Pilot Test of an Efficient Membrane Process for Post-Combustion CO_2 Capture

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Membrane Technology and Research, Inc.

NETL CO_2 Capture Technology Meeting

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Outline

- Project overview
- Technology background
- Current status of technology
- Project timeline and objectives

Project Overview

Award name: Pilot testing of a membrane system for post-combustion CO_2 capture

Project period: 10/1/10 to 9/30/15

Funding: $15 million DOE; $3.75 million MTR

DOE program manager: Jose Figueroa

Participants: MTR, Babcock & Wilcox, Southern Company (NCCC), EPRI

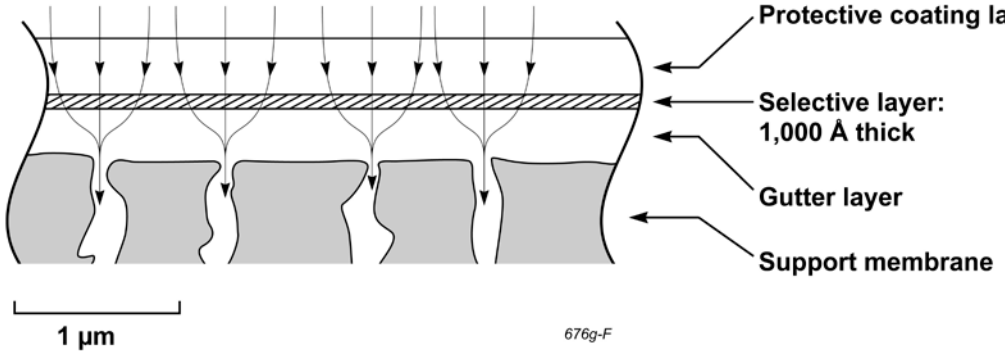
Project scope: Demonstrate a membrane process to capture 20 tons of CO_2/day (20 TPD) from a flue gas slipstream of a coal-fired power plant

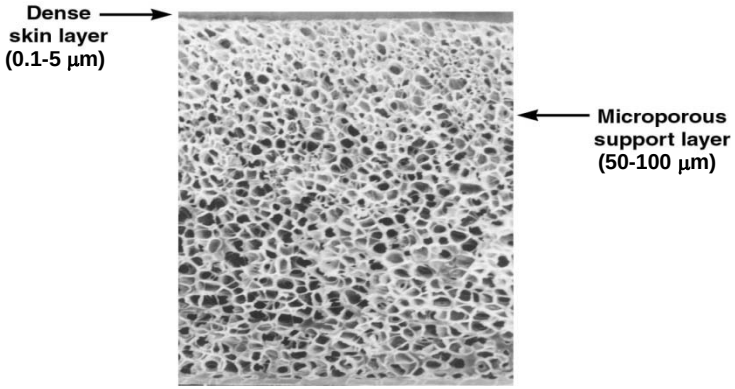
Project plan: The key project work organized by budget period is as follows:

- BP1 – Membrane optimization though continued slipstream testing on the 1 TPD system and evaluation of sweep recycle with B&W
- BP2 – Design and construction of the 20 TPD system
- BP3 – Six-month pilot test of the 20 TPD system and comparative economic analysis

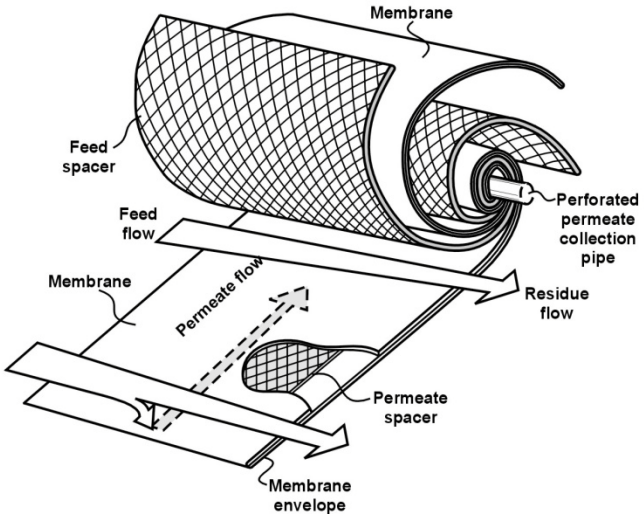
Membrane Technology Basics

- Membranes have to be thin to provide useful fluxes.





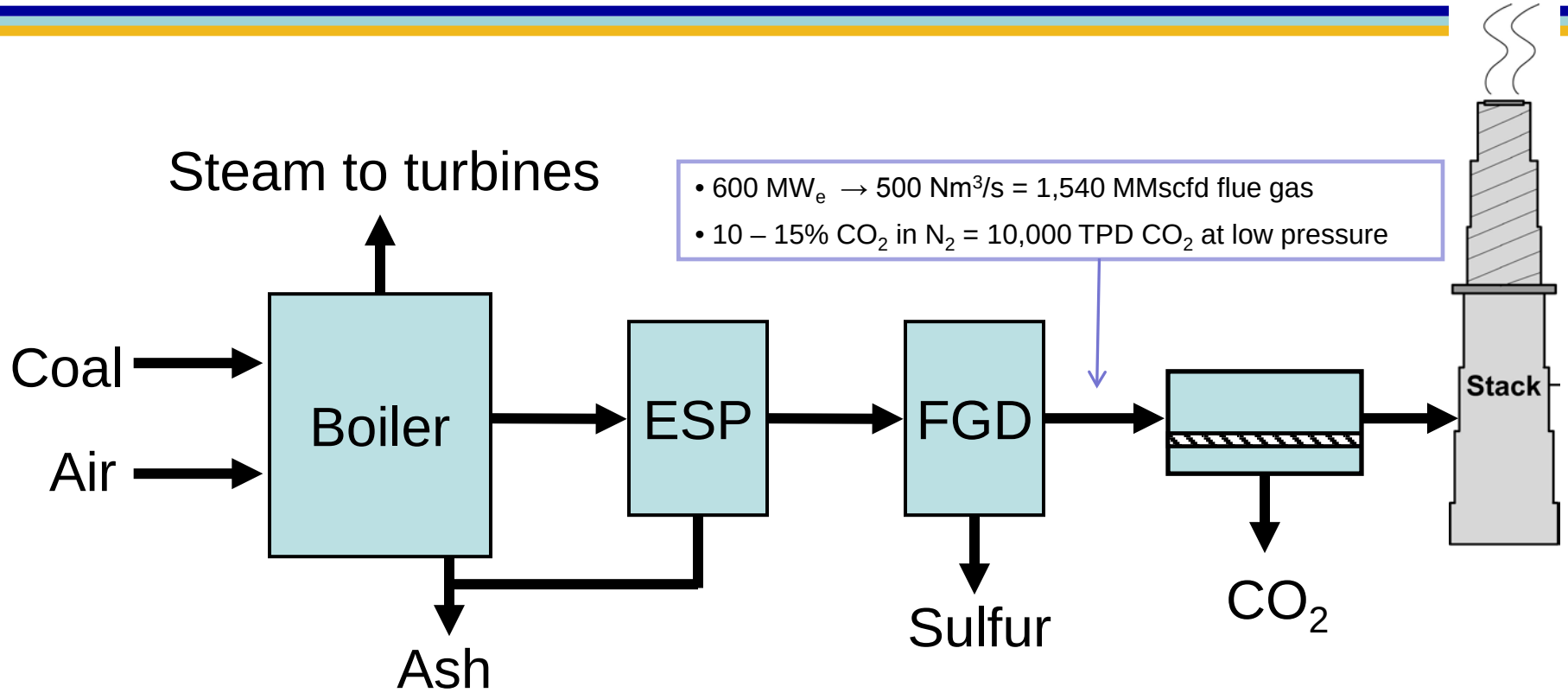
- Membranes are packaged in modules for industrial separations.



Advantages of a Membrane Process

- Simple operation; a passive, continuous process
- No use of hazardous chemicals; no chemical handling or disposal issues
- Tolerance to high levels of SO_x and NO_x; inert to oxygen
- Compact and modular; easily scalable; easy turndown
- Inherently energy efficient (20% parasitic energy at 90% capture)
- No additional water used (recovers water from flue gas)
- No steam use, so no modifications to existing boiler and steam turbine are needed
- Builds on existing, low-cost technology already used at a similar scale for water desalination and natural gas treatment

CO_2 Capture at a Coal-Fired Power Plant



Membrane challenges for treating this large volume of gas include:

- How to generate driving force without using large compression or vacuum power?
- Large membrane area needed → high CO_2 permeance is a must!
- Harmful contaminants (fly ash, SO_2, NO_x, water, etc) potentially reduce effectiveness and lifetime.

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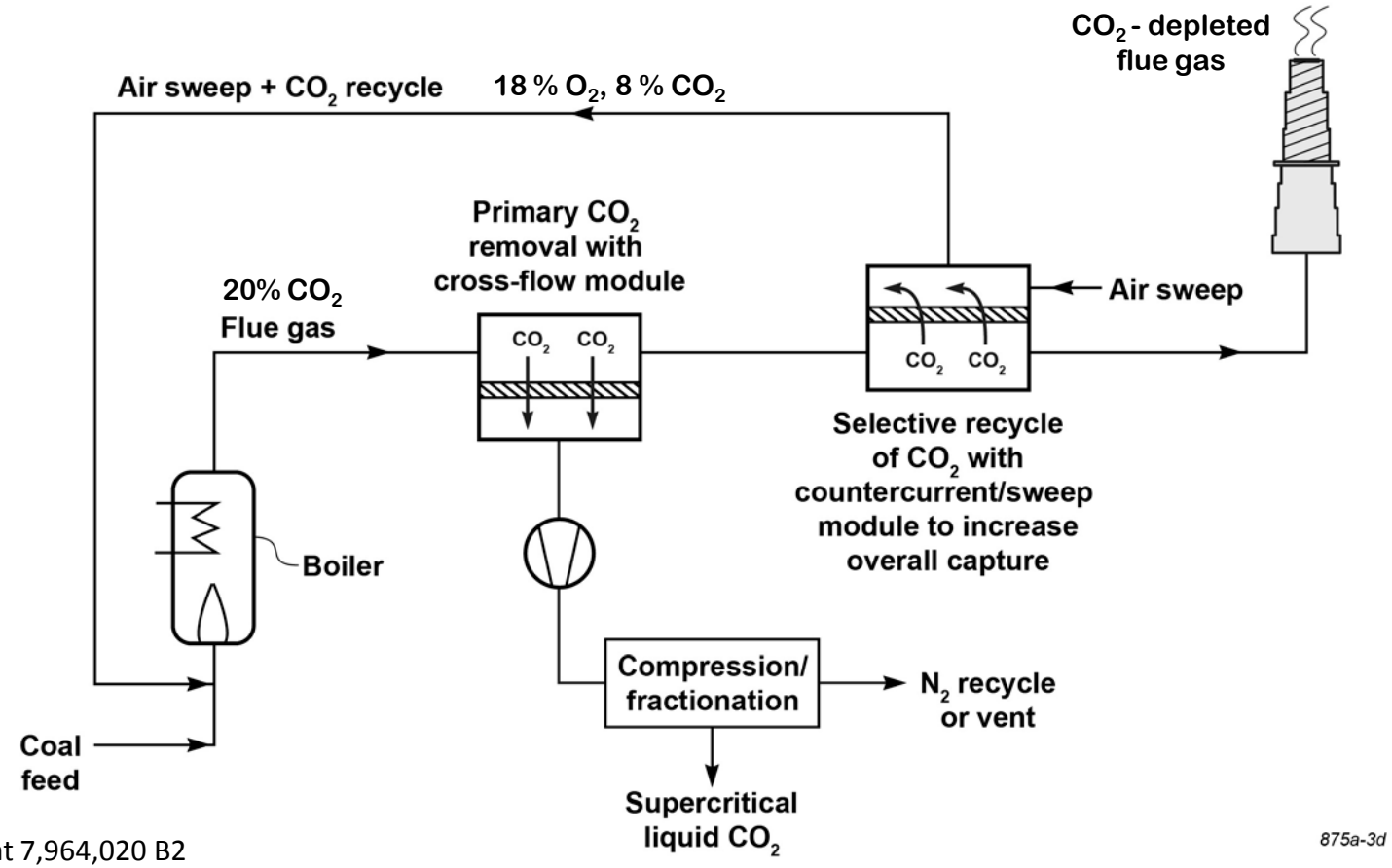
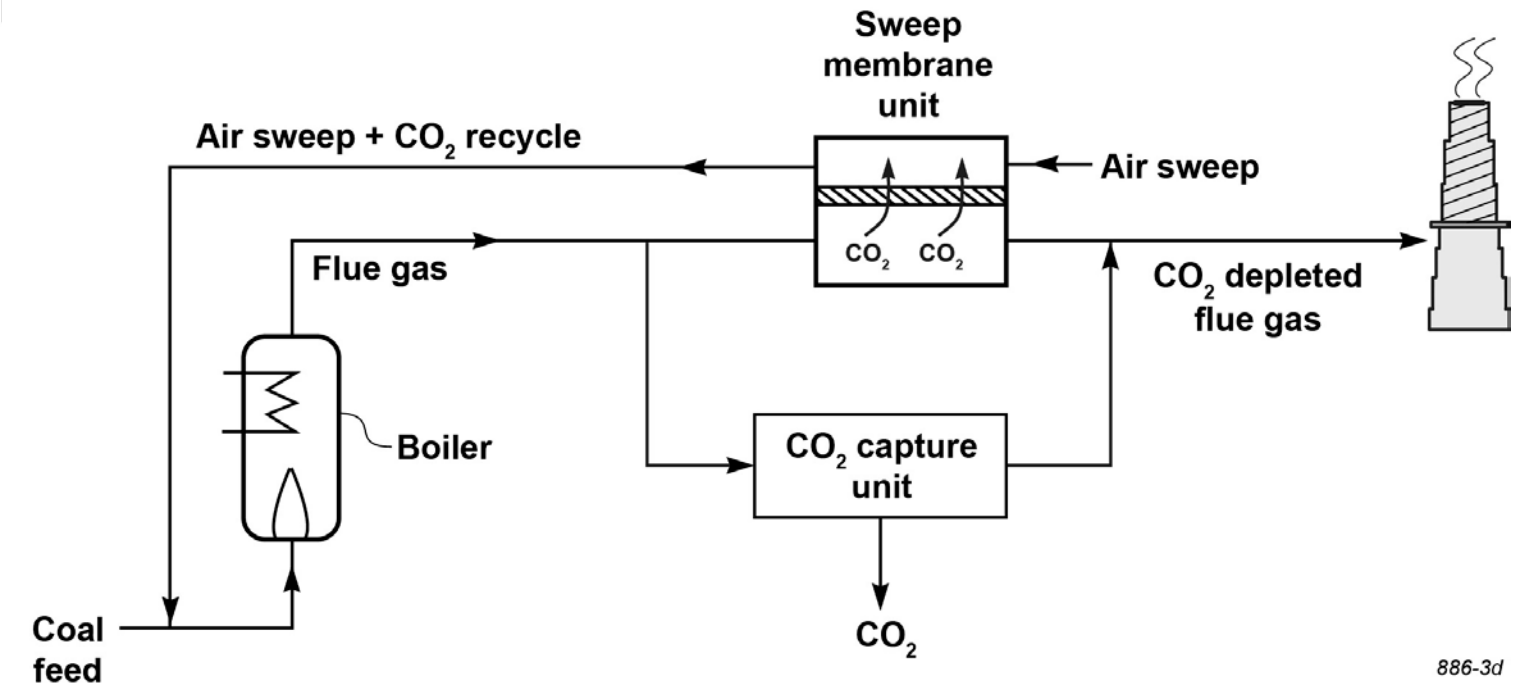
An Efficient Membrane CO_2 Capture Process



U.S. Patent 7,964,020 B2

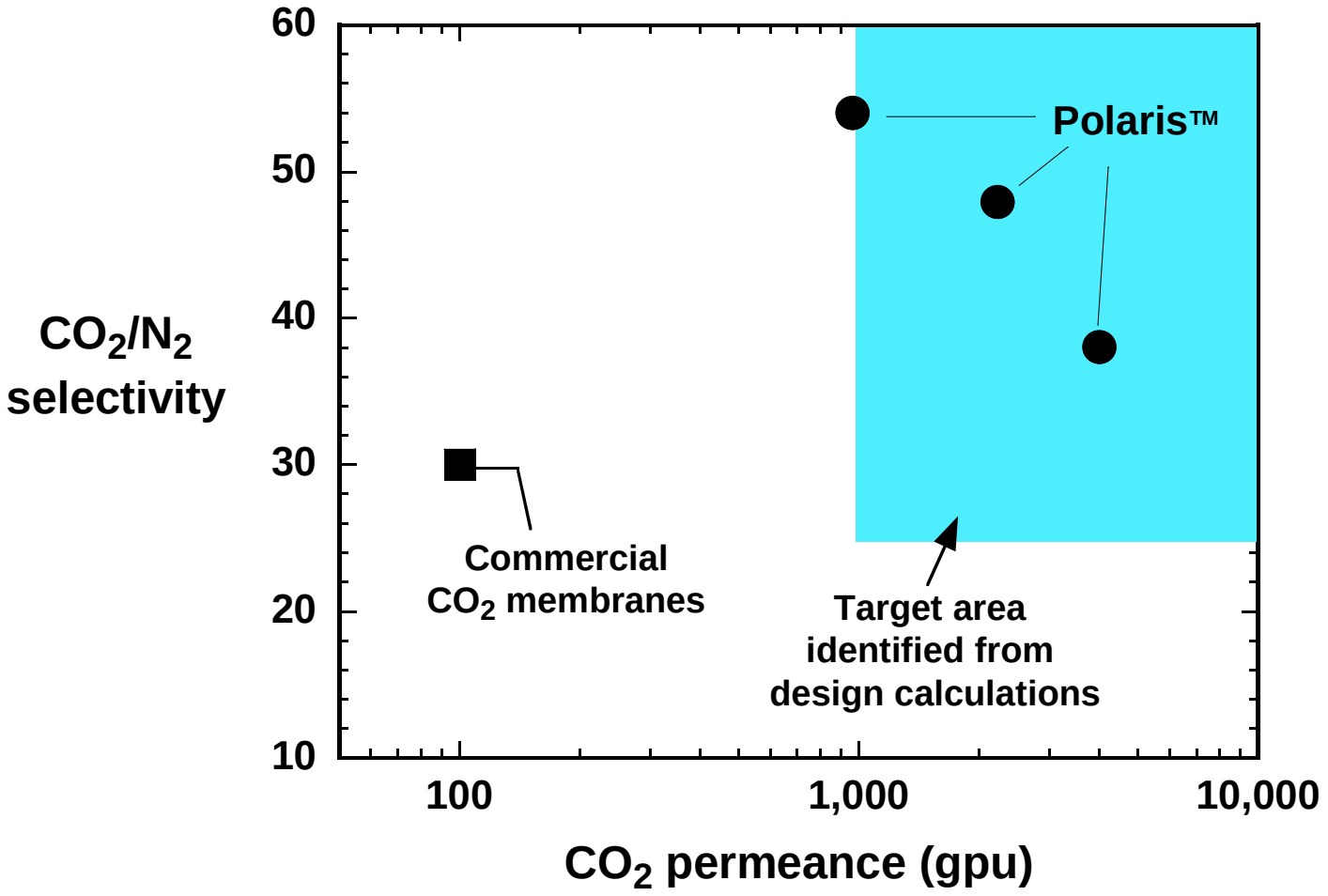
- Countercurrent/sweep with combustion air pre-concentrates CO_2 with little energy input
- An optimized process produces a 50% increase in LCOE at 90% capture

A Hybrid CO_2 Capture Process



- This parallel design avoids the use of any compression or vacuum equipment
- For natural gas, an enrichment factor of 4 to 5 can be achieved with selective exhaust gas recycle

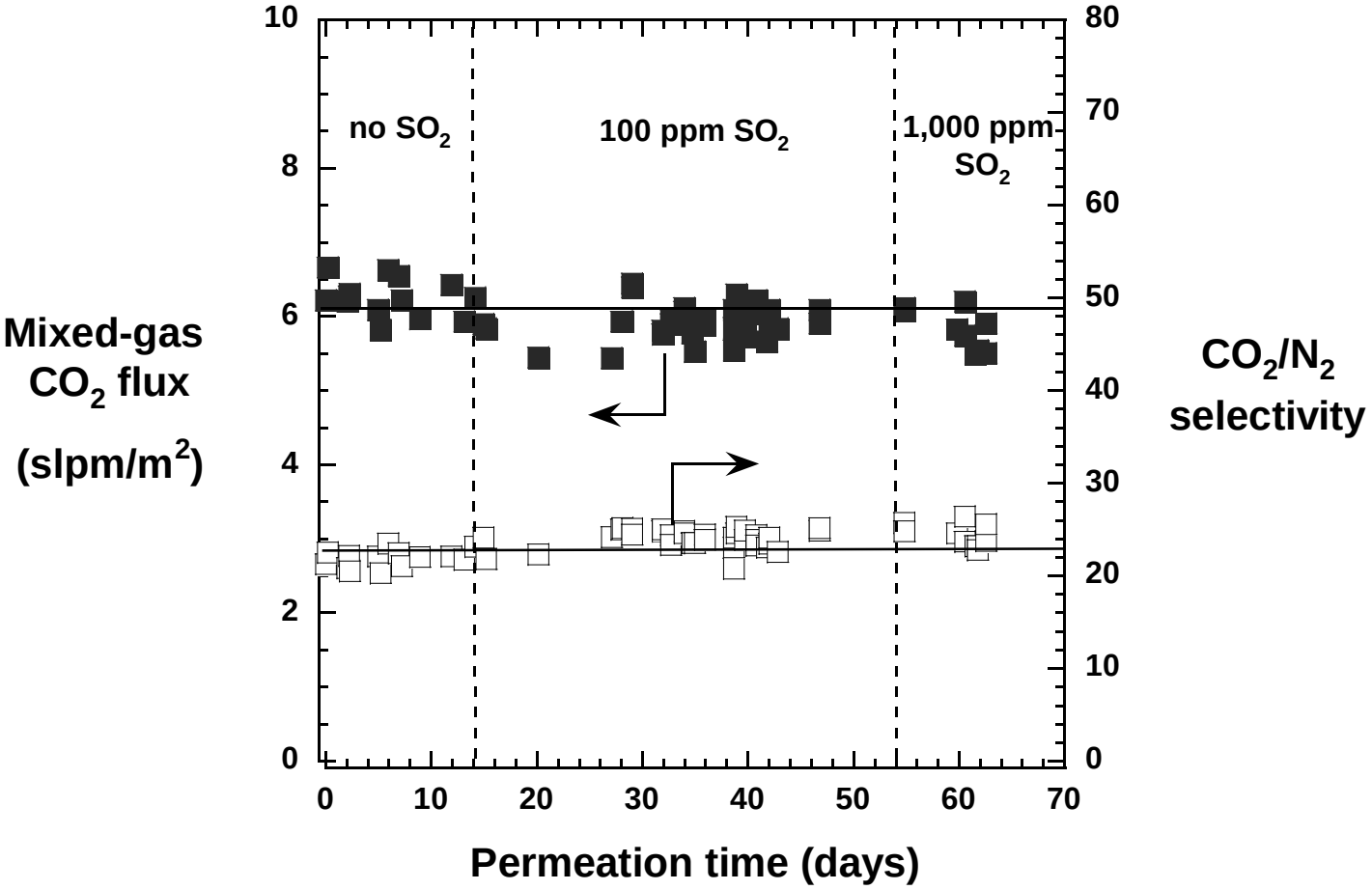
Polaris™ Membranes



Pure-gas data at 25°C and 50 psig feed pressure

1 gpu = 10^{-6} cm^3(STP)/(cm^2 s cmHg)= 3.35 x 10^{-10} mol/(m^2 s Pa)

Polaris Membranes Are Stable in SO_2



Feed composition: 18% CO_2 in N_2; temperature: 50°C

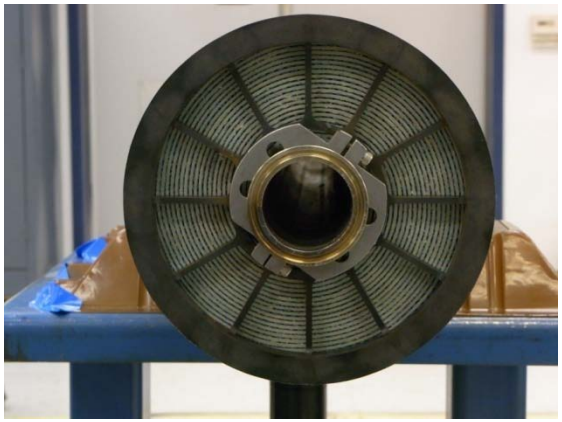
1 TPD Slipstream Test at APS Cholla

- Cholla is a 995 MW_e PC plant using sub-bituminous coal
- Membrane skid houses 8” diameter cross-flow and countercurrent sweep modules
- System captures 1 TPD CO_2

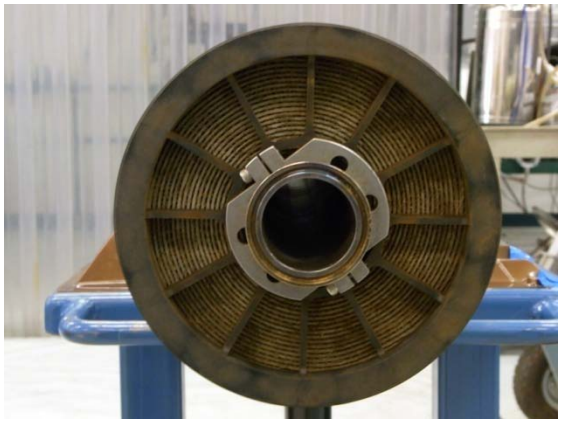
- Field test ran from April – July 2010
- Purpose of test was:
  - to evaluate membrane lifetime with real flue gas
  - Demonstrate sweep modules

Cholla Test Results: Modules Are Stable

Fresh module



After 45 days of operation at Cholla



Module Number	Normalized CO_2 Permeance		Normalized CO_2/N_2 Selectivity	
	Before	After	Before	After
5839 (Cross-flow)	100%	110%	100%	118%
5879 (Sweep)	100%	108%	100%	96%

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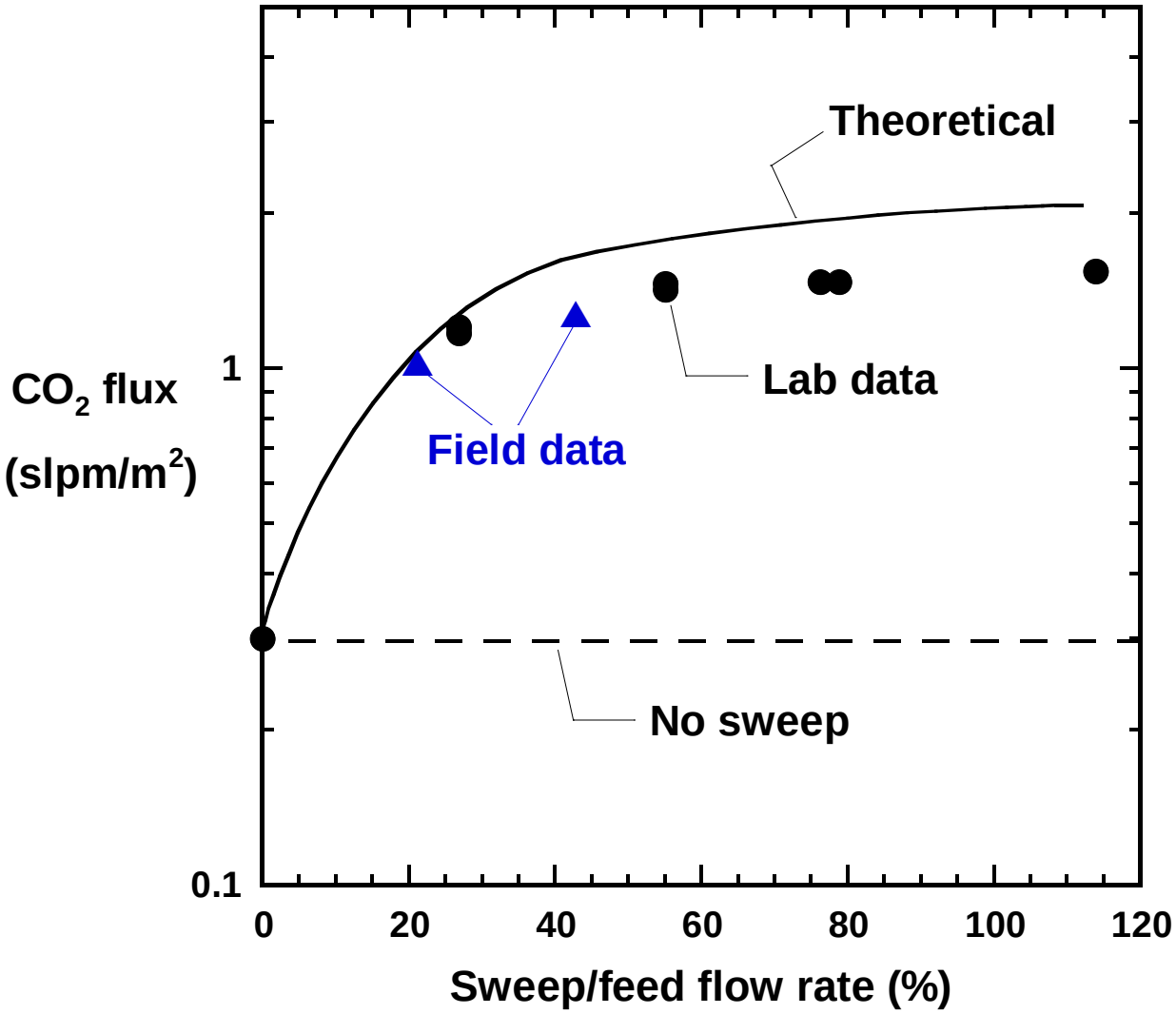
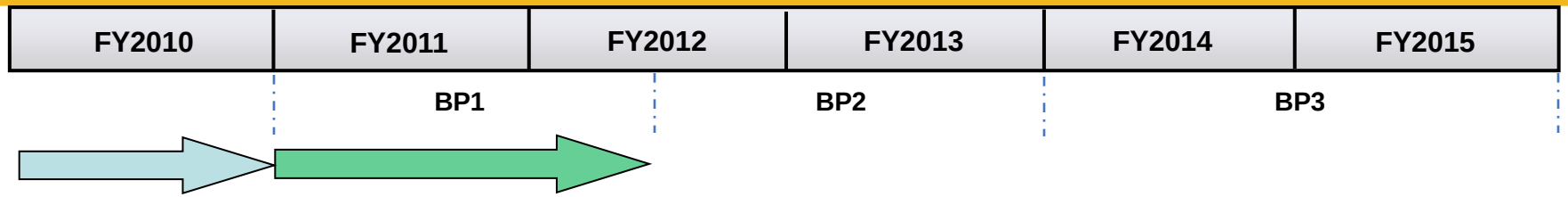
Cholla Test Results: Sweep Operation Works



Next Steps: 20 TPD Project Timeline



Cholla I (1 TPD)
- DOE project NT0005312 (completed 3/31/11)
- Collaboration with APS and EPRI
- Slipstream testing at Cholla plant

Complete a Preliminary Systems and Economic Analysis

Continue Membrane Optimization on 1 TPD System
- Run continuous tests at National Carbon Capture Center (NCCC)
- Improve membrane/module performance
- Investigate low-fouling module geometries

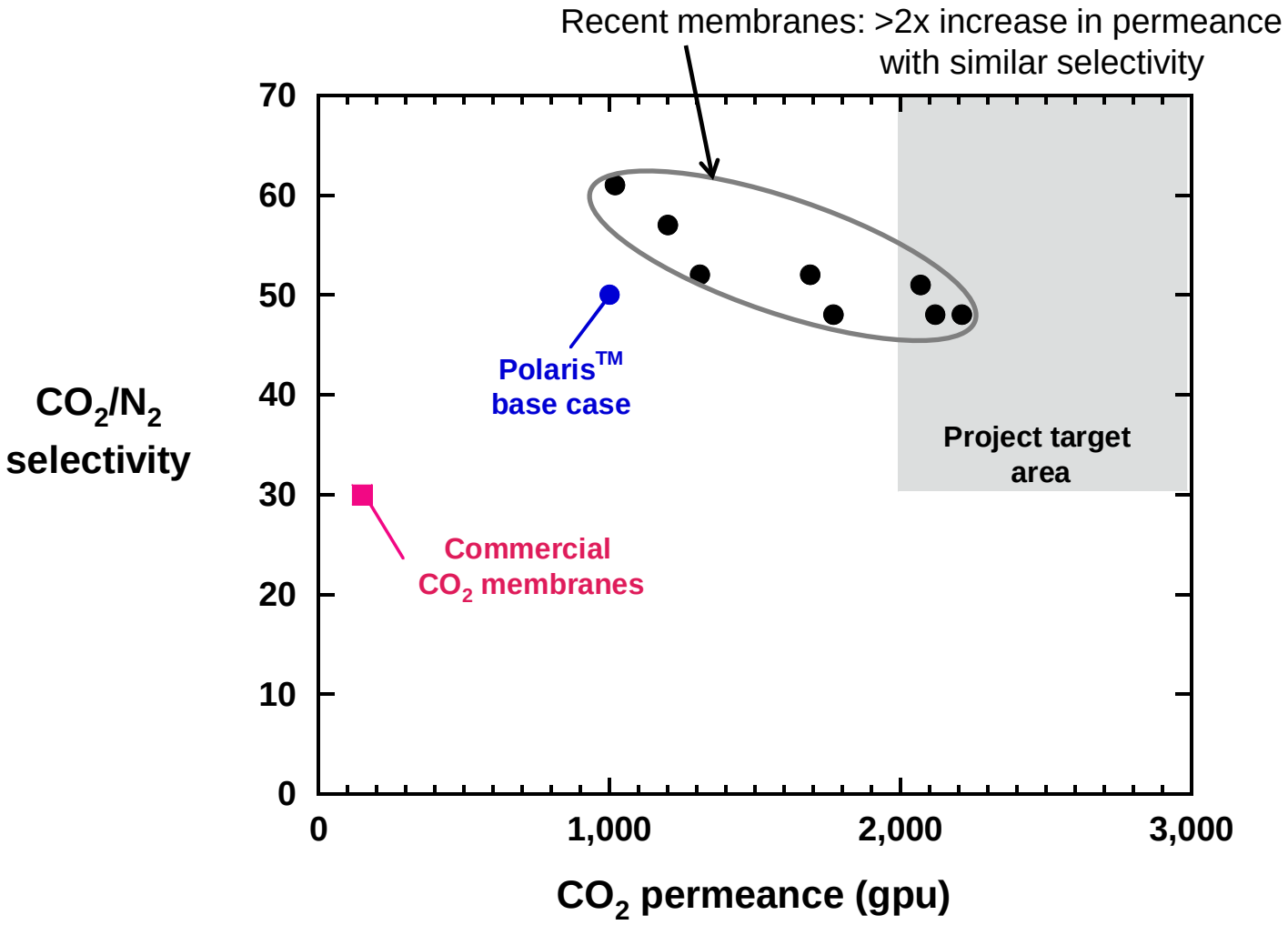
Boiler Recycle / Water Recovery Study
- Evaluate CO_2 recycle and plant integration with B&W
- Investigate flue gas water recovery/management with EPRI

Design and Install 20 TPD Demo (1 MW_e)
- Design, build, and install the 20 TPD test system at NCCC

Operate 20 TPD Demo (1 MW_e)
- Run 6 month test
- Analyze results and prepare a comparative systems analysis

Blue arrow = DE-NT0005312
Green arrows = DE-FE0005795

Membranes Are Getting Better



1 TPD System Testing at NCCC

1 TPD test system is a valuable field laboratory. System startup at NCCC is scheduled for September 2011. Items to study include:

- Performance and lifetime of rotating equipment and other system components
- New high performance membranes
- Low pressure drop module configurations
- New low-fouling module designs; compare with current baseline module
- Disposition of contaminants in membrane process

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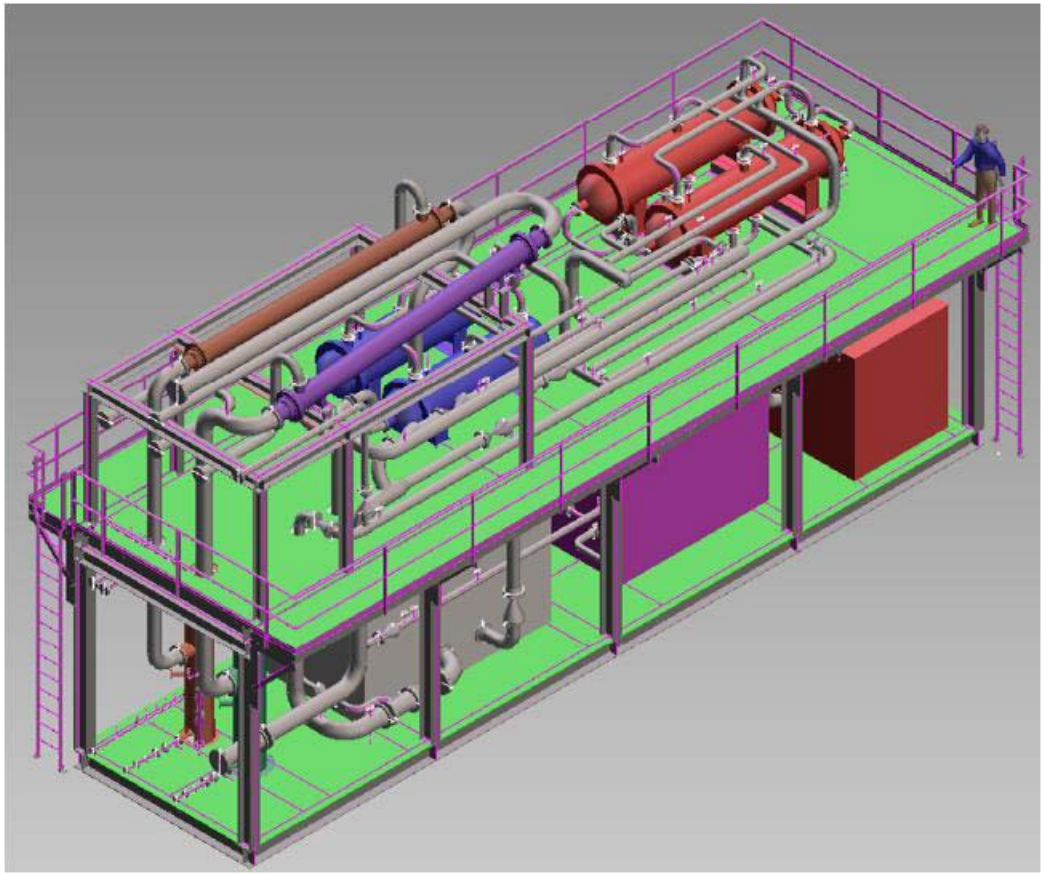
Preliminary Design of 20 TPD System



- 20 TPD skid (or 1 MW_e) will begin operation in 2013
- Uses commercial-sized membrane modules
- Approximate skid dimensions are 50 ft x 18 ft x 26 ft (l x w x h)

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20 TPD System at NCCC/PC4

Picture courtesy of Mr. Tony Wu, Southern Company

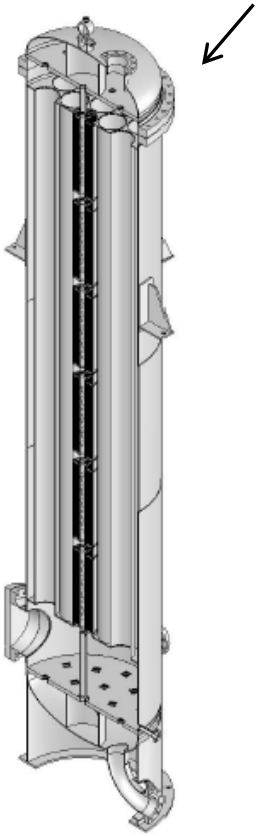
What Would a Large Membrane System Look Like?

Ashkelon desalination plant

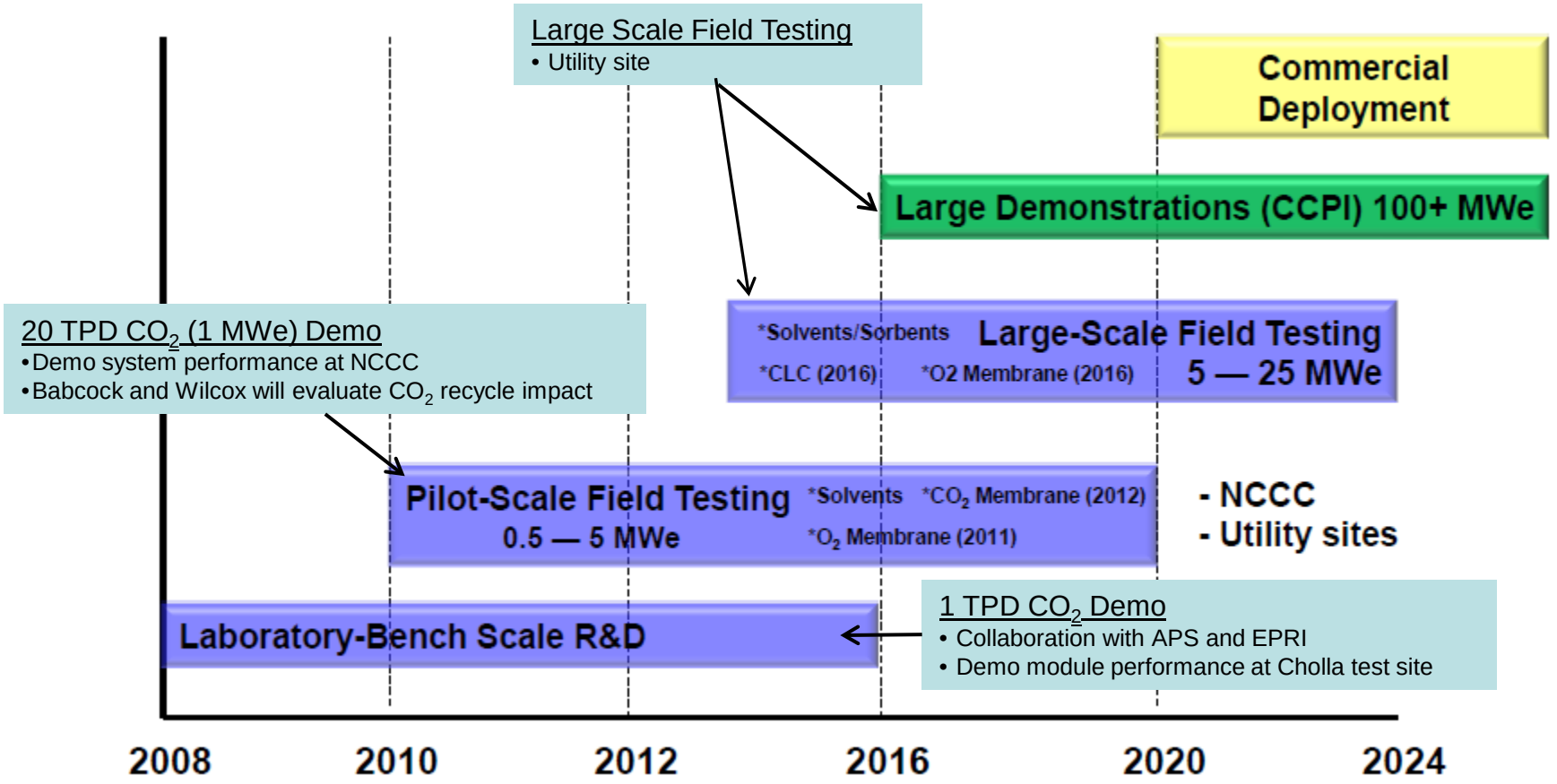
- 40,000 spiral-wound RO membrane modules (Dow Filmtec®)
- 1.5 million m^2 membrane area

Flue gas membrane vessels

- ~100 vessels required for 550 MW_e plant with current membranes
- Double the permeance → halve the vessels



DOE CO_2 Capture Timeline



Summary

- Membranes have some advantages and can play a role in post-combustion CO_2 capture
- Process design is important to address how to provide affordable pressure ratio
- Membranes are getting better and have significant potential for further improvements
- Membrane technology is at the slipstream test stage; this testing is key to work out real world problems

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Acknowledgements

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