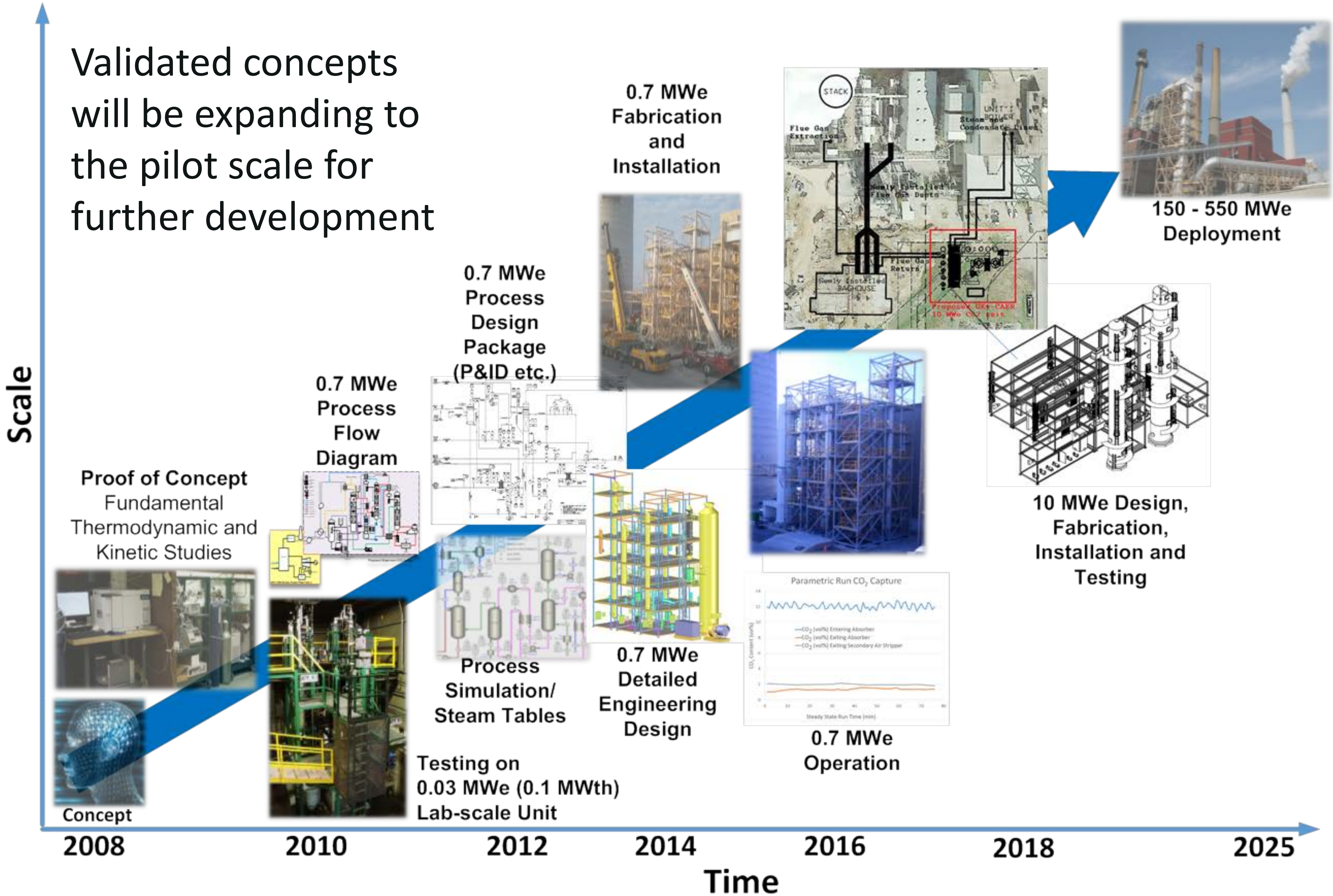




Zeolite Y membranes have been grown on alumina support materials, confirmed phases through XRD.

Future Testing

Validated concepts will be expanding to the pilot scale for further development



Acknowledgements

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