High-Permeance Membranes for CO_2 Capture from Industrial Steel Production

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2024 FECM/NETL Carbon Management Research Project Review Meeting

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Project Overview

- **Project:** Point Source Capture Technology
- **Funding Source**: NETL Point Source Capture Multiyear Research Plan (MYRP)
- **Project Objective:** **developing a scalable thin-film composite (TFC) membrane for industrial carbon capture that has a** ***CO_2 permeance >3,000 gas permeance unit (GPU)*** **and** ***CO_2/N_2 selectivity of >25***. **All the membrane support, gutter layer, and selective material will be optimized for scalability and performance stability (or non-aging property).**
- **Project Participants:**

National Energy Technology Laboratory

Idaho National Laboratory

National Carbon Capture Center

United States Steel

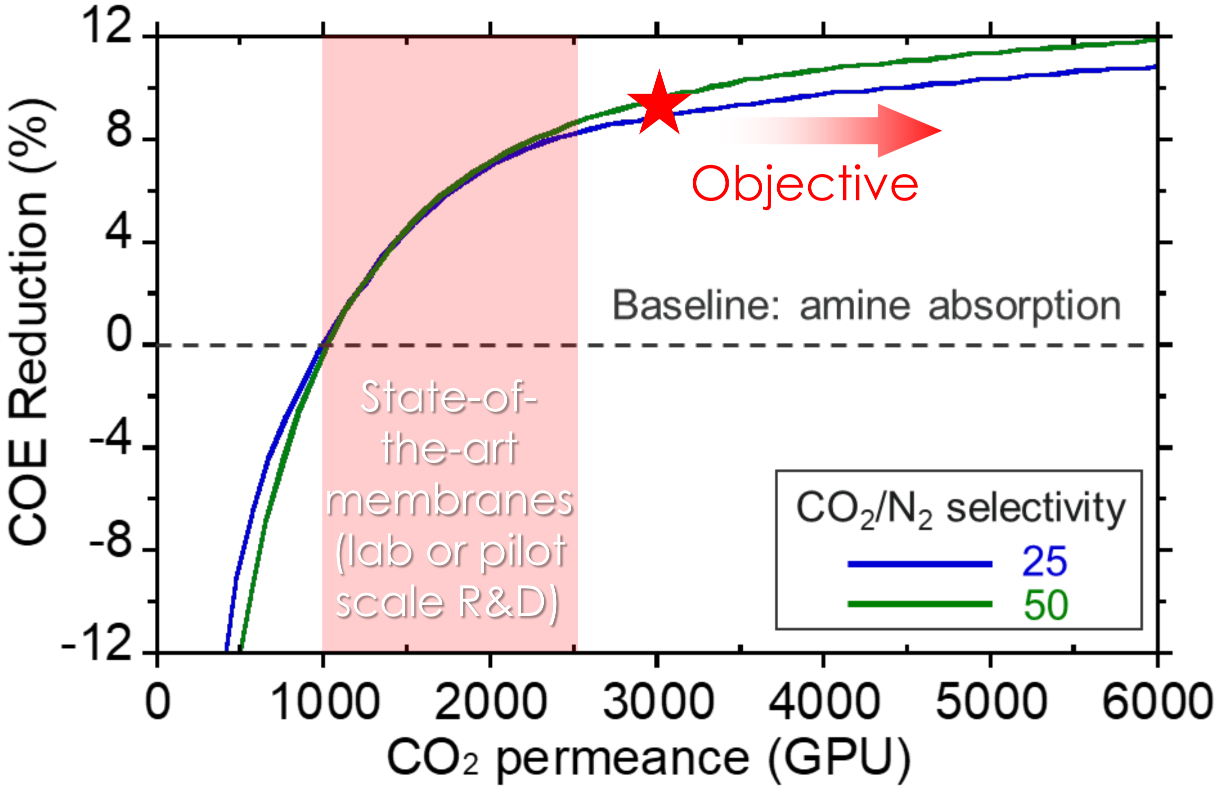
Carnegie Mellon University

CCSI² Carbon Capture Simulation for Industry Impact

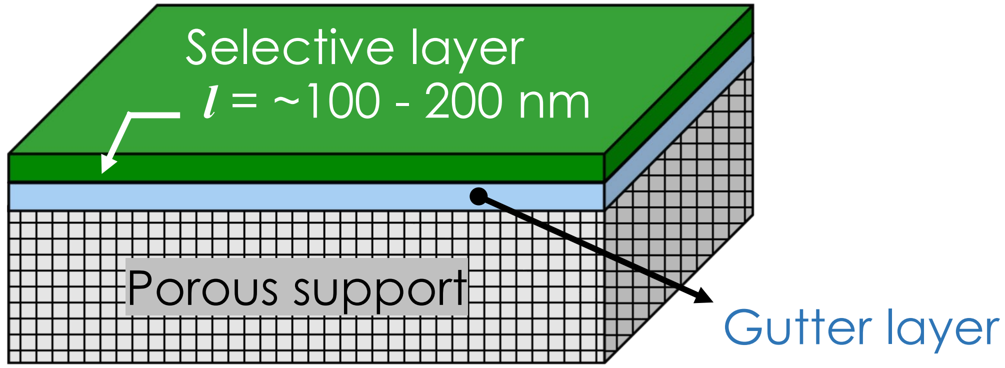
The University of Toledo

Importance of High-Permeance Membranes

Higher permeance leads to lower capture cost because fewer membrane areas are required.



Thin-Film Composite (TFC) Membranes



Selective layer: CO_2/N_2 separation

Gutter layer: preventing pore penetration

Porous support: mechanical reinforcement

Alex Zoelle *et al.*, Performance and Cost Sensitivities for Post-Combustion Membrane Systems, 2018 NETL CO_2 Capture Technology Project Review Meeting

COE: cost of electricity

Membrane Development Activities at NETL:
Prior Accomplishments

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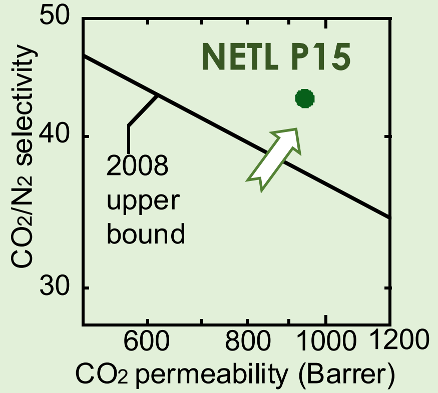
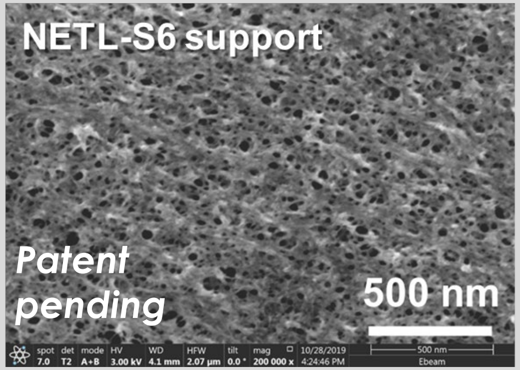
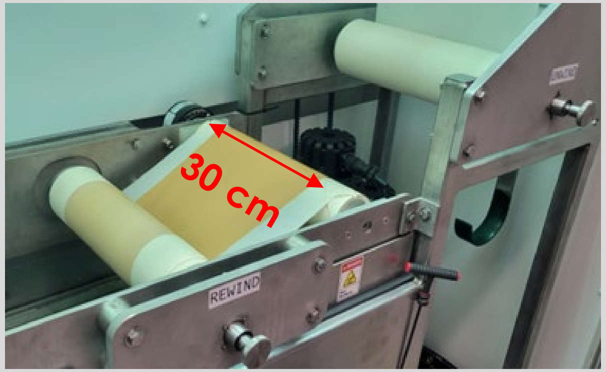
1. Selective layer material innovation

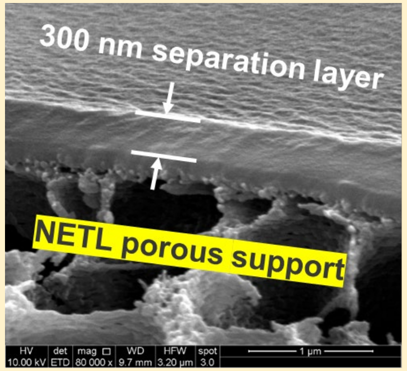


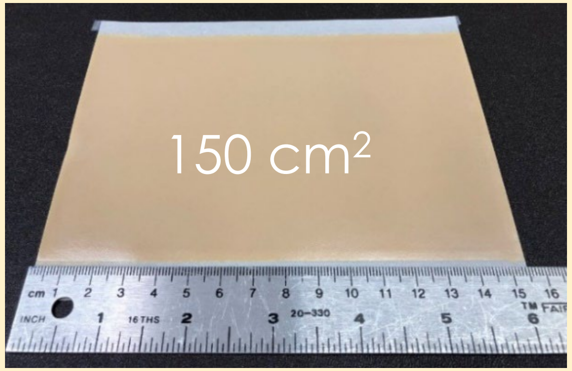
2. Membrane support development



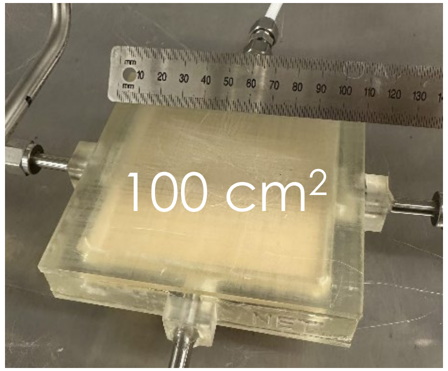


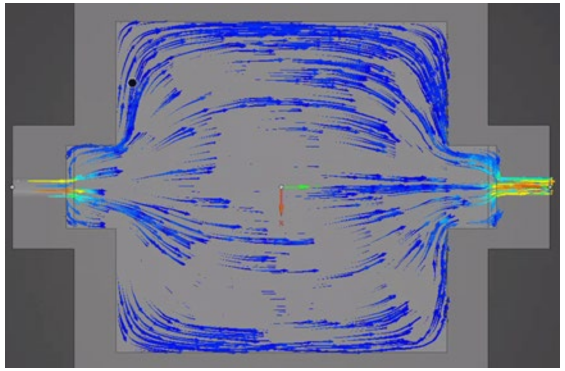
3. Scalable thin-film coating





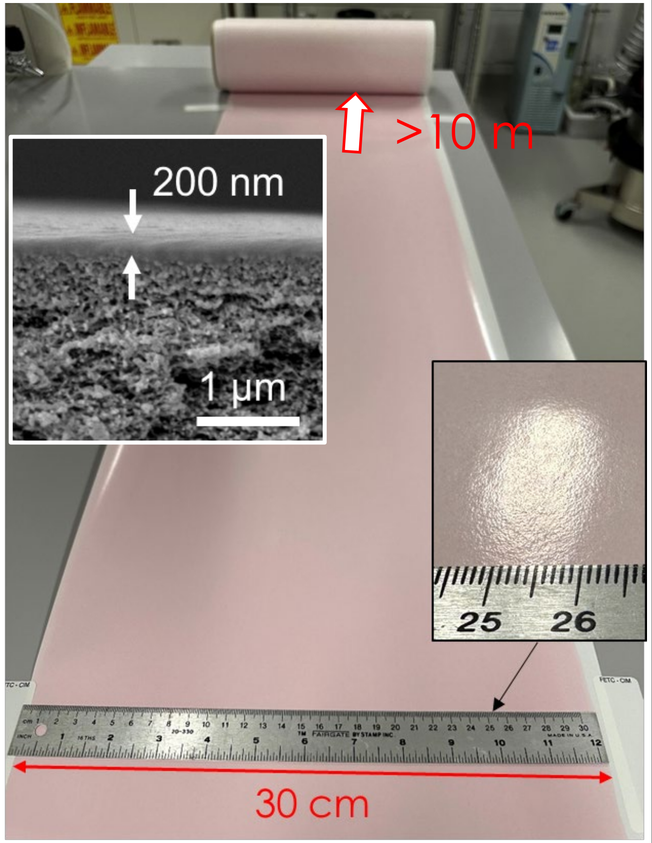
4. Module design, 3D printing and testing



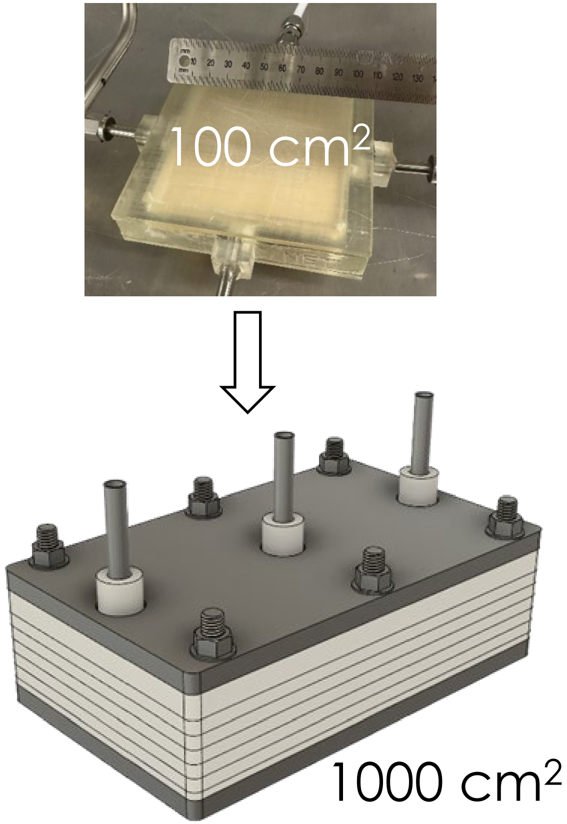


Membrane Development Activities at NETL:
2023-2024 Accomplishments

Roll-to-Roll TFC Fabrication



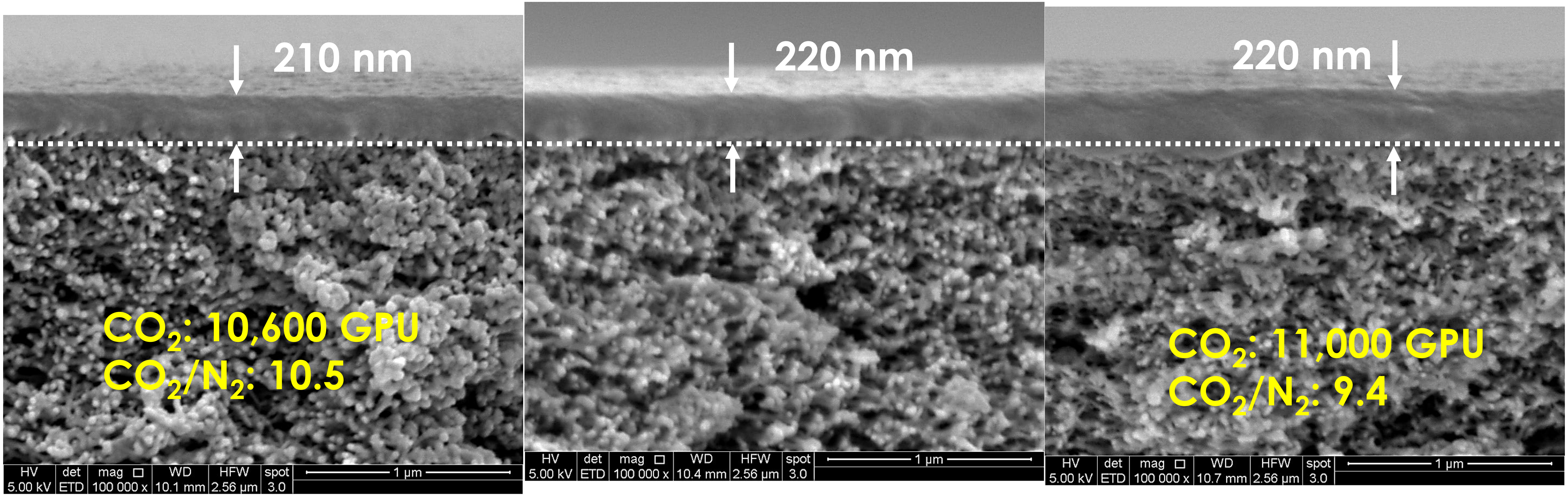
3D-Printed Module Scaleup & Testing



NETL Mobile Membrane Test Skid

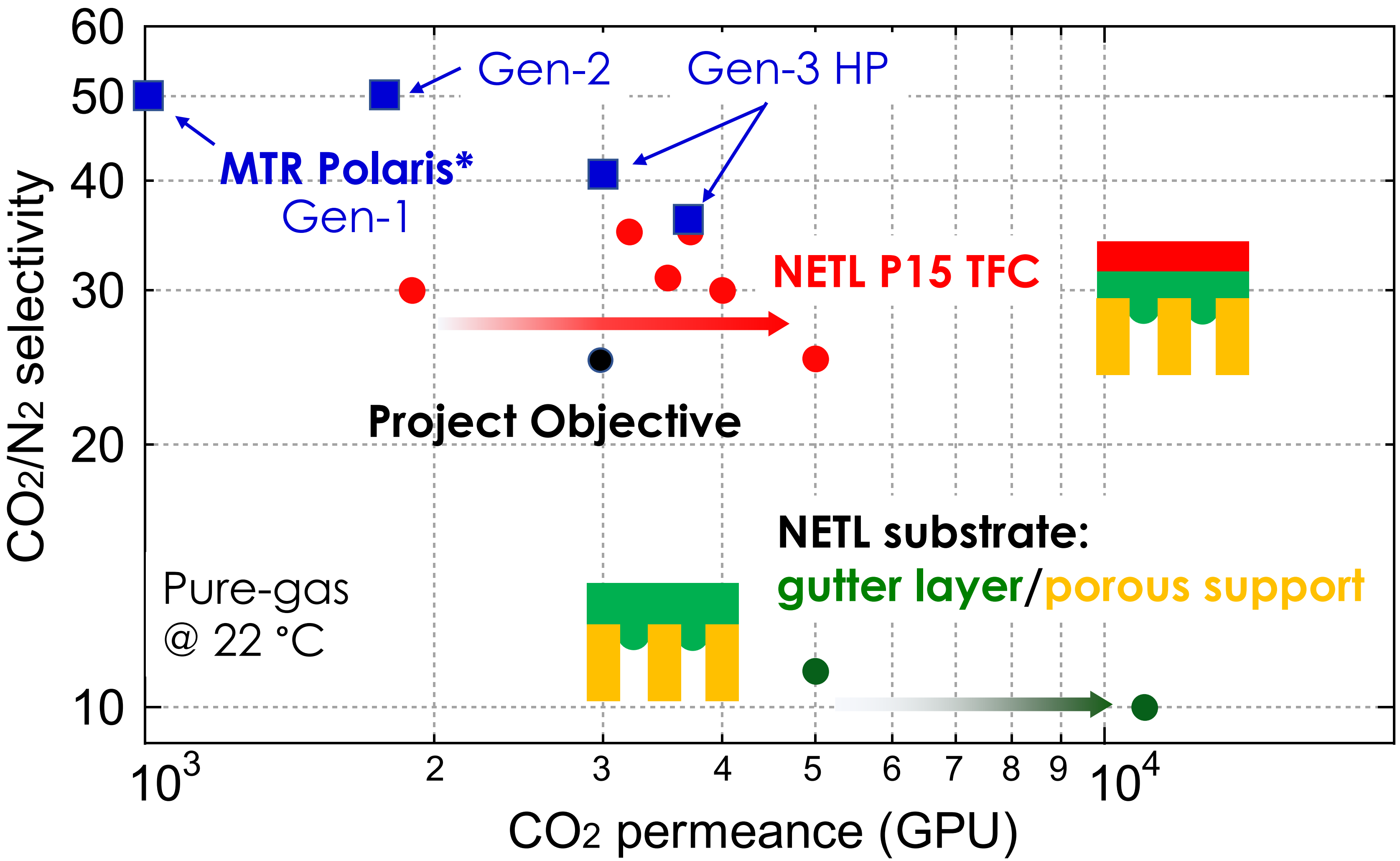
Uniform Coating Thickness in the Roll-to-Roll (R2R) Process

3 samplers out of a 12m long thin-film coating; 100k magnifications under SEM



@1st meter — @6th meter — @12th meter

Membrane Separation Performance Benchmark



- NETL results are based on scalable R2R coating.
- Increasing gutter layer permeance leads to the improvement of TFC performance.
- NETL's 11,000 GPU substrate is the key to our high-permeance TFCs.

*Source of MTR results: DE-FE0031596 Project Close Out Meeting, May 31, 2024

NETL Gutter Layer Membrane Exceeds Other Reports in Terms of Combined Performance and Scalability

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	NETL	MTR-conventional	MTR-isoporous	Tianjin U, China	U. Melbourne, Australia
CO_2 permeance(GPU) @ test temp (°C)	11,000 @ 22C	6,000 @ 30C	11,800 @ 30C	10,000 @ 25C	14,000 @ 35C
CO_2/N_2 selectivity	10	n/a	n/a	10	9.0
G-layer thickness (nm)	~200	90	120	125	~50
Coating method	R2R	R2R	R2R	R2R	Spin coating
Porous support	polymer w/ good solvent resistance	An engineering polymer	Isoporous block copolymer (costly & weak solvent resistance)	Polysulfone (weak solvent resistance)	Polyacrylonitrile
Solvent resistance	**Good**	n/a	Weak	Weak	Good
Comments on scalability	**Easy to scale up at low material cost**	**Demonstrated at MTR's Polaris membranes**	Hard to scale up due to the difficulties in forming isoporous supports at scale	**Scalable** but needs special machinery for dip coating of wet supports	**Not scalable** due to the coating method used
Reference	This work	MTR's DE-FE0031596 Project Close Out Meeting, May 31, 2024		Sep. Purif. Technol. 239 (2020) 116580	Chem. Eng. J. 462 (2023) 142087

Scaleup Fabrication of Plate-and-Frame Membrane Modules for the U. S. Steel Field Test

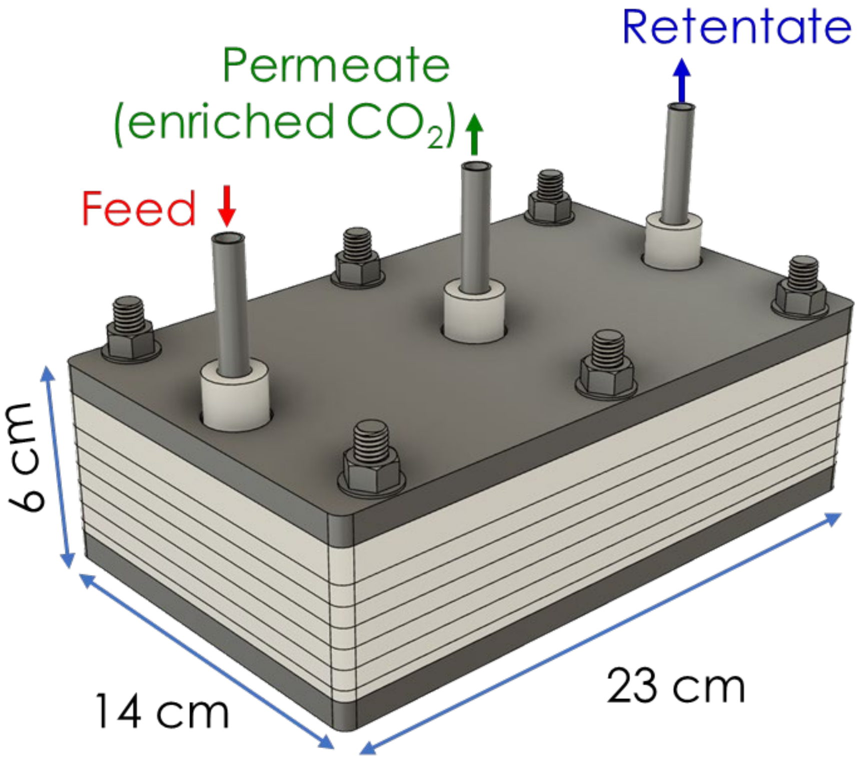
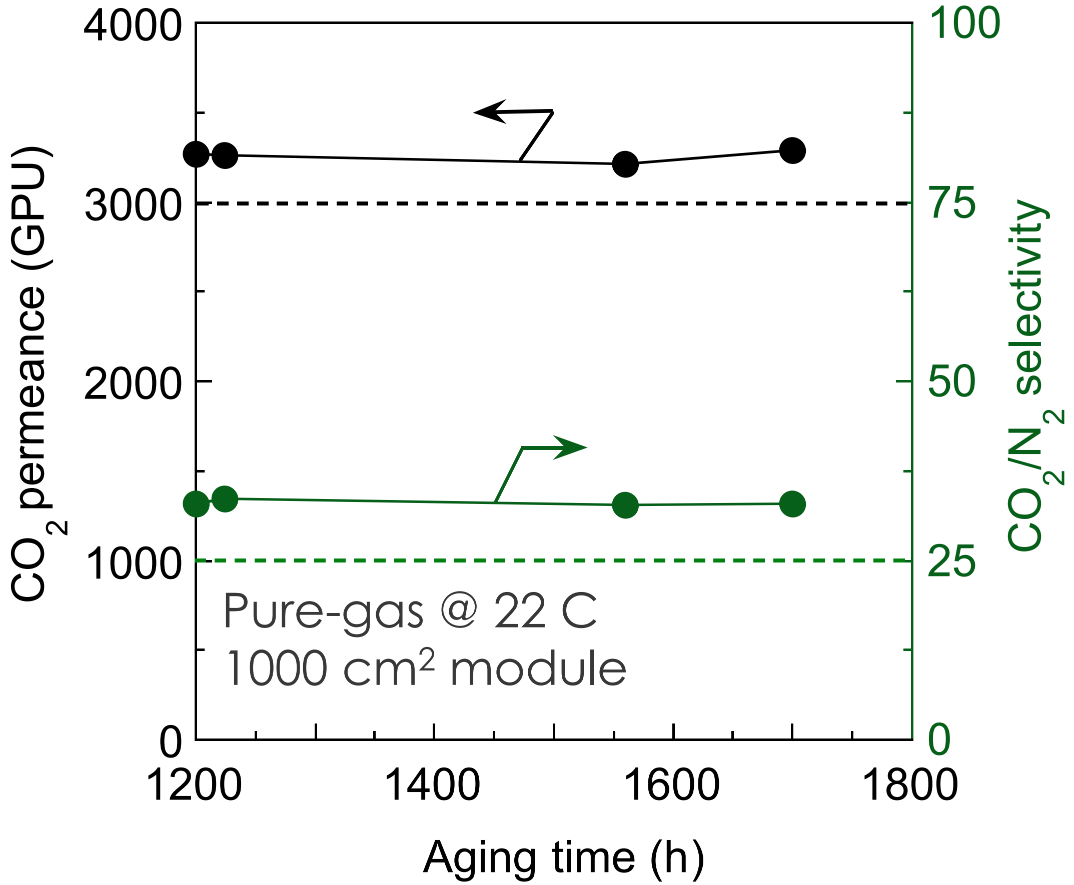
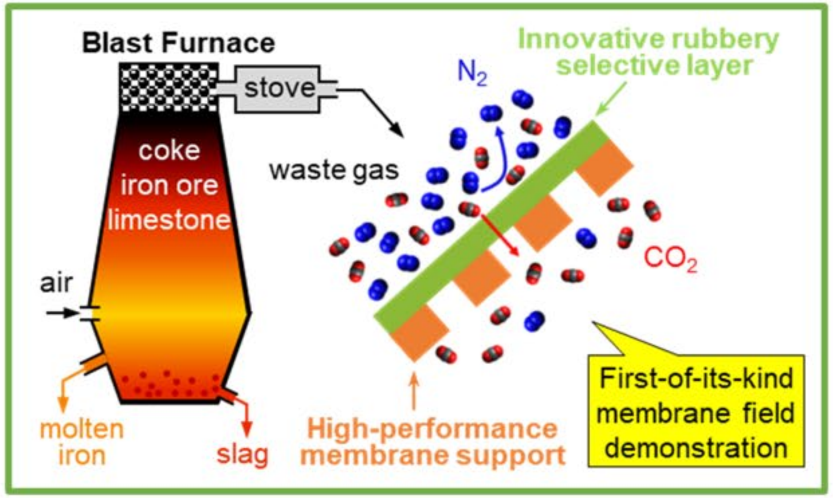


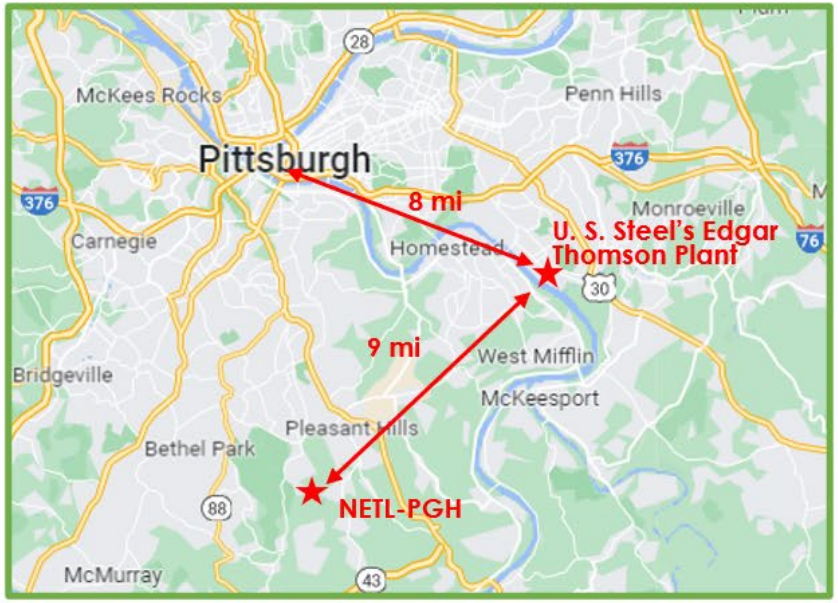
Illustration of a **1,000 cm²** membrane module for the U. S. Steel test: simple to increase membrane area by adding more stackings.



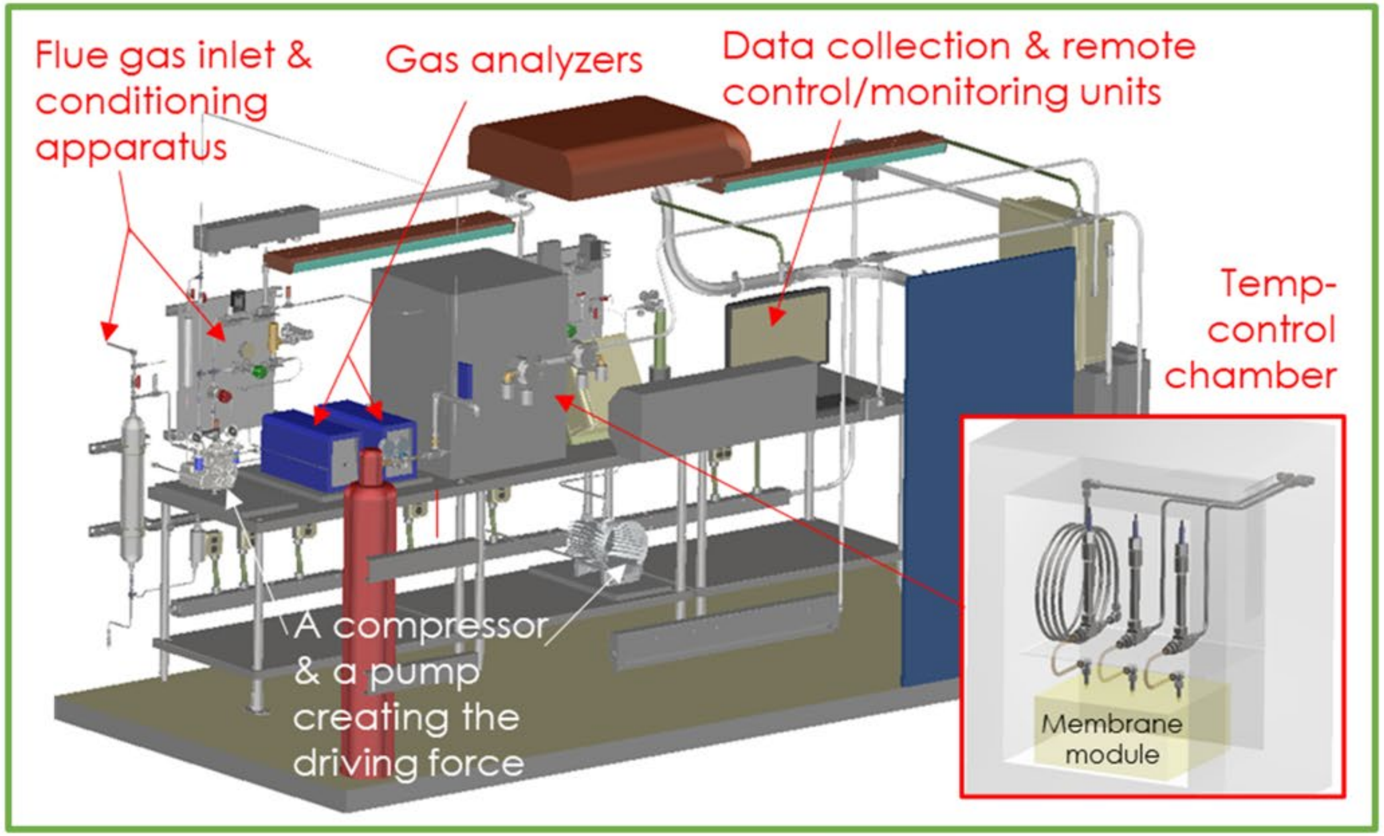
Membranes were stored for 50 days (1200 h) before being assembled into a module for testing.

Preparations for the Field Demonstration in 2025

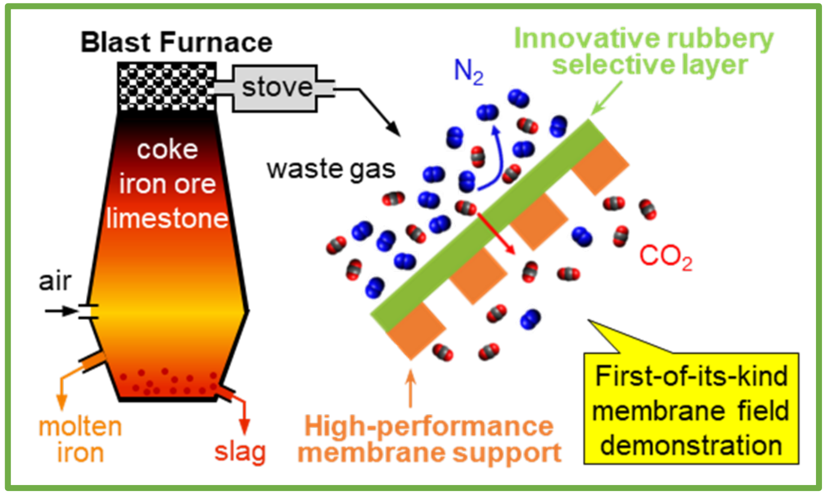


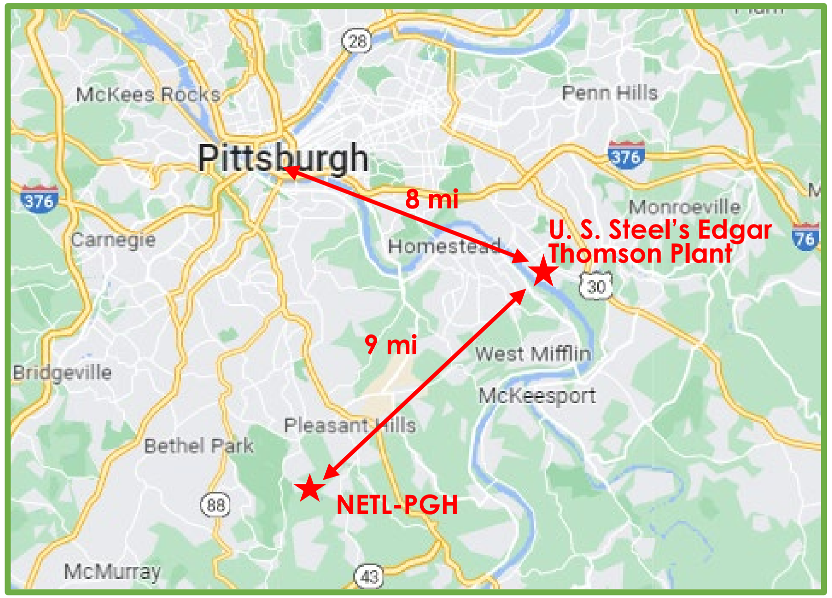


Collaborate with U. S. Steel for field test using blast furnace waste gas (>20% CO_2) at U. S. Steel's Edgar Thomson Plant, Braddock, PA.



Preparations for the Field Demonstration in 2025





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Summary: NETL High-Permeance TFC Membranes' Pathway to Scale-Up and Field Demonstrations

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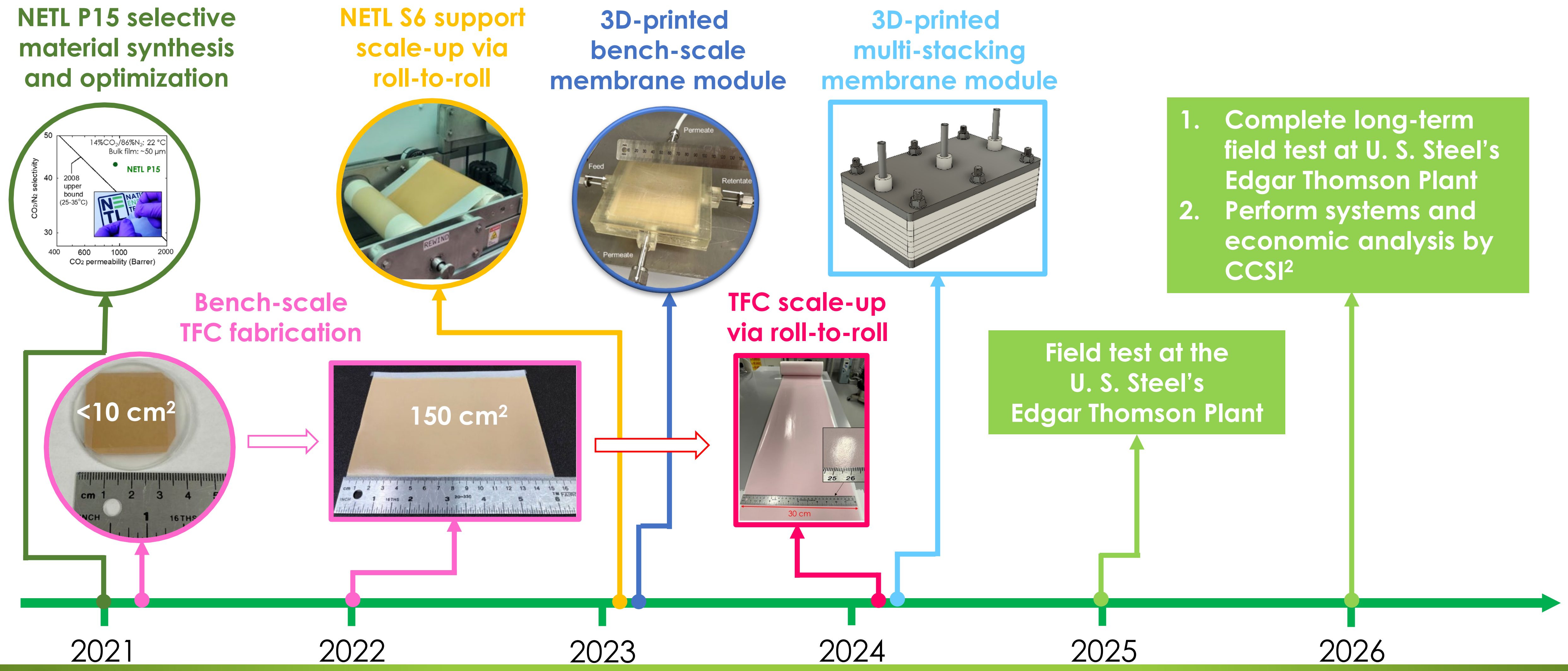

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