MEMBRANE TECHNOLOGY & RESEARCH

Commercial-Scale FEED Study For MTR's Membrane CO_2 Capture Process (DE-FE0031846)

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U.S. Department of Energy

National Energy Technology Laboratory

Carbon Capture Front End Engineering Design Studies and CarbonSafe

2020 Integrated Review Webinar

August 17-19 2020

Project Overview

Award name: Commercial-Scale FEED Study for MTR's Membrane CO_2 Capture Process (DE-FE0031846)

Project period: 10/1/19 to 9/30/21

Funding: $5.12 million DOE; $1.28 million cost share ($6.4 million total)

NETL Federal project manager: Sai Gollakota

Participants: MTR, Basin Electric, Sargent & Lundy, Trimeric, EPRI, Carbon Management Strategies

Project scope: Conduct a FEED study of MTR's capture process applied to Basin Electric's 400 MW_e Dry Fork Station power plant

Project plan: The project is organized into 6 tasks with a total duration of 24 months. The end product will be a FEED report with detailed designs, a completed NEPA study, a construction schedule, and costs estimated with ±15% reliability

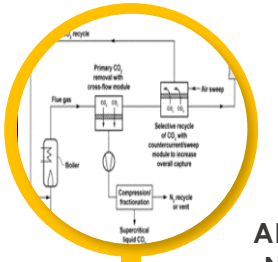
MTR

Role of Participants

- MTR – project lead and liaison with DOE; will coordinate project activities, prepare membrane system design, and report to DOE
- Basin Electric – operator of the Dry Fork Station (DFS), host site for the proposed capture plant; will provide plant specific information needed for the FEED study
- S&L– previously managed construction of the DFS, will lead the FEED study
- Trimeric – will provide engineering services related to flue gas pretreatment and the CO_2 purification unit (CPU)
- EPRI – will work with Basin to determine best use of water collected by the capture plant
- Carbon Management Strategies – will provide engineering support related to CO_2 take off requirements that inform capture design

MTR's CO_2 Capture Development Timeline

Feasibility Study
(NT43085)
- Sweep concept proposed
- Polaris membrane conceiv ed

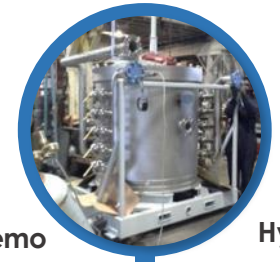


APS Cholla Demo
(NT0005312)
- First Polaris coal flue gas test
- 1TPD CO_2 captured (50 kWe)

APS Red Hawk NGCC Demo
- First Polaris flue gas test
- 250 lb/d CO_2 for algae farm

NCCC 1 MWe Demo
(FE0005795)
- 11,000 hrs of 1 TPD system operation
- 1 MWe (20 TPD) system operation

Low Pressure Mega Module
(FE0007553)
- Design/build 500 m^2 module



Hybrid Capture
(FE0013118)
- Membrane solv ent hybrids with UT, Austin

B&W Integrated
(FE0026414)
- Integrated operation of 1 MWe system with B&W's 0.6 MWe coal-fired boiler

10 MWe Large Pilot
(FE0031587)
- Phase I (feasibility)
- Phase II (design) and
- Phase III (construction/operation)

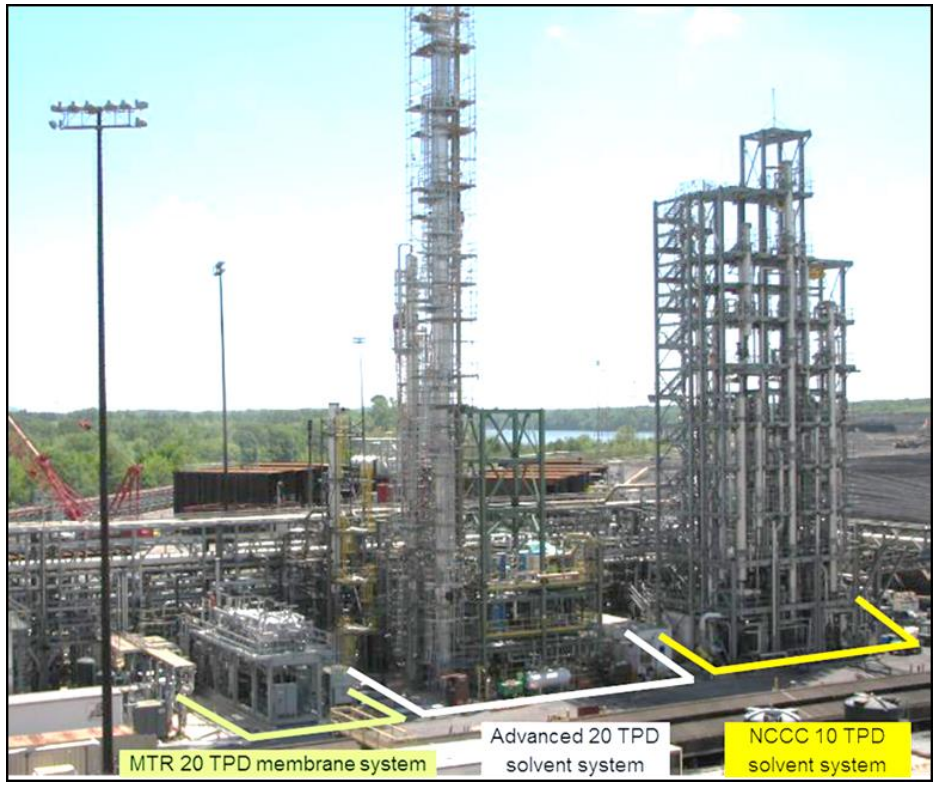
Full Scale FEED
(FE0031846)
- Retrofit study for Dry Fork Station
- Partial capture conditions
- Coordination with CarbonSAFE

TRL3 TRL4 TRL5 TRL6 TRL7 TRL8

2006 2008 2010 2012 2014 2016 2018 2020

Membrane CO_2 Capture Features

- Simple, passive operation with no hazardous chemical handling, emissions, or disposal issues
- Compact, modular technology
- Recovers water from flue gas
- No steam use → no modifications to existing boiler/turbines
- Near instantaneous response; high turndown possible
- Efficient partial capture



Site Background: Dry Fork Station, Unit #1

- Single unit, 422/385 MWe sub-critical coal fired power plant in Gillette, WY
- Commissioned in 2011
- Low sulfur, sub-bituminous PRB coal from the nearby Dry Fork Mine.
- Low NOx burners w/ OFA, SCR, dry lime fluidized bed, FF
- Owned by Basin Electric (92.9 percent), and the Wyoming Municipal Power Agency, Lusk, Wyoming. (7.1 percent).
- Cooling via an air-cooled condenser (one of the largest in N. America)
- Home to the Wyoming Integrated CO_2 Test Center.
- Home to the Dry Fork CarbonSAFE project.

Site Selection: Dry Fork Station

Basin Electric's DFS offers a number of attractive features:

- A modern, efficient power plant that came online in 2011
- Built with a graded plot adjacent to the plant for future CO_2 capture retrofit
- Low air leak gives relatively high CO_2 content → membrane capture economics improve strongly with increasing CO_2 content
- Cool, dry climate lowers water content of feed to membrane → reduced vacuum pump power
- Low cost of power → important for a capture process powered only by electricity
- Ideally located for future CO_2 utilization → near GreenCore CO_2 pipeline in a basin amenable to tertiary oil recovery

MTR

FEED Study Elements

FEED Study:

- Builds upon EPRI led, full-scale Pre-FEED retrofit application to Duke Energy's East Bend Station (FE0031589)
- Sargent & Lundy was EPC for Dry Fork Station and WY Integrated Test Center
- Same team is responsible for Large Pilot FEED (FE0031587) at Dry Fork Station
- Will include environmental review, permitting, and assessment of best use of collected waters from the capture plant

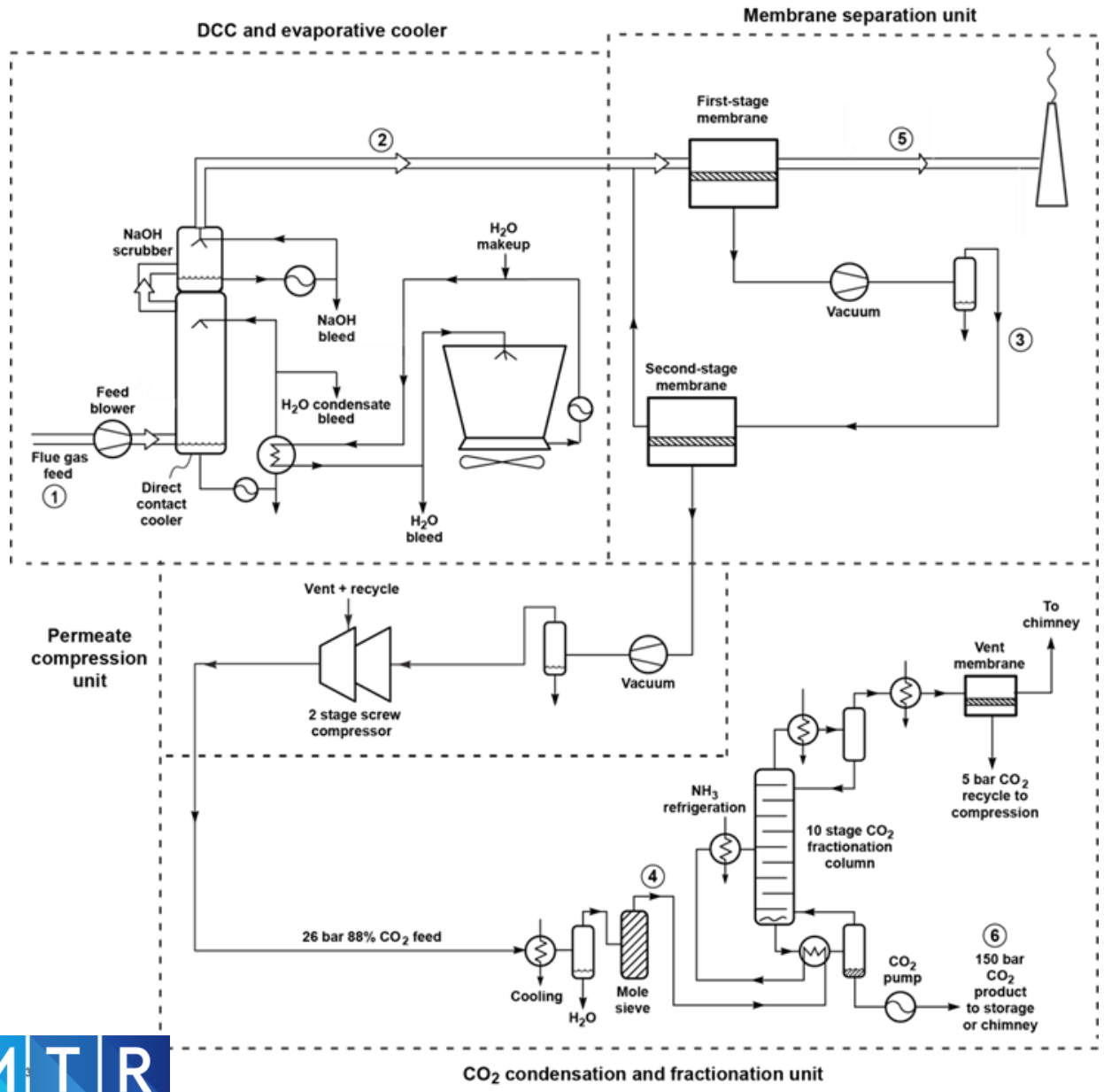
TABLE KEY			
Membrane Technology Research	MTR	Electric Power Research Institute	EPRI
Trimeric	TRI	Carbon Management Strategies	CMS
Owner (Basin Electric)	BAS	Equipment manufacturer / supplier	OEM
Sargent and Lundy	SL		

Task Description	Lead Entity	Support
Overall Project Management	MTR	ALL
Project Management Plan	MTR	ALL
FEED Study	S&L	ALL
Project Design Basis		
Site Characteristics	BAS	SL, EFA
Site Ambient Conditions	BAS	SL
Flue Gas Characteristics	BAS	MTR
Environmental Requirements	S&L	WIA, WITC
Site Specific Design Considerations	BAS	SL ,TRI, EFA
System Description		
Process Flow Diagrams, Heat & Material Balances	MTR	TRI
Piping & Instrumentation Diagrams (P&IDs), Utility List	MTR	TRI
Process Equipment List, Process Piping Line List, Tie-In List	MTR	TRI
Process Equipment Specifications/Data Sheets	MTR	TRI, OEM
Process Instrument List	MTR	SL, TRI
Process Operating & Control Description	SL	MTR, TRI, OEM
Process Loop Diagrams, Process Equipment Layout	SL	MTR, TRI
Process Equipment Load List	MTR	SL, TRI, OEM
Wastewater/Effluent Composition	MTR	TRI, EPRI
Detailed Design		
Design Criteria (mechanical, electrical, I&C, structural)	SL	MTR, TRI, BAS
BOP/Support Systems Design		
Power Supply, Auxiliary Systems Design	SL	MTR, BAS
Makeup Water System Design	SL	MTR, BAS, TRI
Wastewater Treatment System Design	SL	EPRI
Cooling System Design	SL	MTR, TRI
Fire Protection System Design, Facility Security Design	SL	BAS
HVAC Design	SL	
Building/Security Infrastructure Plans	SL	BAS
Mechanical Design		
Project Water Balance, General Arrangement Drawings	SL	MTR, BAS, TRI
Project 3D Model	SL	MTR
Project Site Plan, Terminal Point List	SL	MTR, BAS
Piping and Utility Relocation Drawings	SL	BAS
Demolition and Relocation Drawings	SL	BAS
Mechanical Equipment List, Pipe and Utility Rack Design	SL	MTR
Piping Isometric Diagrams, Piping Layout/Routing Drawings	SL	MTR
BOP System Descriptions, BOP Piping Line List	SL	MTR
BOP Piping and Instrument Diagrams (P&IDs)	SL	MTR, EFA
BOP Mechanical Equipment Specifications/Data Sheets	SL	MTR
Civil/Site work Design		
Geological Analysis, Soil Load Analysis	BAS	SL
Spill / Containment Plan, Storm water Runoff Plan	SL	BAS
Structural Design		
Architectural Design, Foundation Design	SL	MTR

Technical Approach: Project Milestones

Milestone Number	Task/ Subtask No.	Milestone Description	Planned Completion Date (*)	Verification Method
1	1	Kickoff meeting completed. Project schedule revised. Updated PMP	End of Q1	Quarterly Report
2	2	Project Design Basis completed	End of Q4	Quarterly report
2	3	Preliminary, process design, layout done, environmental drafted, and ready for preliminary Hazop.	End of Q5	Quarterly Report
3	4	All PFD's and P&ID's of major equipment completed, final Hazop done, environmental permits obtained	End of Q7	Quarterly Report
4	5/6	Costing completed, FEED study documents/reports finalized	End of Q8	Final Report and FEED study

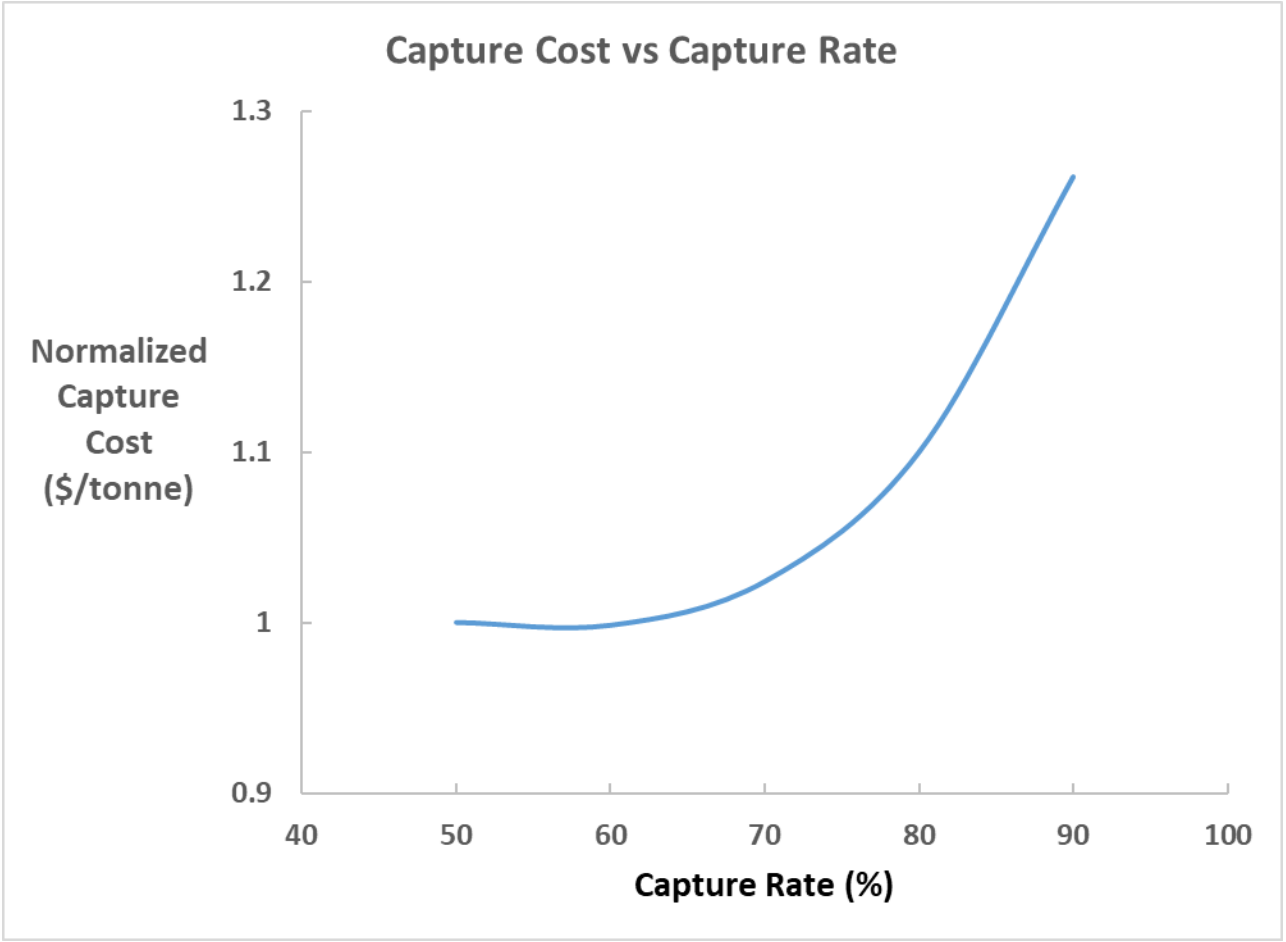
Progress to Date: Process Design Determined



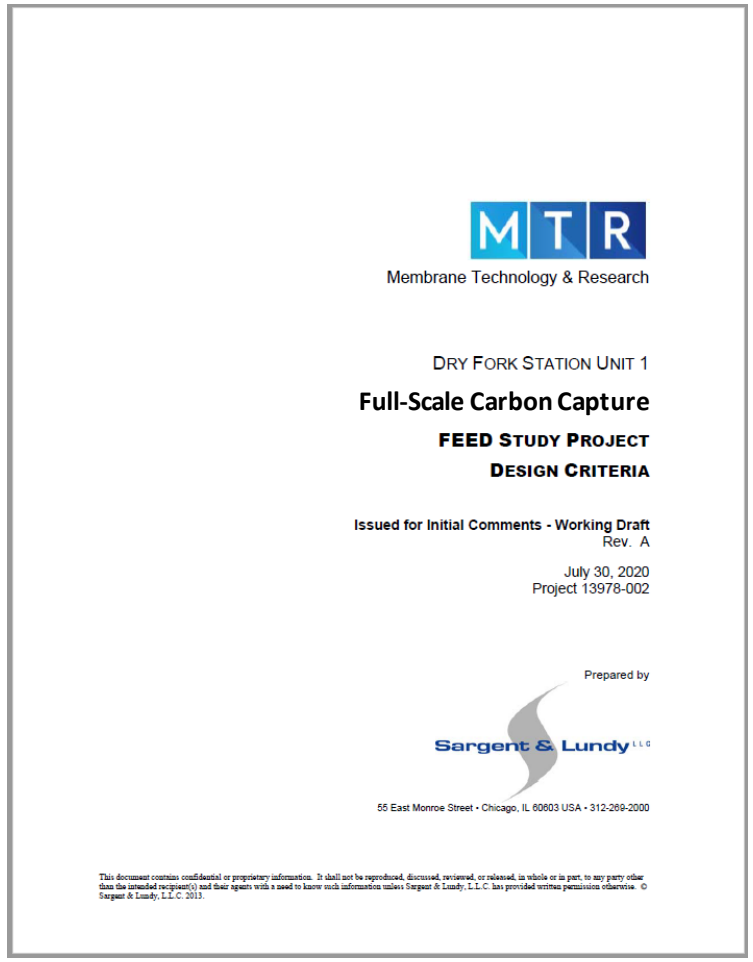
- Two stage Polaris membrane system with CO_2 liquefaction
- No recycle to boiler
- Will capture 70% of plant CO_2 emissions (~5600 tonnes/ day)
- High purity CO_2 (>99.5%) available for offtake at 150 bar

Process Optimization Studies

- For a simple membrane system without recycle, capture costs begin to increase above 70% capture
- Above 80% capture, costs increase more rapidly due to increasing membrane area and energy demands



Development of the Design Basis


Membrane Technology & Research

DRY FORK STATION UNIT 1

Full-Scale Carbon Capture

FEED STUDY PROJECT

DESIGN CRITERIA

Issued for Initial Comments - Working Draft
Rev. A

July 30, 2020
Project 13978-002

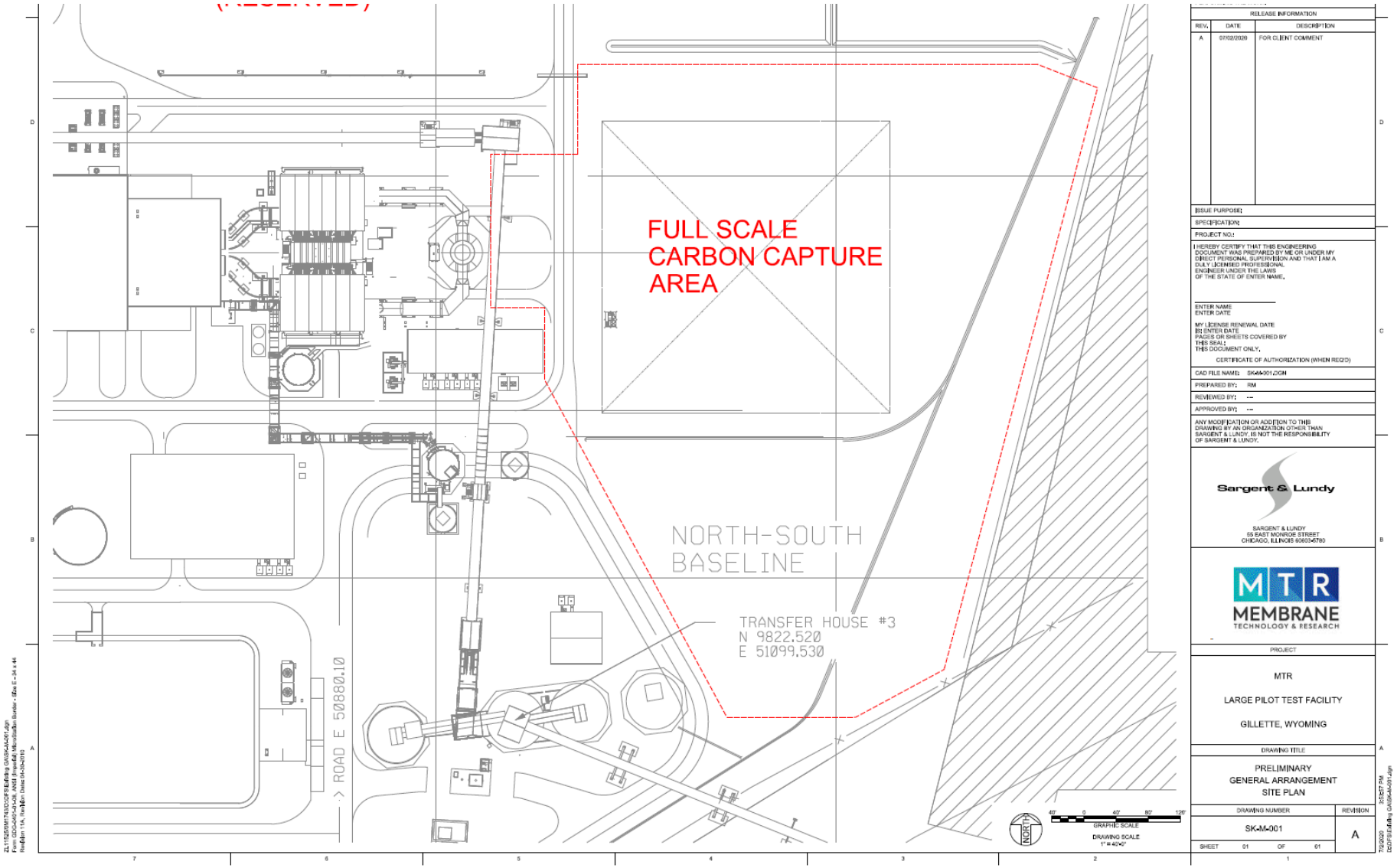
Prepared by

Sargent & Lundy LLC

55 East Monroe Street • Chicago, IL 60603 USA • 312-269-2000

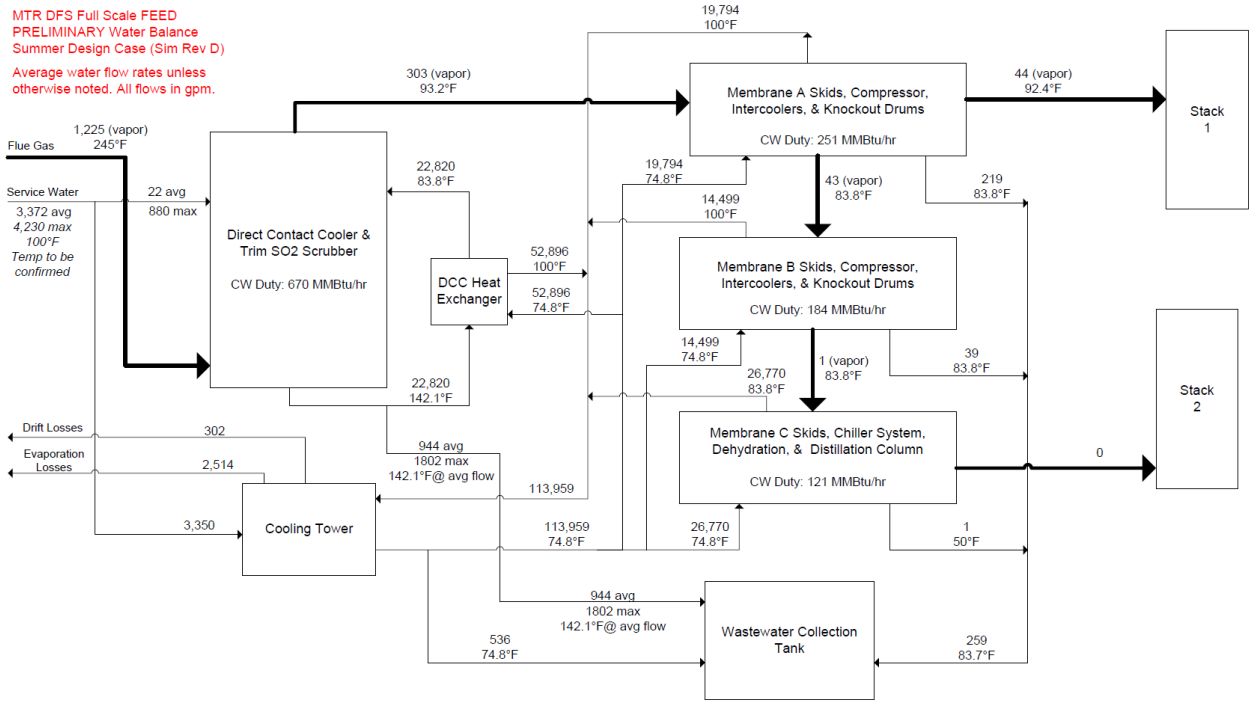
- Draft document issued July 31
- On schedule for completion before end of project Q4
- Design basis establishes:
  - Conditions and the battery limit for the capture plant
  - Detailed flue gas characterization
  - Site conditions, capture plant location
  - Capture system description
  - Mechanical system design basis
  - Electrical design
  - Instrumentation and controls
  - Structural and civil design

Location and Plot Plan for Full-Scale Capture Plant



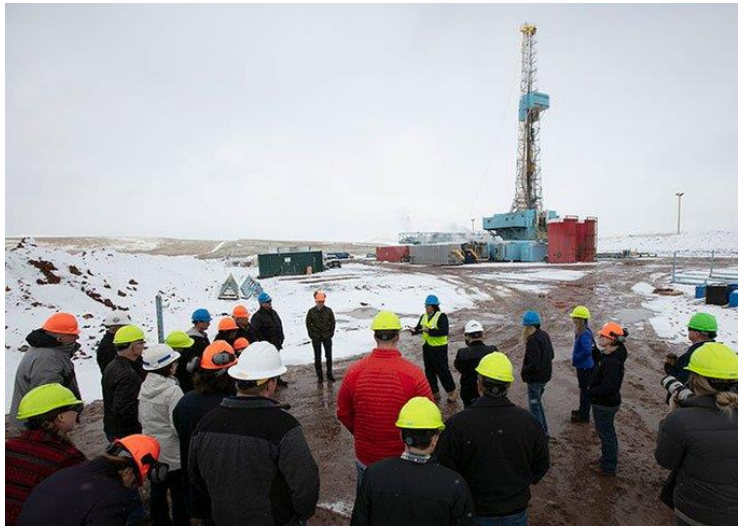
Process Cooling and Water Balance

- Membrane system recovers water from flue gas
- DFS uses mostly air cooling to conserve water resources
- FEED study will examine how to best utilize recovered water and balance capture system cooling demands



Coordination with Wyoming CarbonSAFE

- MTR is coordinating our Full-Scale FEED project with the Wyoming CarbonSAFE project (FE-FE0031624).
- The University of Wyoming recently received their Phase III award, "*Wyoming CarbonSAFE: Accelerating CCUS Commercialization and Deployment at Dry Fork Power Station and the Wyoming Integrated Test Center*"
- *W*ill finalize characterization and obtain a Class VI permit to construct a storage complex in Campbell County, Wyoming.
- The project utilizes Basin Electric's Dry Fork Station to source 2.2 million metric tons of CO_2 per year for storage at three nearby sites within the same storage complex.
- Results of a FEED study of CO_2 capture utilizing MTR's two-stage membrane will be integrated into this project.



Pilot Well adjacent to Dry Fork Station (source: Basin Electric)

UNIVERSITY OF WYOMING

Summary/Next Steps

- MTR membrane system will be sized to capture 70% of CO_2 emissions from 400 MW_e Dry Forks Station (DFS) – about 5,600 tonnes CO_2/day
- DFS is a modern plant well-suited for CO_2 capture retrofit with nearby pipeline and abundant potential utilization opportunities
- FEED study, led by S&L, is underway; preliminary design basis has been issued for review
- Project is on schedule; next steps are to finalize design basis, begin engineering drawings, conduct preliminary hazop

Acknowledgments

This material is based upon work supported by the Department of Energy under Award Number DE-FE0031846.

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Extras

Role of Participants

DOE Office of Fossil Energy

NETL Federal Project Management, Sai Gollakota

Membrane Technology & Research, Inc.

Co-Principal Investigators, Tim Merkel, Brice Freeman

The Project Team

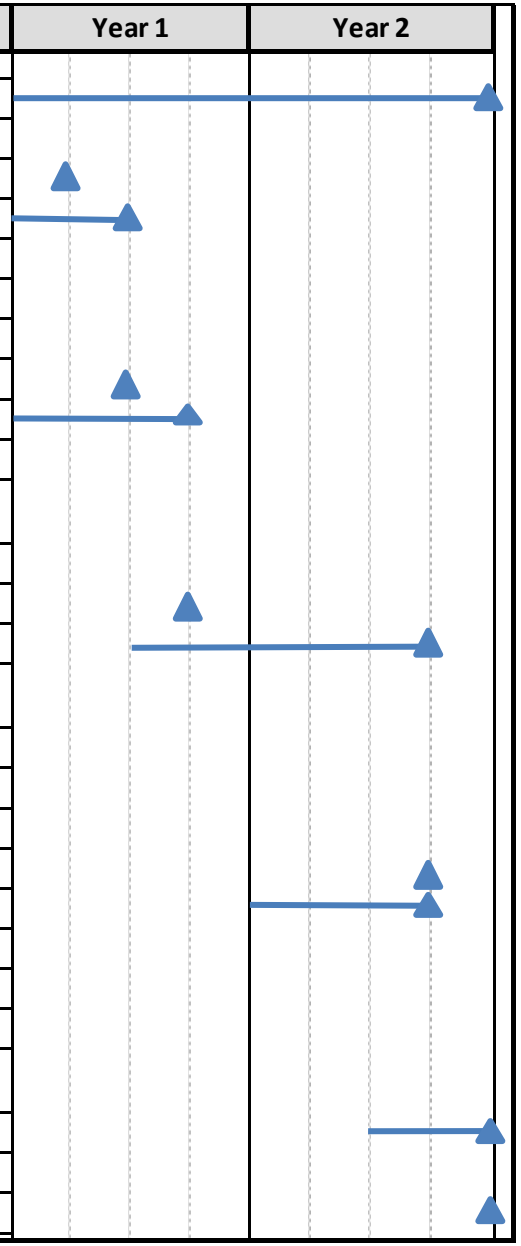
Basin Electric	**MTR**	**Trimeric**	**S&L**	**CMS**	**EPRI**
Host Site	*Technology Provider*	*Engineering*	*EPCM*	*Engineering*	*Engineering*
John Jacobs	Thomas Hofmann	Ray McKaskle	Kevin Lauzze Danielle Koren	Will Morris	Abhoyjit Bhown Jeffrey Preece
Power plant issues	Engineering Design: • Membrane system	Engineering Design: • DCC • CPU	BOP Engineering: • FEED study lead • Permitting	CO_2 off-take requirements	Engineering Study: • Process Cooling • Water treatment and utilization

The Advisory Team

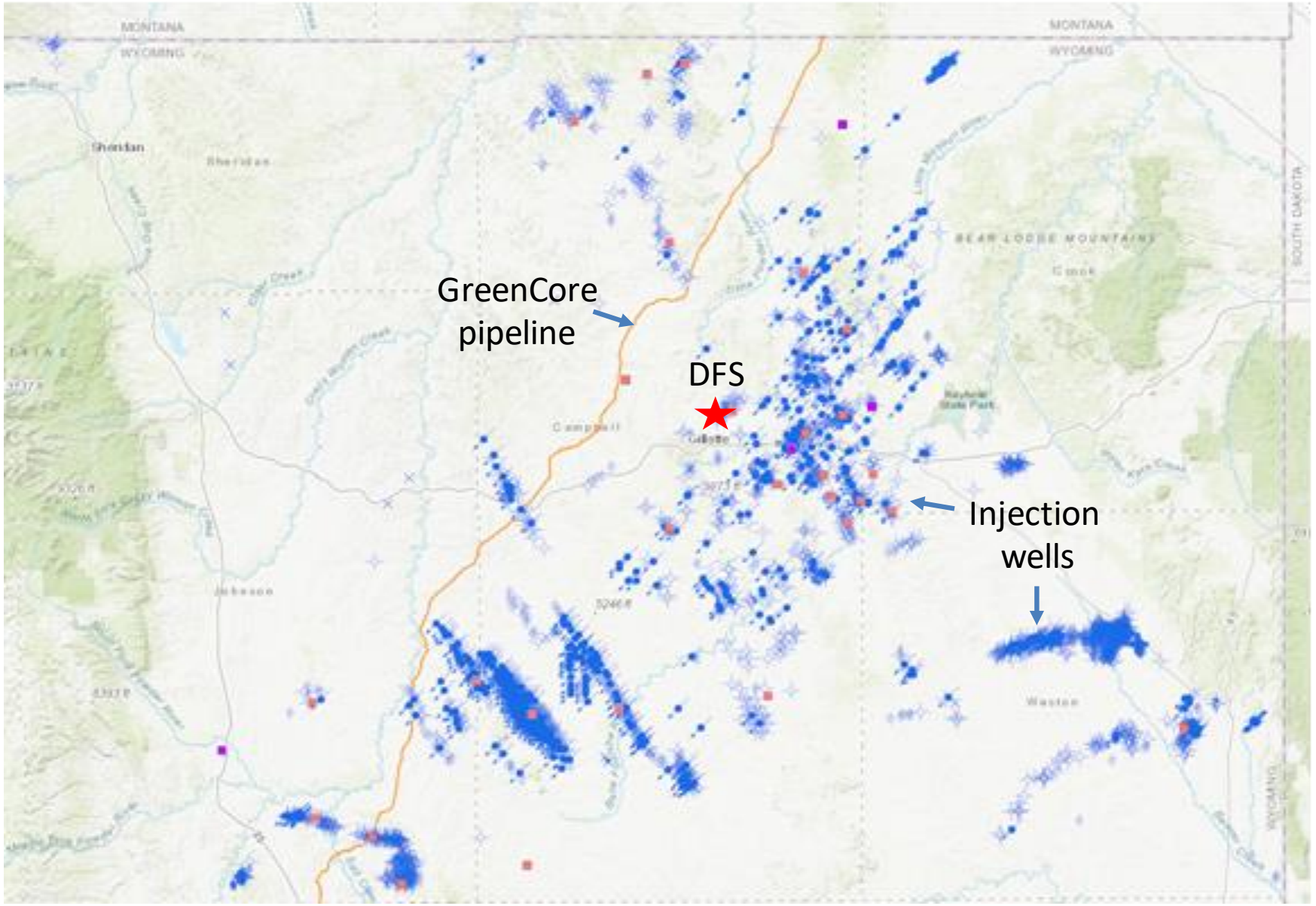
Electric Power Research Institute – CCUS and power industry perspectives
NRG Energy – Utility perspective; experiences with Petra Nova
NRECA – Rural and cooperative utility perspectives
University of Wyoming – CarbonSAFE project lead; relevant technical issues for CO_2 utilization
WIA - State of Wyoming issues, regulations, permitting

Project Tasks and Schedule

Project Tasks		Start Date	End Date	Cost
Task 1.	Project Management & Planning	1-Oct-19	30-Sep-21	$576,006
	Milestones:			
	Updated Project Management Plant (PMP)		31-Dec-19	
Task 2.	Project Design Basis	1-Oct-19	31-Mar-20	$448,005
	Develop RFI for Dry Fork Station			
	Enviromental review, water study			
	Milestones:			
	Design basis document		31-Mar-20	
Task 3.	Preliminary Process Design	1-Oct-19	30-Aug-20	$1,024,011
	Update process simulation			
	Draft process design, set modular design requirments			
	Milestones:			
	Initial process design package		30-Aug-20	
Task 4	Detailed Process Design	1-Apr-20	30-Jun-21	$2,880,031
	Develop detailed process design (P&ID, GA, electrical, controls)			
	Process equipment selection			
	Develop construction plan and schedule			
	Milestones:			
	Detailed design		30-Jun-21	
Task 5.	Cost Estimating	1-Oct-20	30-Jun-21	$1,088,012
	Equipment and O&M cost estimating			
	Site works and installation cost estimating			
	Milestones:			
	Completed equipment and installation cost estimate		30-Jun-21	
Task 6.	Final Report	1-Apr-21	30-Sep-21	$384,004
	Milestones:			
	Final project report		20-Sep-21	



Wyoming CO_2 Infrastructure



Technical Approach: Risk Mitigation

Description of Risks	Probability (Low, moderate, high)	Impact (Low, moderate, high)	Risk Management Mitigation and Response Strategies
Management/Resource Risks			
Timing uncertainty related to NEPA review or other required environmental permits assessments	Low	High	S&L has experienced environmental asset and impact personnel and was involved in the permitting process for the original power plant and the WITC test facility. No serious problems are expected.
Difficulties coordinating team activities	Low	Moderate	MTR has extensive experience managing large commercial projects involving customers, EPCs, and subcontractors. MTR has also worked with DOE for more than a decade executing a string of projects on time and within budget. In addition, much of the project team has experience working together. The scope of work outlined for each team member is in keeping with the size, complexity and overall level of effort from routine project work. Task 1 is focused on managing the project through this Project Management Plan (PMP), as well as regular meeting with the team members and DOE.
MTR's engineering capability to bring this technology to this scale	Low	High	MTR will provide management for the overall program and the membrane unit of the project. These are activities that our company's engineers do on a regular basis and no serious problems are expected. We have involved S&L and Trimeric to assist with balance of plant engineering assessment. S&L is a large, well-known and experienced EPC contractor in the power industry with over twenty years experience in design, engineering and costing of CO_2 capture projects up to commercial-scale. Trimeric has extensive experience with commercial CO_2 purification units.

Current MTR DOE Projects

MTR Development Program	2018	2019	2020	2021	2022
Large Pilot, Integrated Test Center (10 MWe), WY (FE0031587)					
Phase I - Feasibility study(completed)					
Phase II - FEED study					
Phase III - Build, install & operate					
Full-Scale Pre-FEED, Duke Energy's East Bend Station (640 MWe), KY (EPRI's FE0031589)					
Scale Up and Testing of Advanced Polaris Membrane CO_2 Capture Technology, TCM Norway (FE0031591)					
Commercial-Scale FEED Study, Basin Electric's Dry Fork Station (400 MWe), WY (FE0031846)					

Full-scale FEED is the next logical step on the membrane CO_2 capture commercialization path