DOE Contract DE-FE0031946

Engineering Scale Design and Testing of Transformational Membrane Technology for CO_2 Capture

Shiguang Li,[1] Yang Han,[2] Winston Ho,[2] Travis Pyrzynski,[1] Weiwei Xu,[1] and Howard Meyer[1]

1: Gas Technology Institute (GTI)

2: The Ohio State University (OSU)

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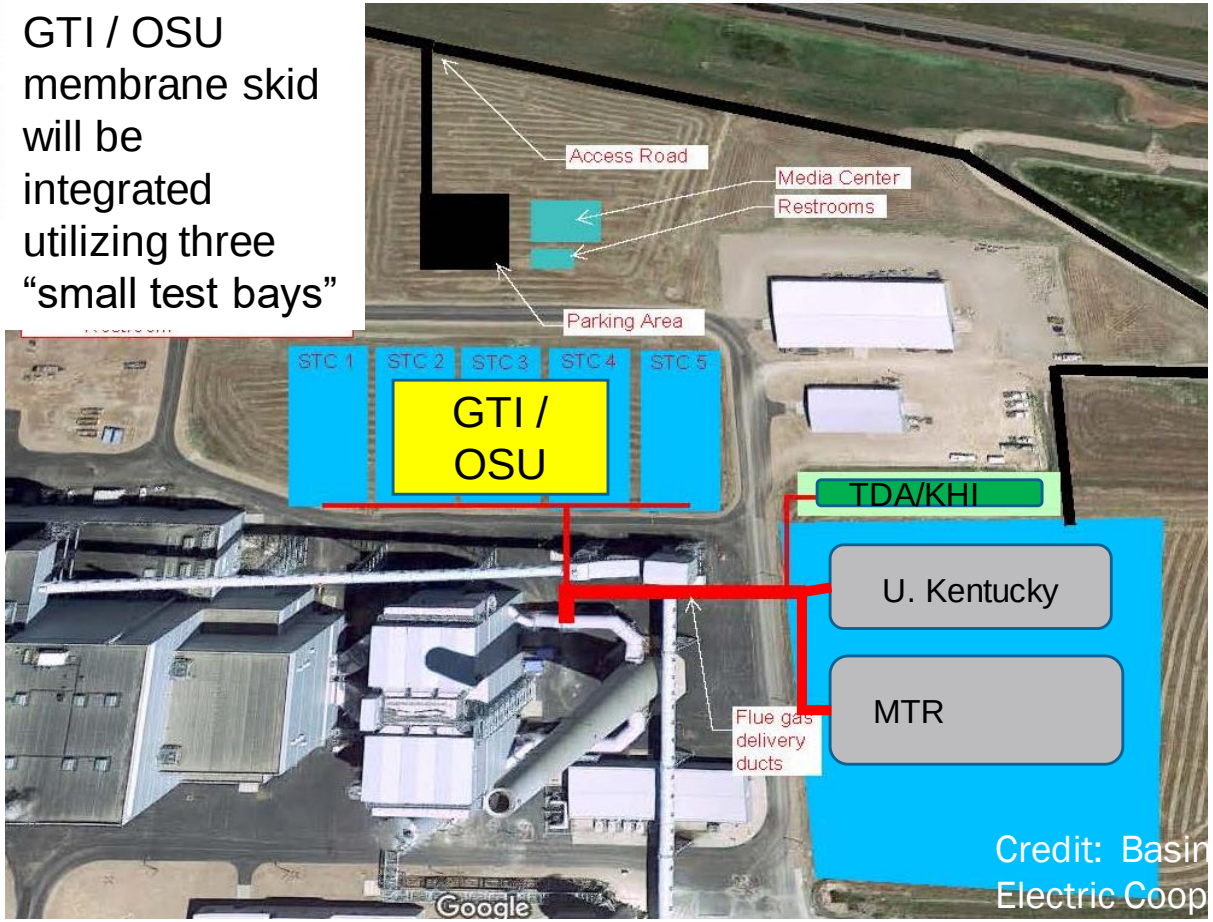
Project overview

- **Performance period**: October 1, 2020 – March 31, 2025
- **Total funding**: $16.25 MM (DOE: $13 MM, Cost share: $3.25 MM)
- **Objectives**: 1) Design and build an engineering-scale CO_2 capture system using OSU's transformational membrane in commercial-size, spiral-wound membrane modules; 2) Conduct tests on coal flue gas at the Wyoming Integrated Test Center (ITC) and demonstrate a continuous, steady-state operation for a minimum of two months; and 3) Gather data necessary for further process scale-up
- **Goal:** Achieve DOE's Transformational Carbon Capture performance goal of CO_2 capture with 95% CO_2 purity at a cost of $30/tonne of CO_2 captured and at a cost of electricity (COE) at least 30% less than baseline CO_2 capture approaches by 2030
- **Team**:

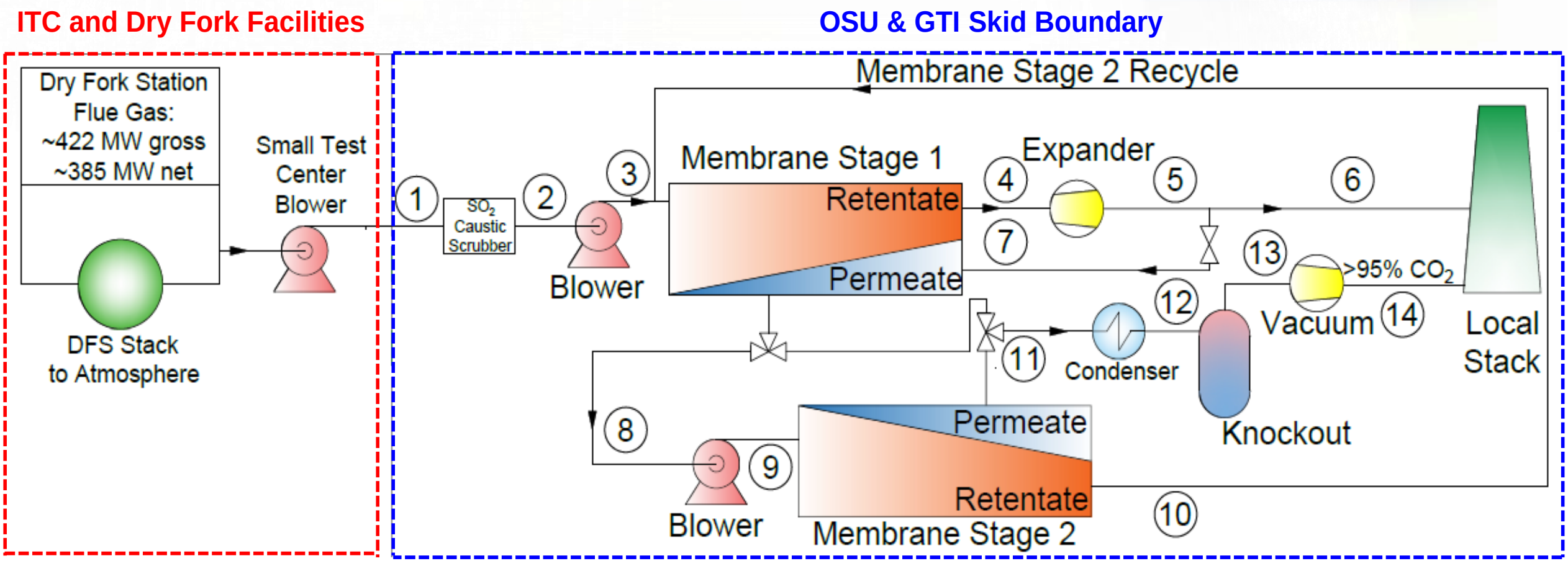
Member	Roles
gti	• Project management and planning • Lead on skid design, selection of skid constructor, skid installation, and field testing • Support TEA and EH&S assessment
The Ohio State University	• Participate in project management and planning • Membrane and module fabrication and QA/QC testing • Support skid design and field testing, TEA and EH&S study
ITC	• Site host, lead on testing site preparation
Trimeric Corporation	• Lead on TEA and EH&S assessment

Testing on Coal Flue Gas at Wyoming Integrated Test Center

GTI / OSU membrane skid will be integrated utilizing three "small test bays"

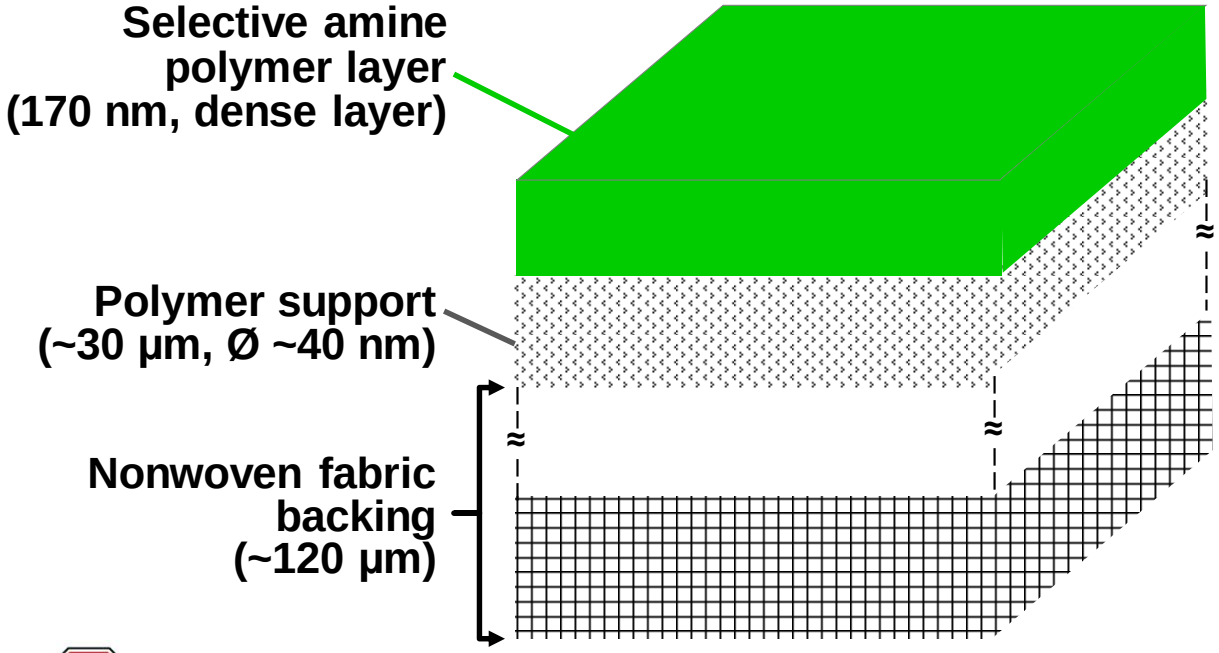


Process description

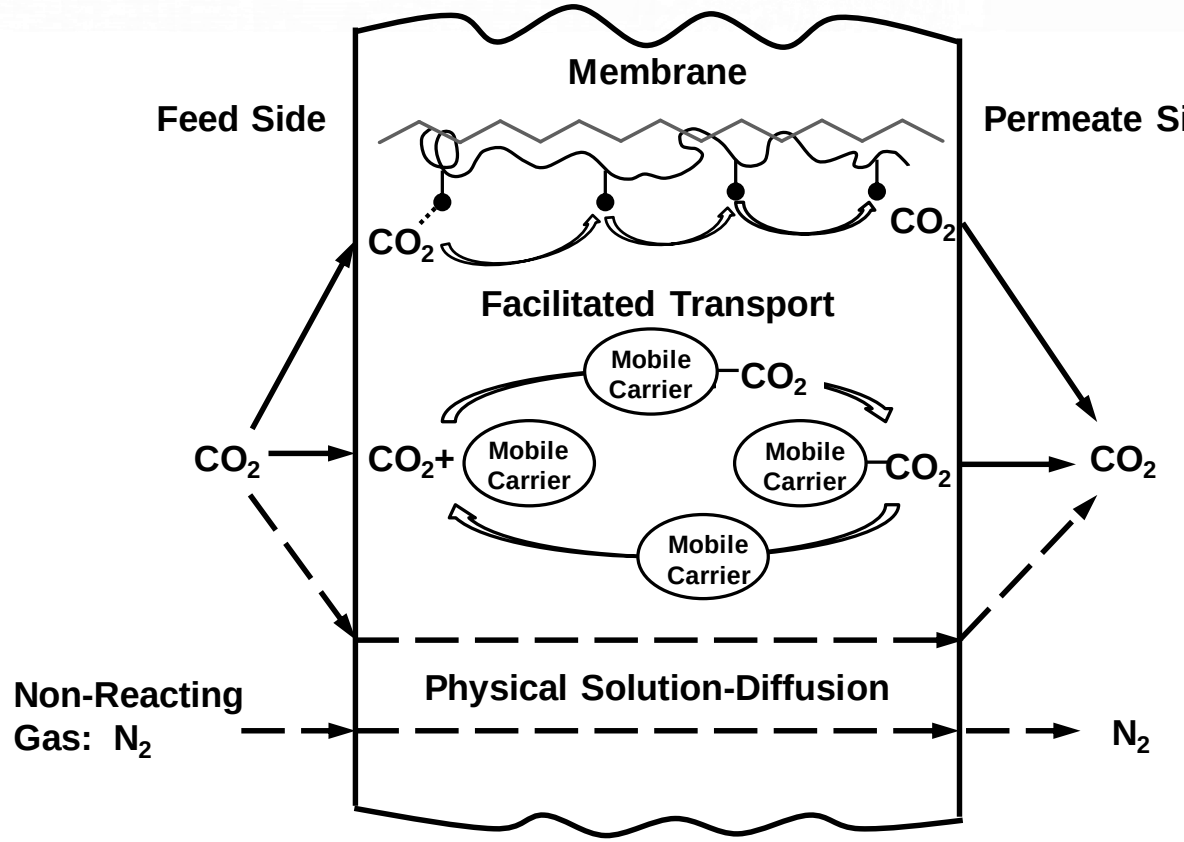


OSU membrane structure and transport mechanism

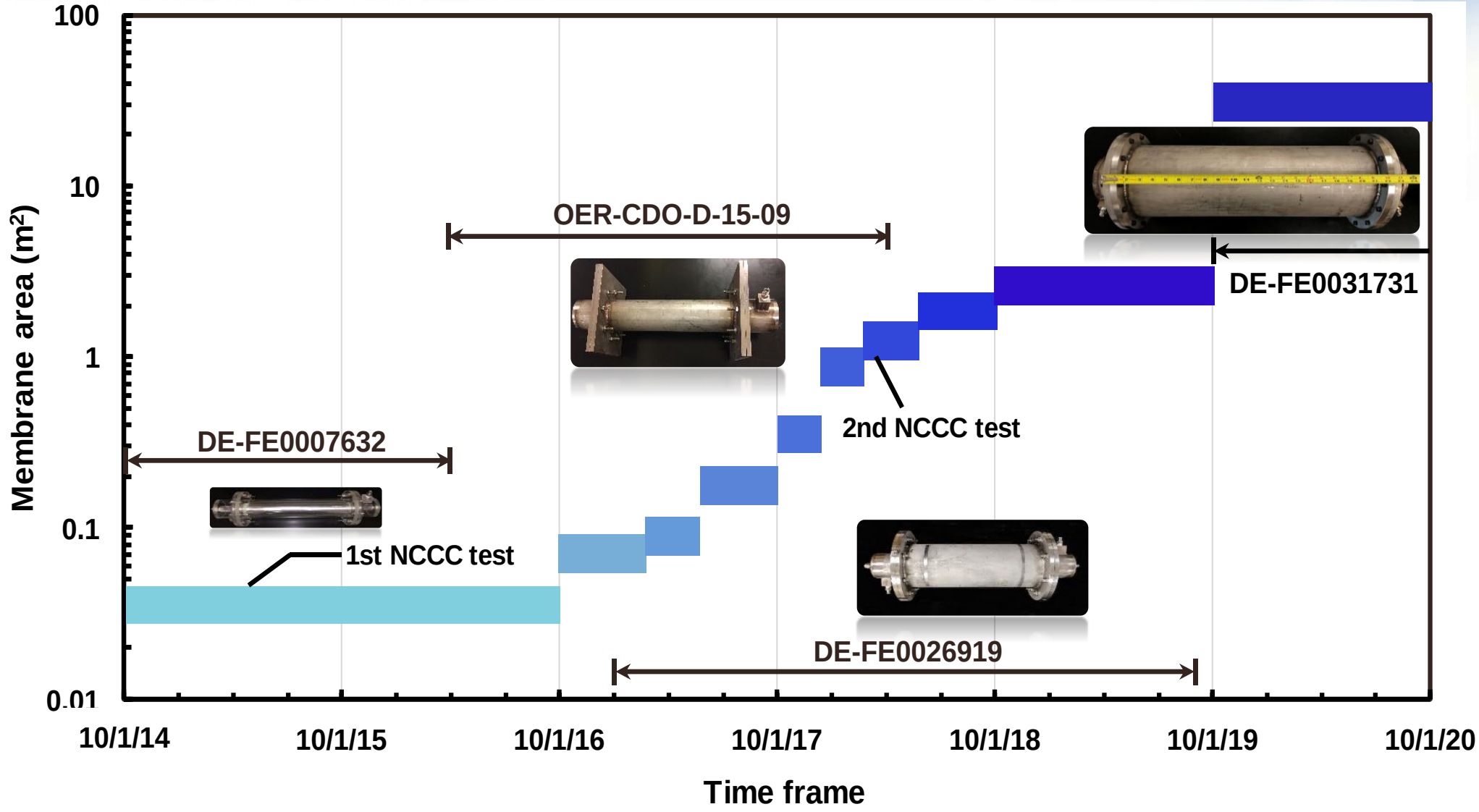
Simplicity of membrane for low cost: thin selective amine polymer layer on polymer support



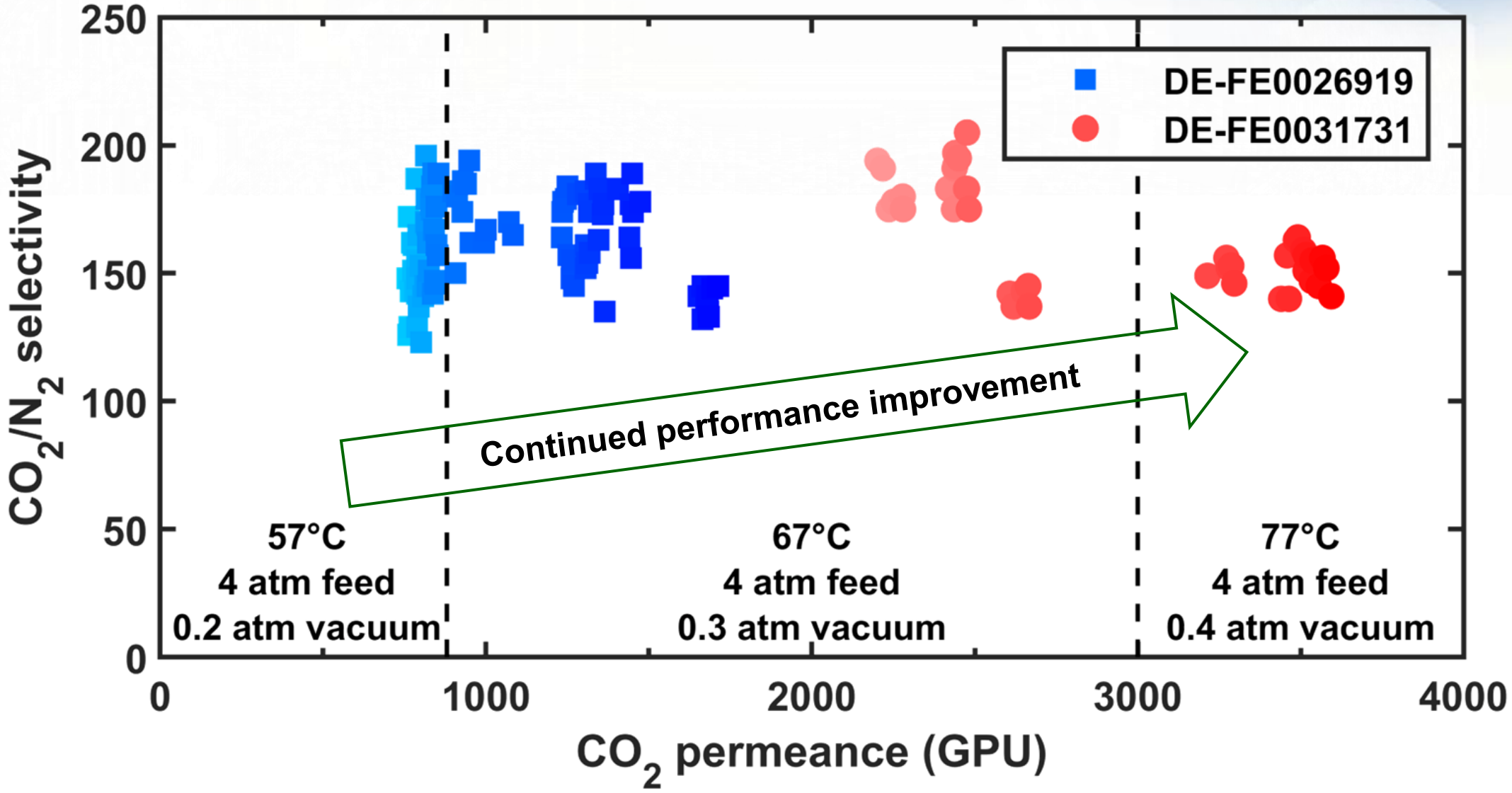
High-selectivity due to facilitated transport mechanism



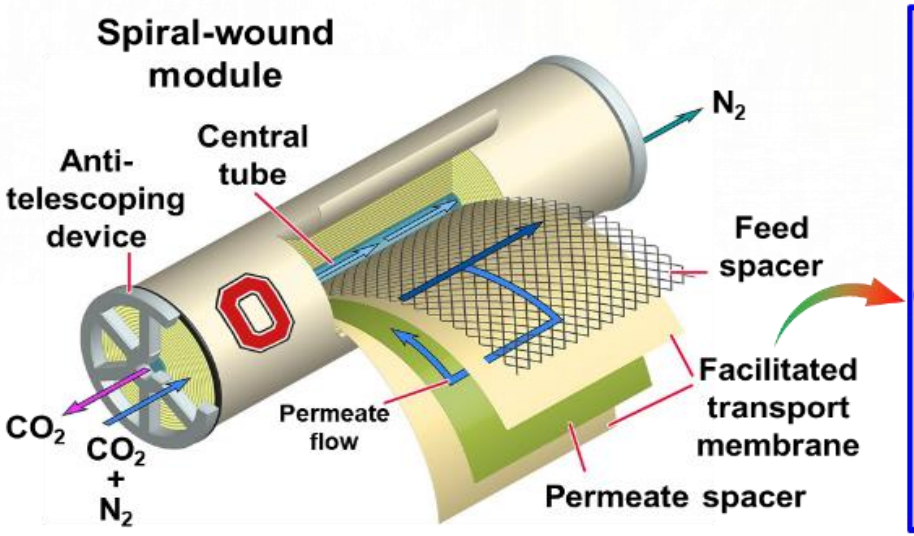
OSU funding history and progression of module scaleup

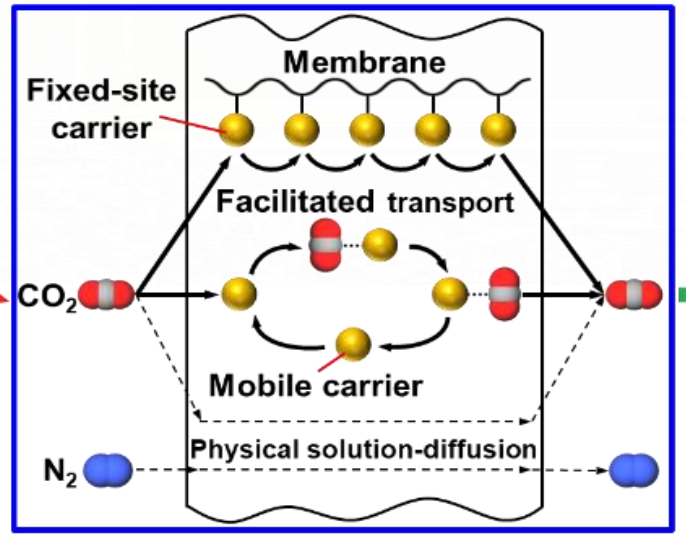


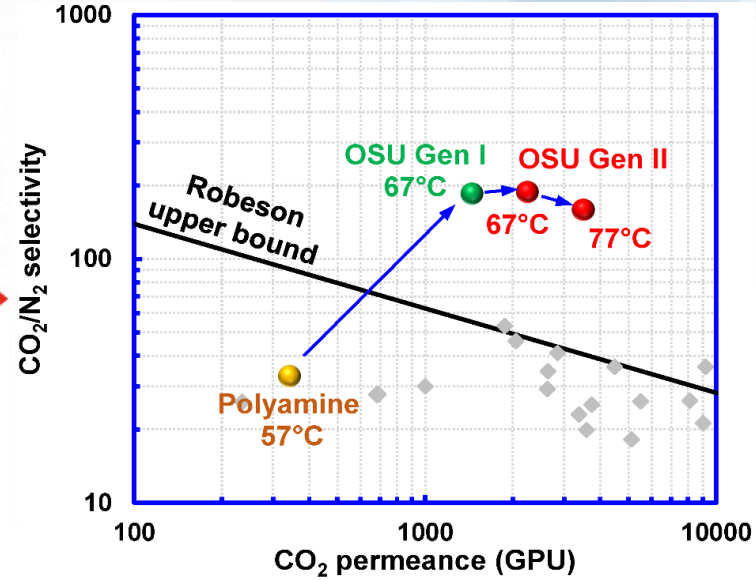
OSU progression of membrane performance



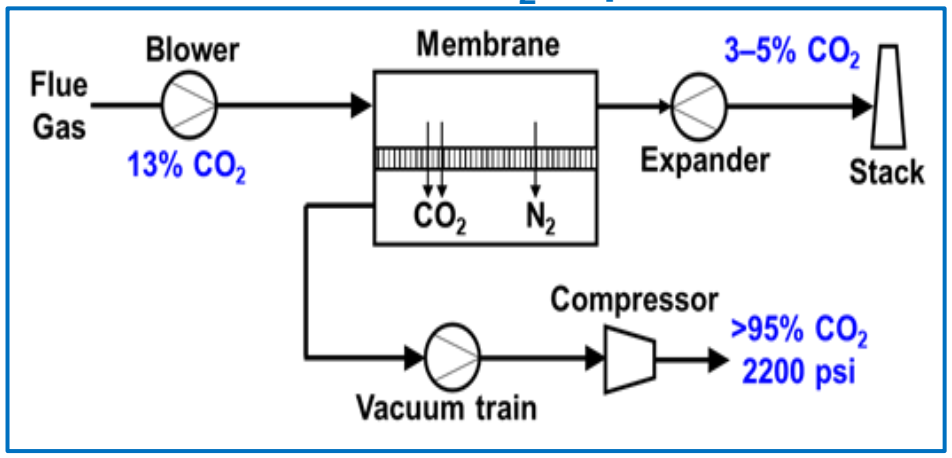
OSU membrane key features: high permeance and high selectivity



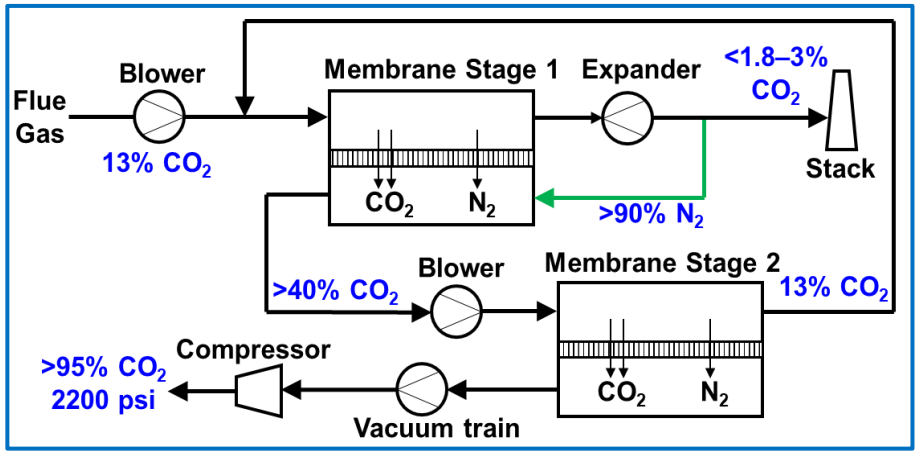




60–80% CO_2 capture

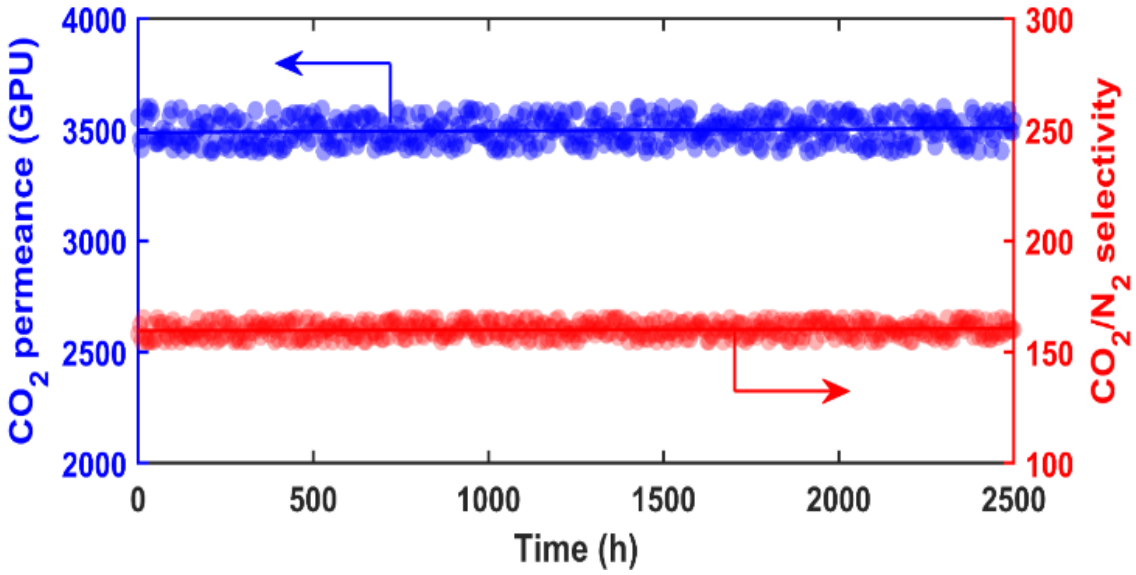


80–90+% CO_2 capture

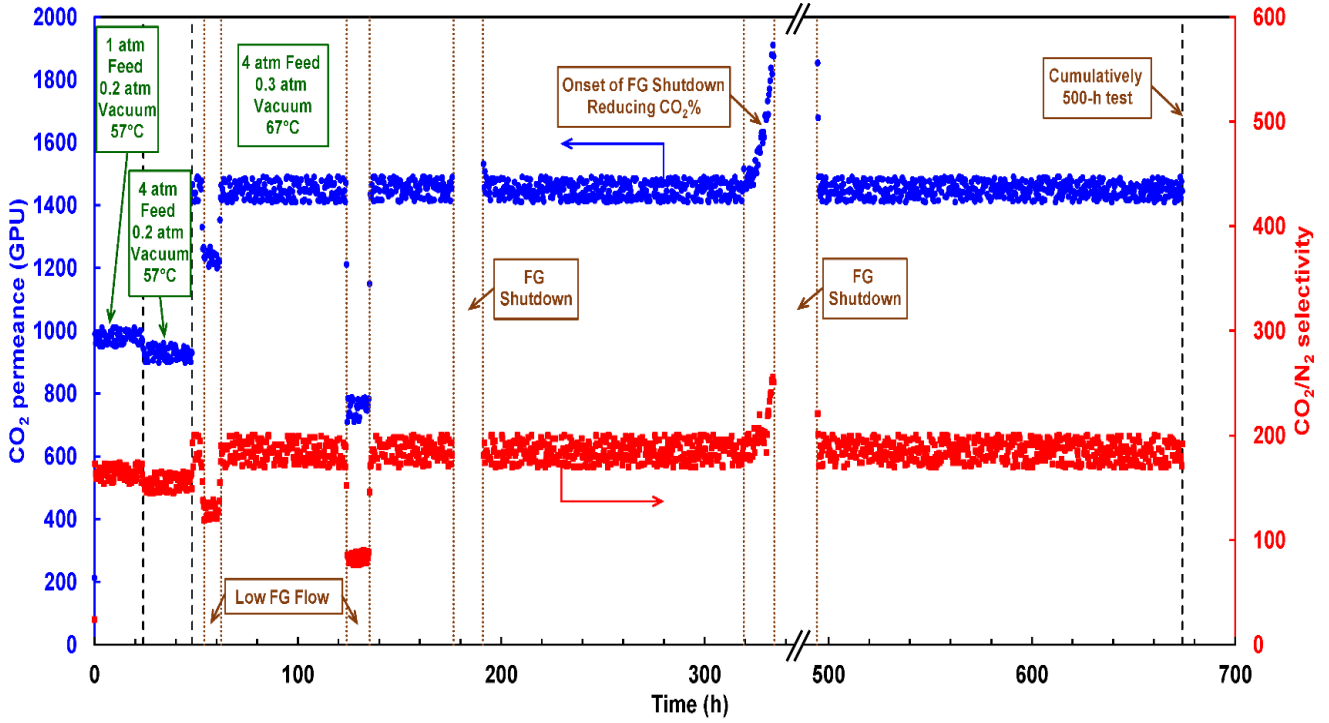


OSU membrane long-term performance confirmed on simulated and actual flue gas at NCCC

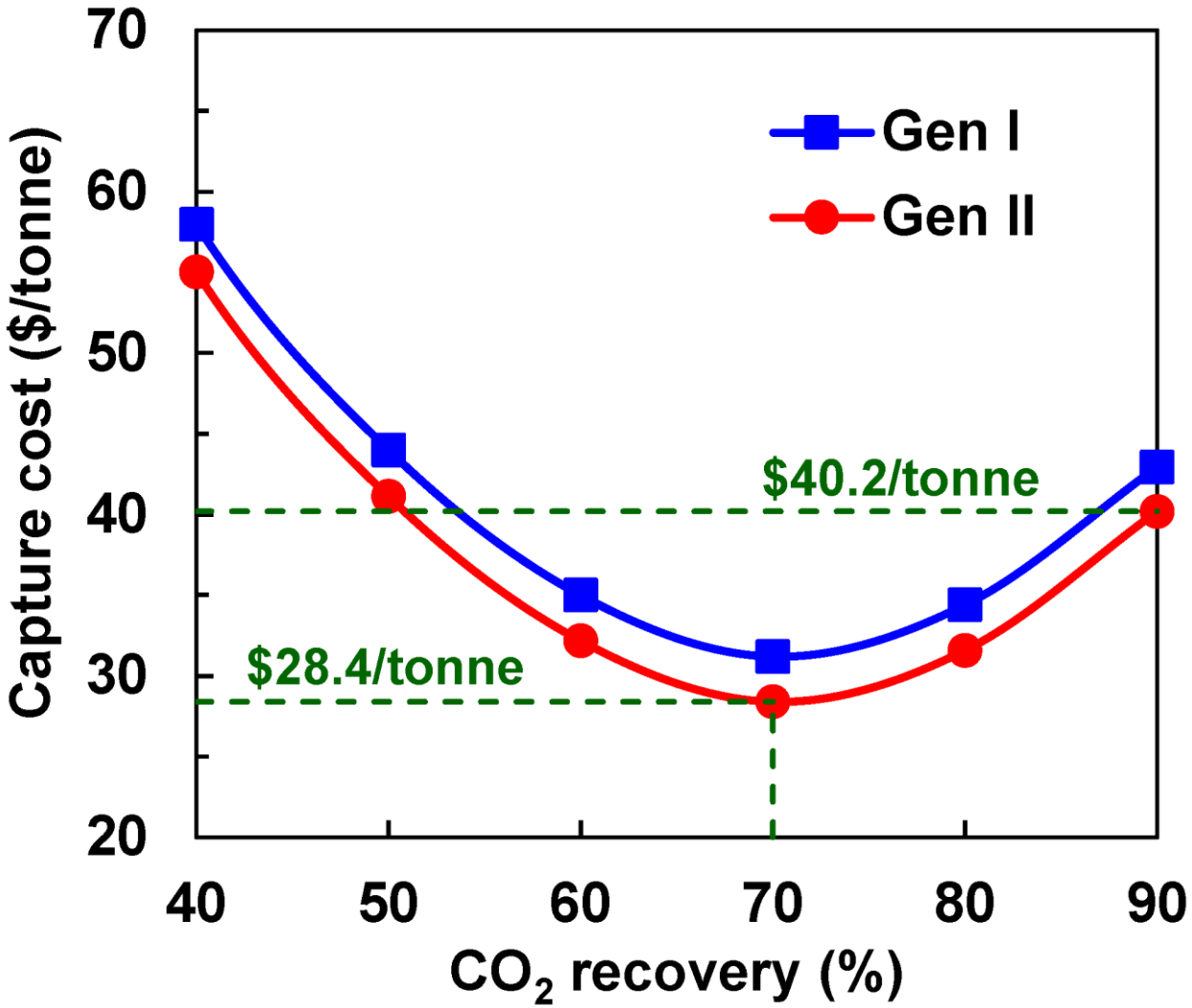
- **Gen II**: 2,500-h lab testing with simulated flue gas containing SO_2, O_2, H_2O



- **Gen I**: 500-h testing with actual flue gas at National Carbon Capture Center (NCCC)

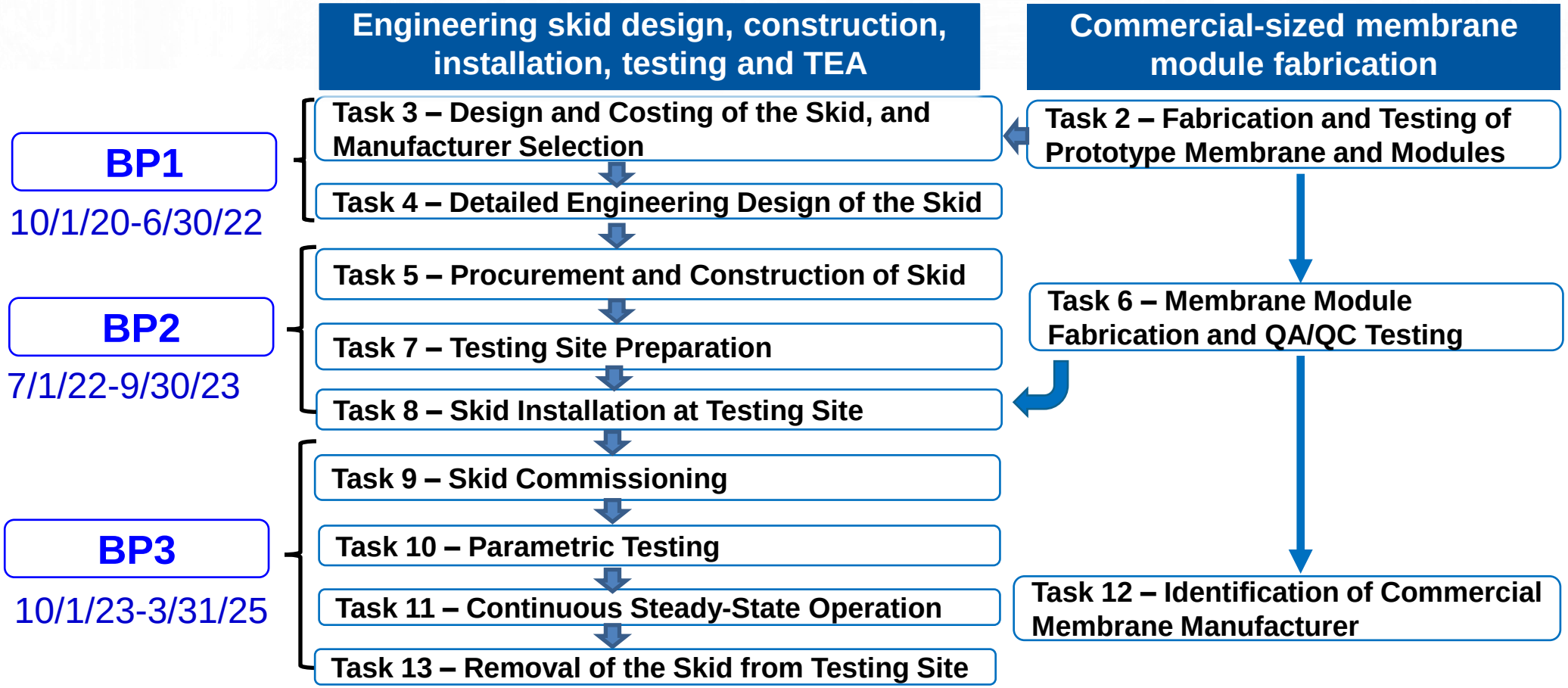


OSU sensitivity study indicates capture cost can be as low as <$28.40/tonne at 70% CO_2 capture



Overview/roadmap

Task 1 Project management and planning (*throughout the project)*



Success criteria

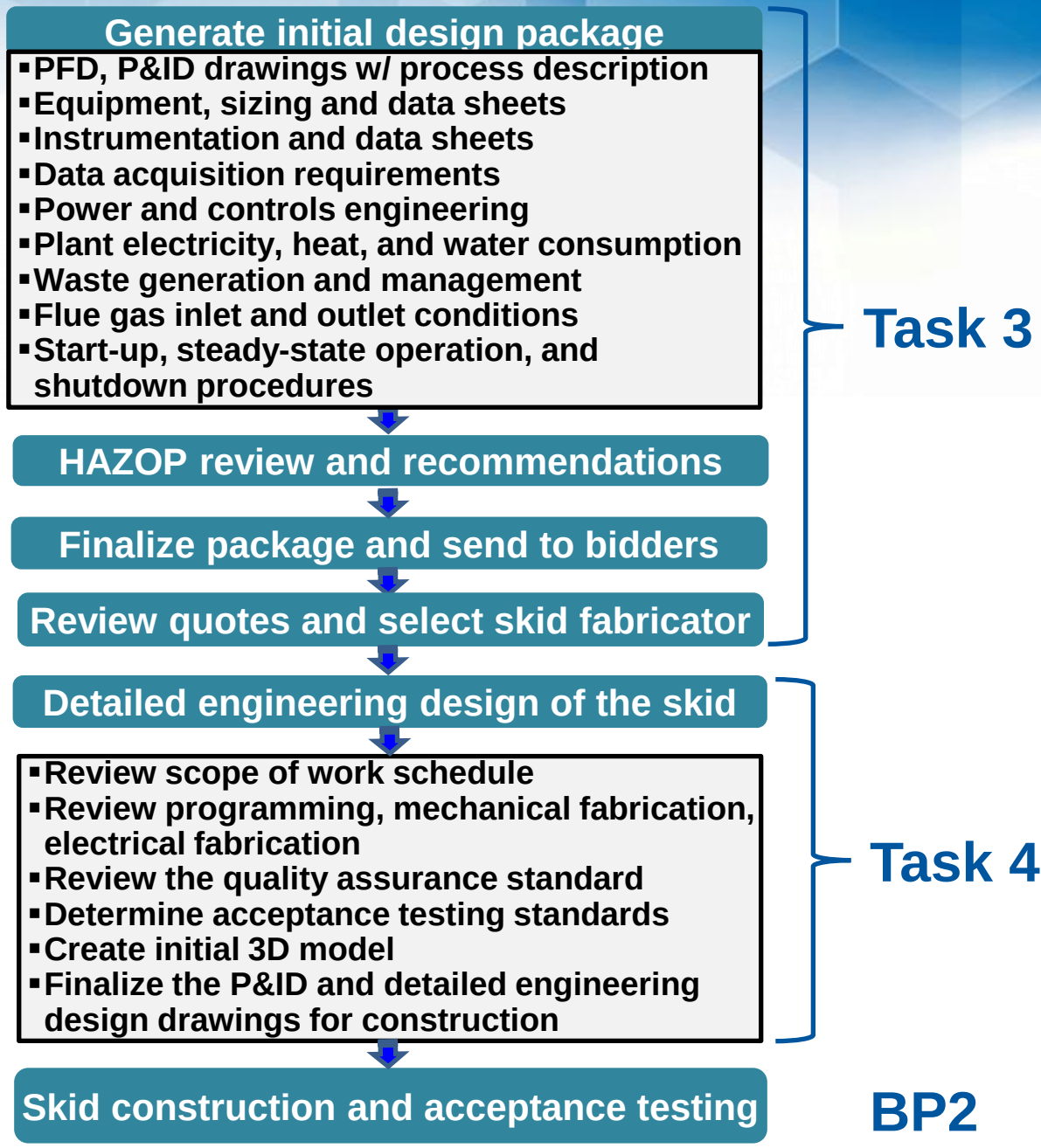
Decision Point	Date	Success Criteria
Go/no-go decision points	6/30/22	1) CO_2/N_2 selectivity ≥140 and CO_2 permeance ≥3,000 GPU achieved for prototype membrane modules; and 2) Final engineering-plant design package submitted to DOE
Go/no-go decision points	9/30/23	1) Skid constructed and passed factory acceptance testing; and 2) Skid installed at ITC
Completion of the project	3/31/25	1) Demonstrated a steady-state operation for a minimum of two months with the CO_2 capture rate of 60-90% and 95% CO_2 purity achieved 2) Final TEA delivered to DOE with 95% CO_2 purity at a cost of $30/tonne of CO_2 captured and at a COE at least 30% less than a supercritical pulverized coal power plant validated 3) Final EH&S and TMP reports delivered to DOE 4) Commercial membrane manufacturer identified for the next phase 10 MW_e scale development 5) Final technical report submitted to DOE (due 6/30/25)

Milestones

#	Task/ Subtask	Milestone Title/Description	Planned Completion Date	Actual Completion Date
M1.1	1.1	Submit updated Project Management Plan to DOE	2/28/21	2/26/21
M1.2	1.1	Complete Kickoff Meeting	6/30/21	7/20/21
M1.3	1.2	Submit Technology Maturation Plan to DOE	6/30/21	4/2/21
M1.4	1.3	Submit initial TEA and EH&S assessment topical reports	6/30/21	
M2.1	2	Achieve CO_2/N_2 selectivity ≥140 (minimum requirement for 95 vol.% purity in the permeate side) and CO_2 permeance ≥3,000 GPU for prototype membrane modules	6/30/22	
M3.1	3	Issue initial engineering plant design package for bidding	12/31/21	
M3.2	3	Complete selection of skid manufacturer	3/30/22	
M4.1	4	Issue engineering plant design package	6/30/22	
M5.1	5	Complete construction of the engineering scale skid	3/30/23	
M6.1	6	Sufficient modules fabricated for engineering scale testing; QC/QC tests indicate >3,000 CO_2 permeance and CO_2/N_2 selectivity ≥140 achieved for these modules	9/30/23	
M7.1	7	Complete site preparation at ITC	3/30/23	
M8.1	8	Complete engineering skid installation at ITC	9/30/23	
M9.1	9	Complete on-site system shake-down at ITC	12/31/23	
M10.1	10	Validate the achievement of 60-90% CO_2 removal rate with 95% CO_2 purity during parametric testing; continuous steady-state operation conditions identified	6/30/24	
M11.1	11	Complete steady-state operation for a minimum of two months; achieve a 60-90% CO_2 removal rate with 95% CO_2 purity	3/31/25	
M12.1	12	Commercial membrane manufacturer identified for the next phase development	3/31/25	
M13.1	13	Remove pilot-scale system and clean up the testing site	3/31/25	
M1.5	1.3	Issue final detailed TEA and EH&S assessment topical reports	3/31/25	
M1.6	1	Submit Final Technical Report	6/30/25	

Status of BP1 tasks

- Task 1.3 – TEA and EH&S Risk Assessment: **Ongoing**
- Task 2 – Fabrication and Testing of Prototype Membrane and Modules: **Ongoing**
- Task 3 – Design and Costing of the Skid, and Manufacturer Selection: **Commenced**
- Task 4: Detailed Engineering Design of the Skid: **Planned**



Risk assessment: challenges and mitigation strategies

Challenges/Risks

1) Particulates fouling the membrane

Mitigation:

- 1a: Membrane modules will be equipped with filters and guards for particulates

2) Corrosion or particulates fouling of membrane system equipment

Mitigation:

- 2a: Materials of construction will be selected based on lessons learned from GTI's previous engineering scale project
- 2b: Process conditions will be modified and pre-treatments added to address fouling issues

3) 95% CO_2 purity not achieved

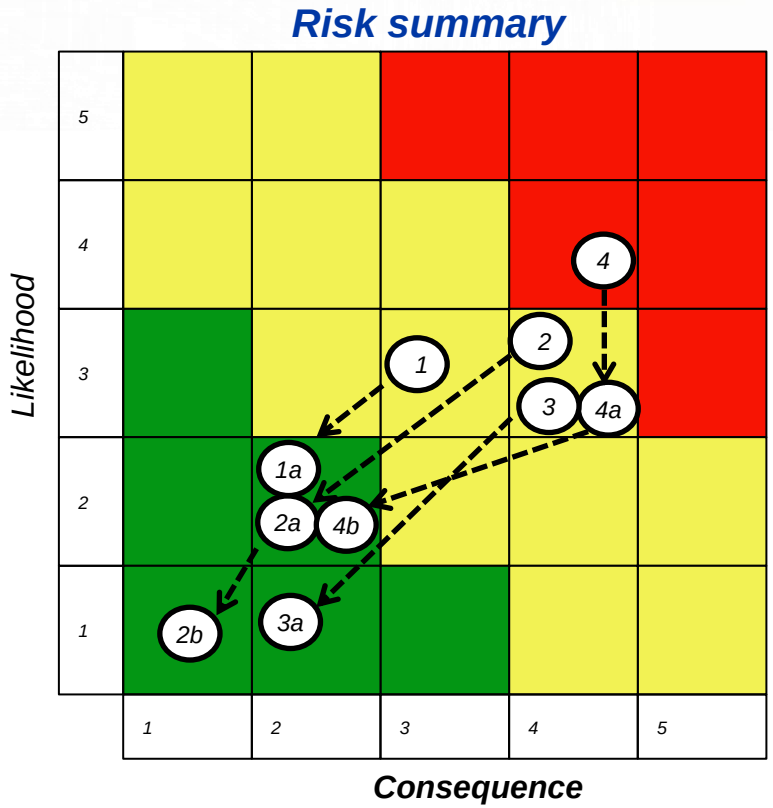
Mitigation:

- 3a: Adjust pressure, temperature, flow rate conditions to achieve 95% CO_2 purity

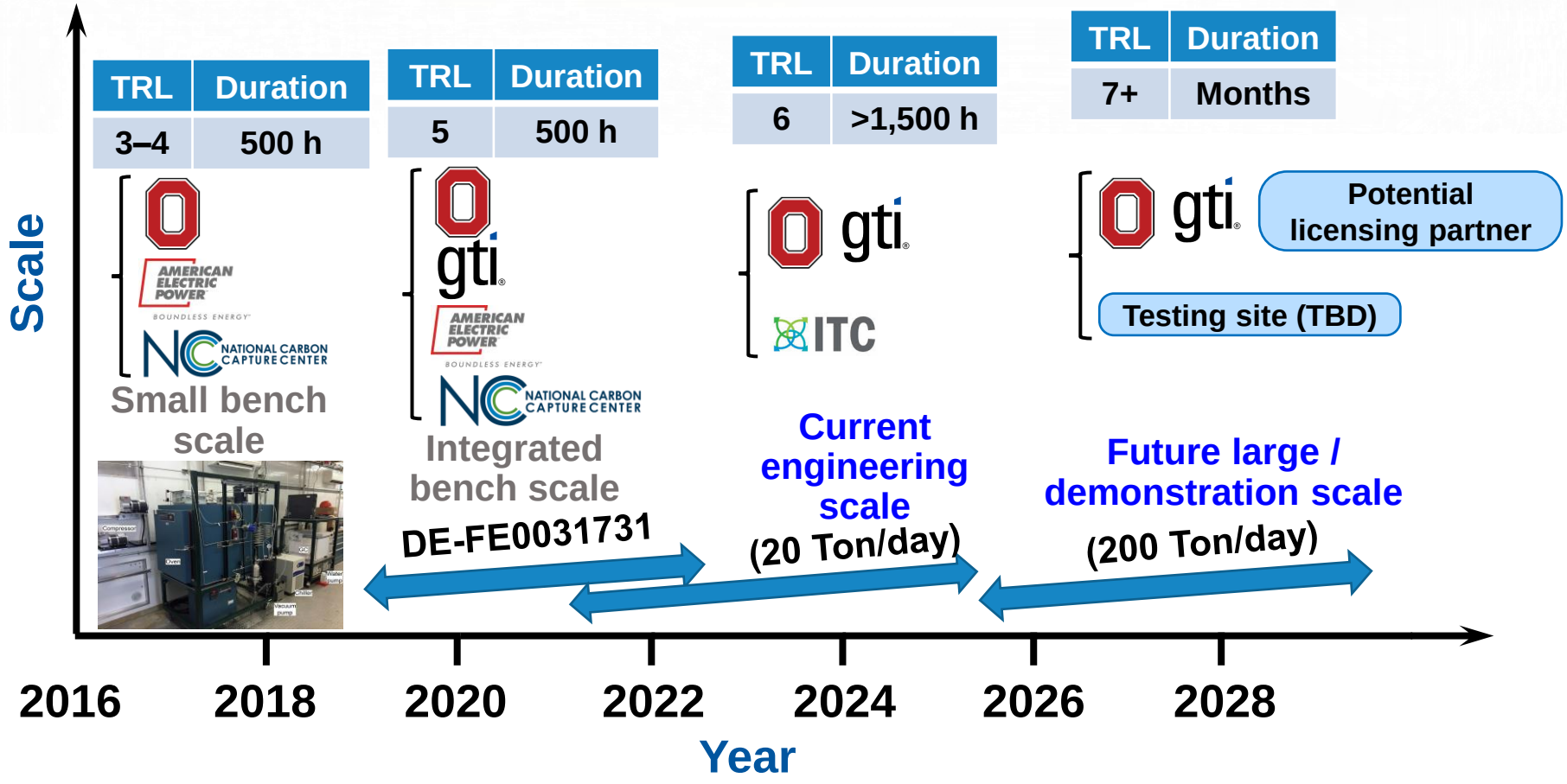
4) CO_2 capture cost not in line with the expected outcome

Mitigation:

- 4a: Optimize process design
- 4b: Improve the manufacturing process to lower membrane costs



Technology development path



Summary

- The OSU Gen II transformational membrane with CO_2 permeance of 3,500 GPU and CO_2/N_2 selectivity of 160 has been successfully developed
- Long-term stability was confirmed on simulated flue gas for OSU Gen II membrane and on simulated and actual flue gas at NCCC for OSU Gen I membrane
- TEA based on bench-scale data suggests the membrane can achieve $28.40/tonne CO_2 captured for a 70% CO_2 capture rate with a one-stage process and $40/tonne for a 90% CO_2 capture rate with an innovative two-stage process
- We are designing an engineering-scale CO_2 capture system using OSU's transformational membrane and process for field testing at ITC
- Fabrication and testing of prototype membrane and commercial-sized membrane modules are underway

NCCC = National Carbon Capture Center

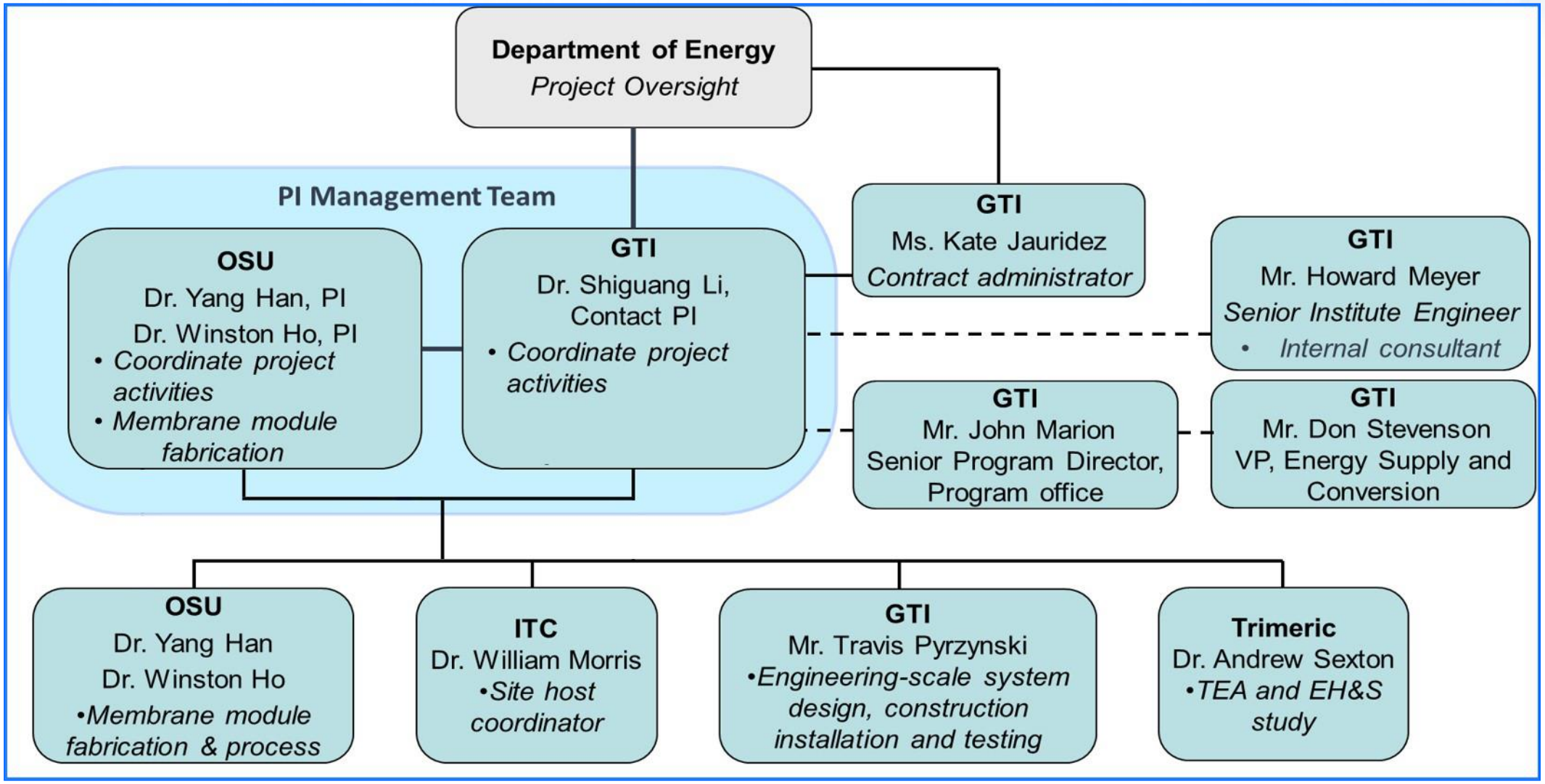
Acknowledgements

- Financial and technical support

DE-FE0031946

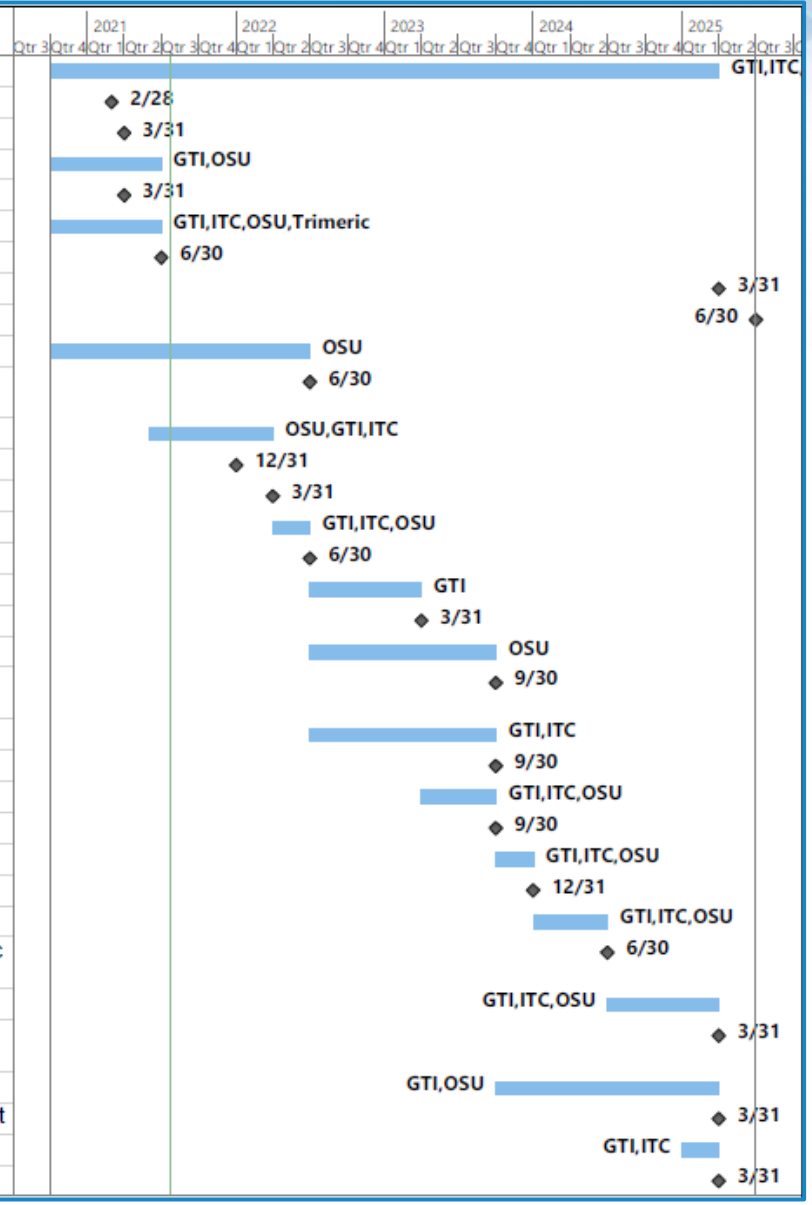
- DOE: Andrew O'Palko, Andy Aurelio, Dan Hancu, José Figueroa and Lynn Brickett
- Partners

Appendix – Project organization and structure



Appendix – Gantt chart

Task No	MS No	Task Name
1.1		Project management and planning
	M1.1	Submit updated project management plan to DOE
	M1.2	Complete kickoff meeting
1.2		Technology maturation plan
	M1.3	Submit technology maturation plan to DOE
1.3		Initial and final detailed TEA and EH&S studies
	M1.4	Submit initial TEA and EH&S assessment topical reports
	M1.5	Issue final detailed TEA and EH&S assessment topical reports
	M1.6	Submit final technical report
2.0		Fabrication and testing of prototype membane and modules
	M2.1	Achieve CO2/N2 selectivity ≥140 (minimum requirement for 95 vol.% purity in the permeate side) and CO2 permeance ≥3,000 GPU for prototype membrane modules
3.0		Design and costing of the skid and skid manufacturer selection
	M3.1	Issue initial engineering plant design package for bidding and costing
	M3.2	Complete selection of skid manufacturer
4.0		Detailed engineering design of the skid
	M4.1	Issue engineering plant design package
5.0		Procurement and construction of the skid
	M5.1	Complete construction of the engineering scale skid
6.0		Membrane module fabrication and QA/QC testing
	M6.1	Sufficient modules fabricated for engineering scale testing; QC/QC tests indicate >3,000 CO2 permeance achieved and CO2/N2 selectivity ≥140 achieved for these modules
7.0		Testing site preparation
	M7.1	Complete site preparation at ITC
8.0		Skid installation at testing site
	M8.1	Complete engineering skid installation at ITC
9.0		Skid commissioning
	M9.1	Complete on-site system shake-down at ITC
10.0		Parametric testing
	M10.1	Validate the achievement of 60-90% CO2 removal rate with 95% CO2 purity during parametric testing; continuous steady-state operation conditions identified
11.0		Continuous steady-state operation
	M11.1	Complete steady-state operation for a minimum of two months; achieve a 60-90% CO2 removal rate with 95% CO2 purity
12.0		Identification of commercial membrane manufacturer
	M12.1	Commercial membrane manufacturer identified for the next phase 10 MWe scale development
13.0		Removal of the skid from testing site
	M13.1	Remove pilot-scale system and clean up the testing site



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