Transformational Membranes for Pre-combustion Carbon Capture

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Winston Ho / Yang Han
William G. Lowrie Department of Chemical & Biomolecular Engineering
Department of Materials Science and Engineering
The Ohio State University

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Project Objective

- **Develop a cost-effective design and fabrication process for a novel transformational membrane and its membrane modules that capture CO_2 from coal-derived syngas**
  - **95% CO_2 Purity**
  - **>99% H_2 Recovery**
  - **COE 30% Less than Baseline Approaches**

2-Budget Period Project

- **BP1: 10/01/2018 – 03/31/2020**
  - **Laboratory-scale membrane synthesis, characterization and transport performance studies**
  - **High-level preliminary techno-economic analysis**

- **BP2: 04/01/2020 – 09/30/2021**
  - **Laboratory-scale membrane synthesis, characterization and transport performance studies to continue**
  - **Fabrication, characterization and transport performance studies of scale-up membrane (14″ wide by 20′ long)**
  - **Fabrication, performance and stability testing of spiral-wound membrane modules**
  - **Update techno-economic analysis performed in BP 1**

- **Integrated program with fundamental studies, applied research, synthesis, characterization and transport studies, and high-level techno-economic analysis**

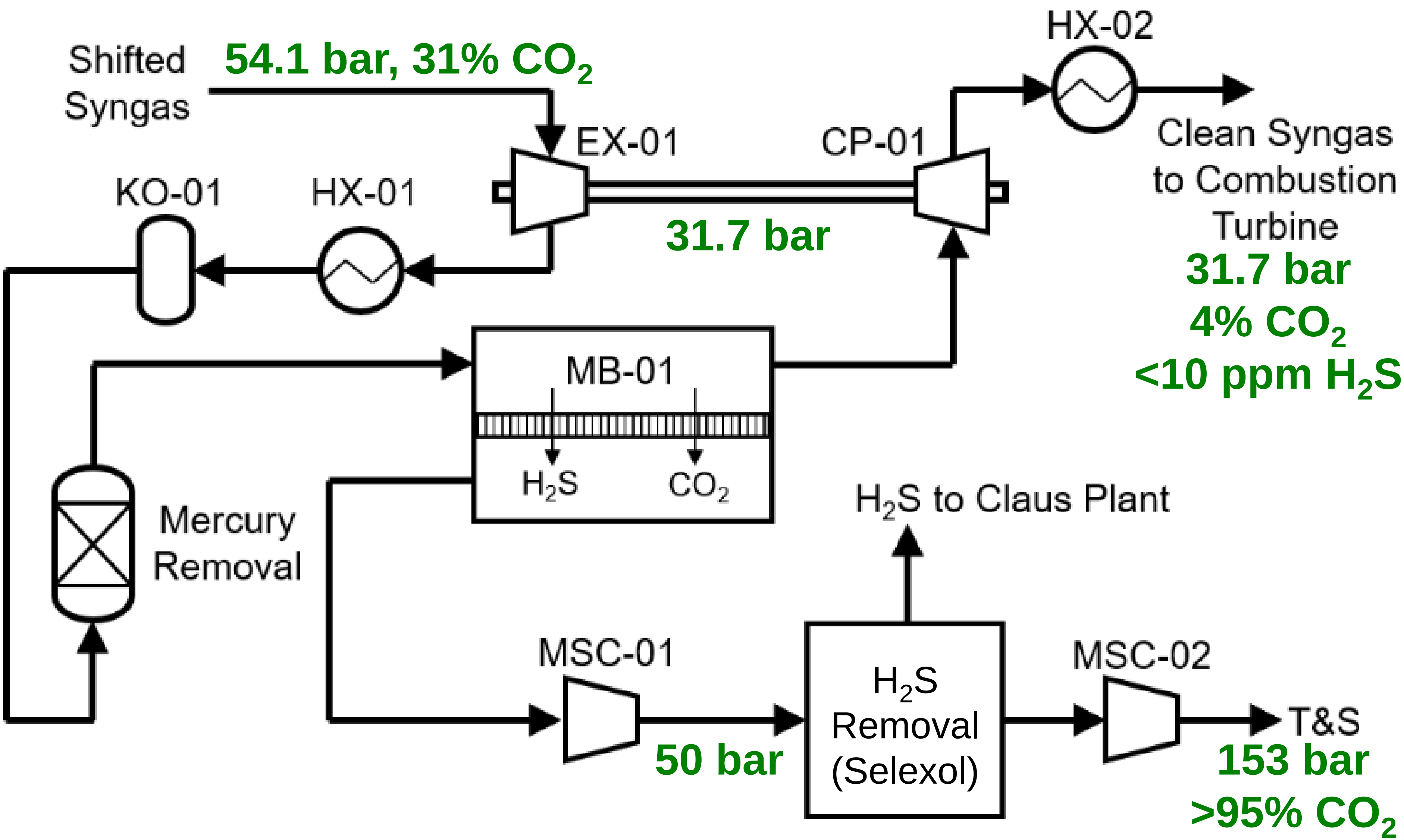
Funding and Performance Dates

- **Total Budget: 10/01/2018 – 09/30/2021**
  DOE: $799,988; OSU: $199,998 (20% cost share)

  - **BP1: 10/01/2018 – 03/31/2020**
    DOE: $386,694; OSU: $96,674

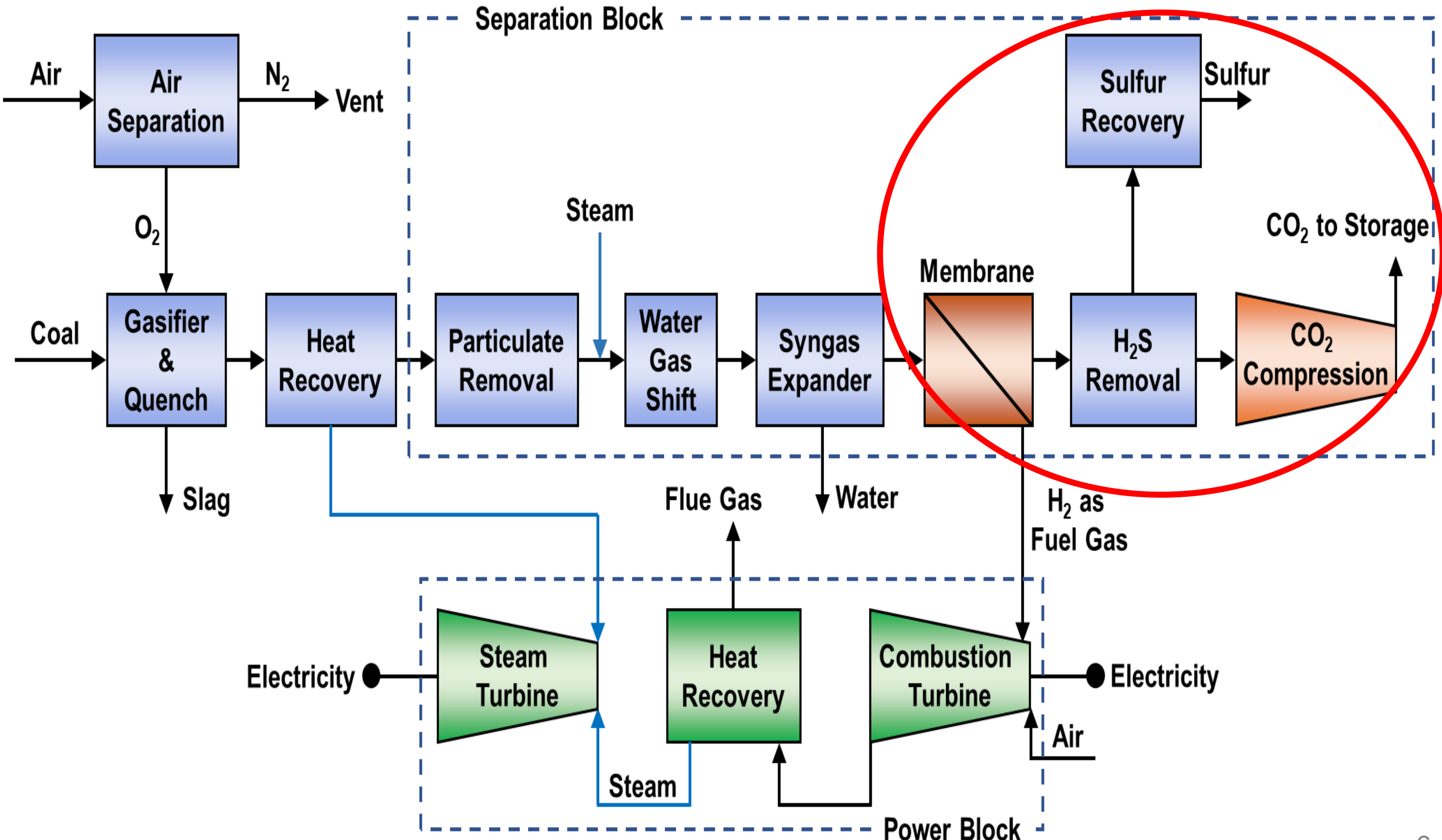
  - **BP2: 04/01/2020 – 09/30/2021**
    DOE: $413,294; OSU: $103,324

Technical Background: Proposed Process



- **Proposed membrane process does not require significant syngas cooling (compared to competition)**

Location of Proposed Technology in IGCC Plant



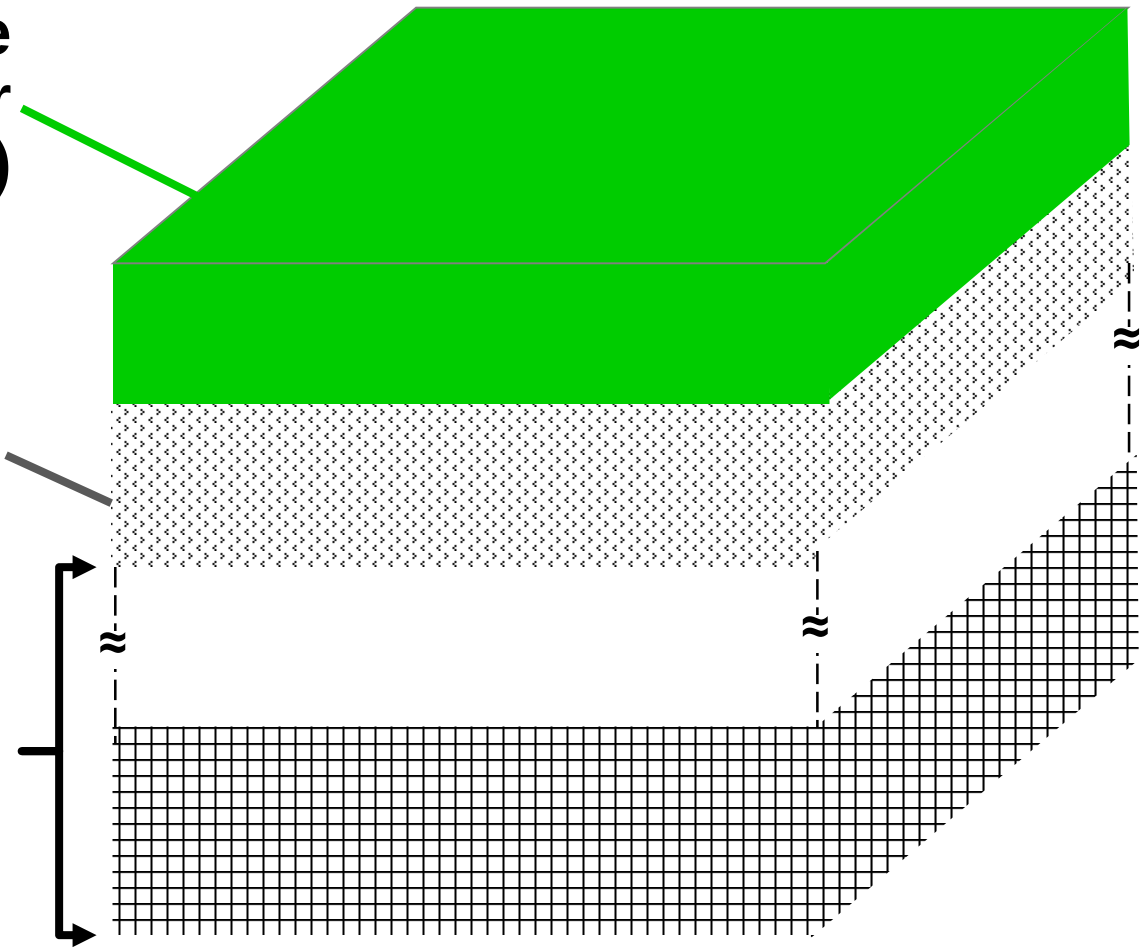
Selective Amine Polymer Layer / Polymer Support

Simplicity of Membrane for Low Cost

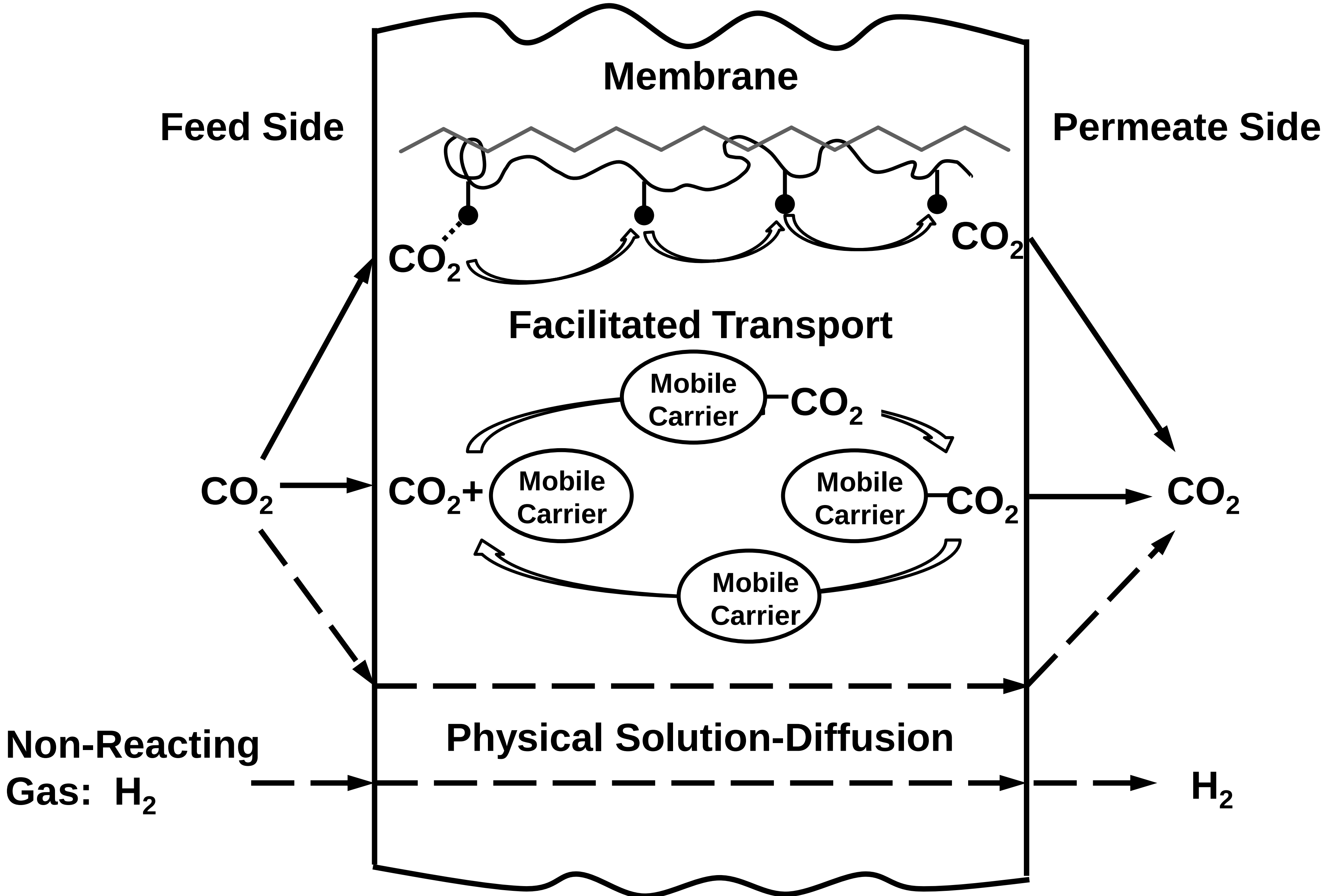
Selective amine polymer layer (~15 μm, dense layer)

Polymer support (~20 μm, Ø ~10 nm)

Nonwoven fabric backing (~100 μm)



Amine Polymer Layer Contains Mobile and Fixed Carriers: Facilitated Transport



Tunable Amine-CO_2 Chemistry

- **Reaction of CO_2 with Unhindered Amines**

$$CO_2 + R{-}NH_2 \rightleftharpoons R{-}NH_2^{+}{-}COO^{-}$$

$$R{-}NH_2^{+}{-}COO^{-} + R{-}NH_2 \rightleftharpoons R{-}NH{-}COO^{-} + R{-}NH_3^{+}$$

Overall:

$$CO_2 + 2\ R{-}NH_2 \rightleftharpoons R{-}NH{-}COO^{-} + R{-}NH_3^{+}$$

- **Reaction of CO_2 with Hindered Amines**

$$CO_2 + R_1{-}NH{-}R_2 \rightleftharpoons R_1R_2{-}NH^{+}{-}COO^{-}$$

$$R_1R_2{-}NH^{+}{-}COO^{-} + H_2O \rightleftharpoons R_1R_2{-}NH_2^{+} + HCO_3^{-}$$

Overall: **Can double the CO_2 capacity**

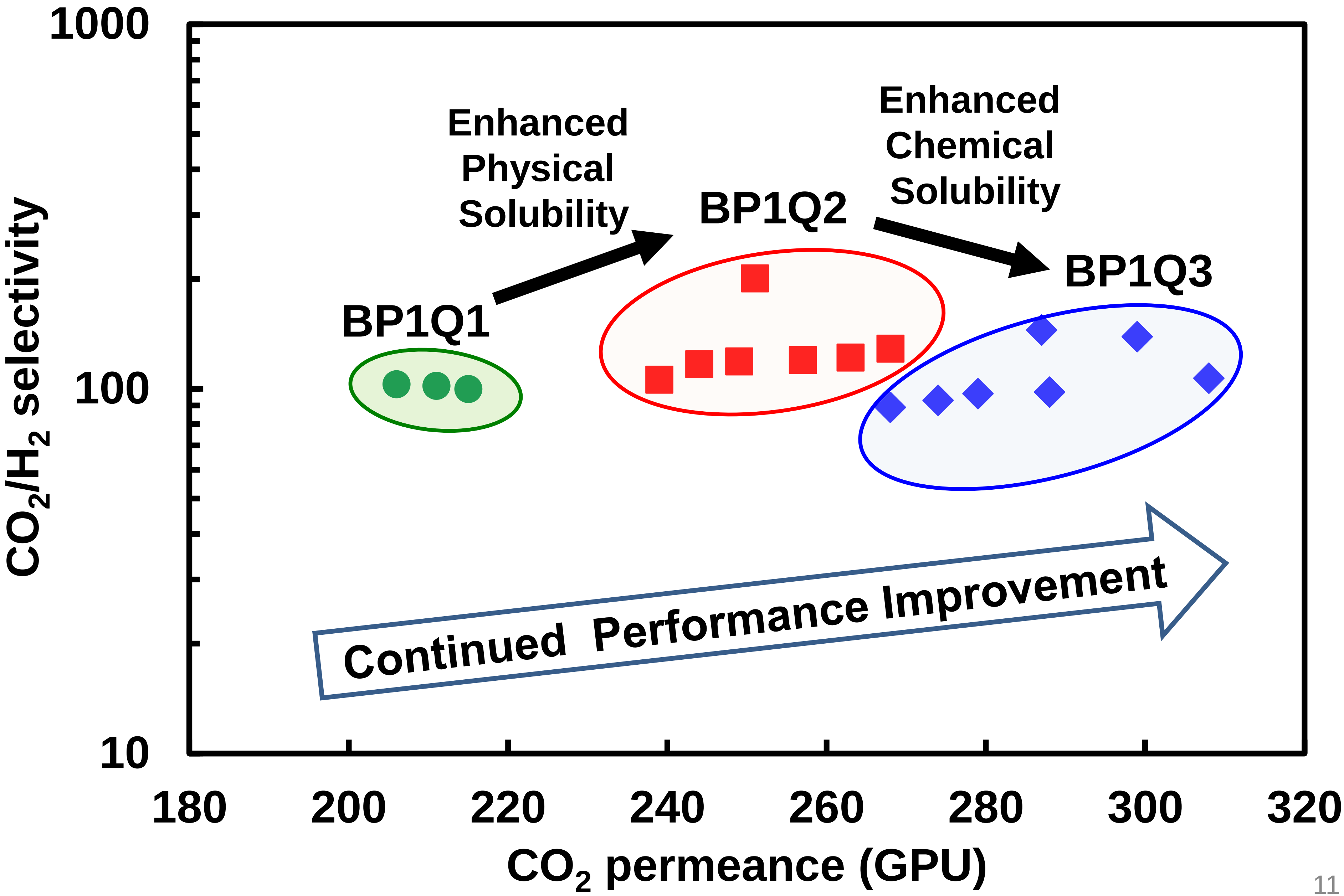
$$CO_2 + R_1{-}NH{-}R_2 + H_2O \rightleftharpoons R_1R_2{-}NH_2^{+} + HCO_3^{-}$$

Facilitated Transport vs. Solution-Diffusion Mechanism

- **CO_2 Facilitated Transport Flux: Very High**
  - CO_2-amine reaction enhances CO_2 flux

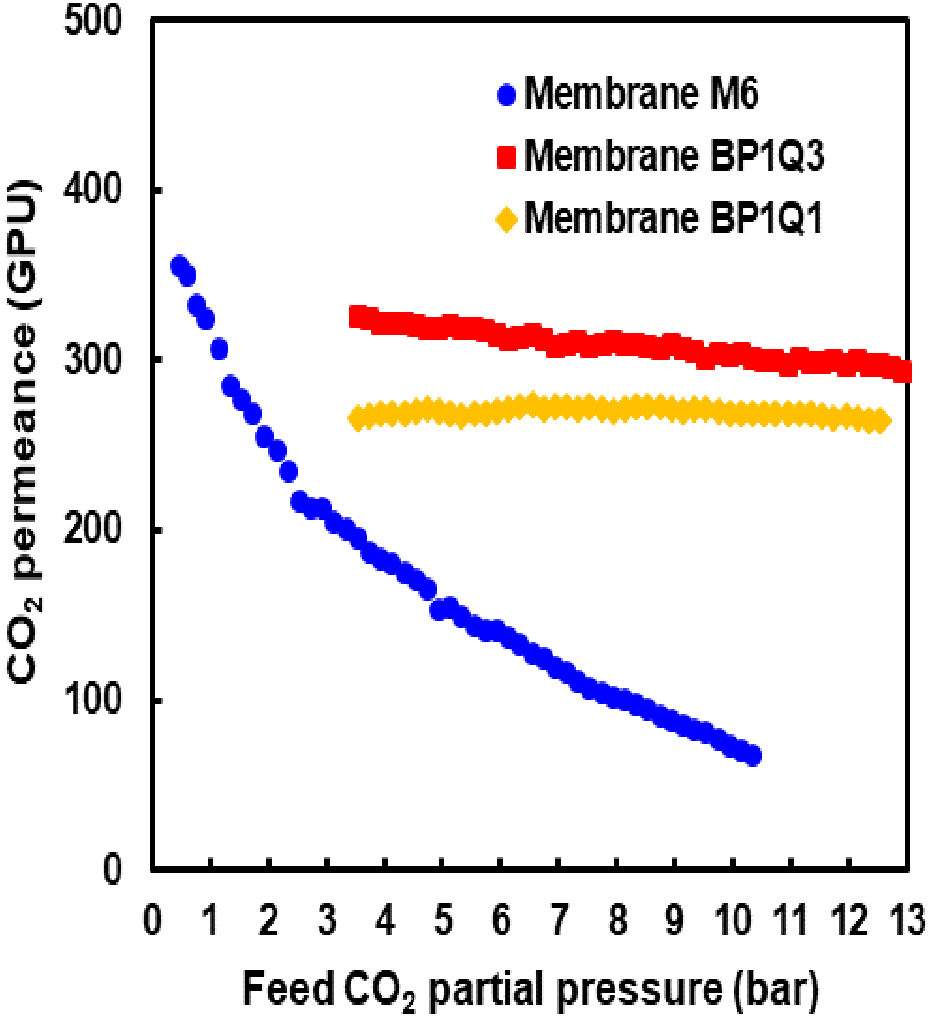
- **H_2 Flux: Very Low**
  - H_2 does not react with amine
  - H_2 transport follows conventional physical solution-diffusion mechanism, which is very slow

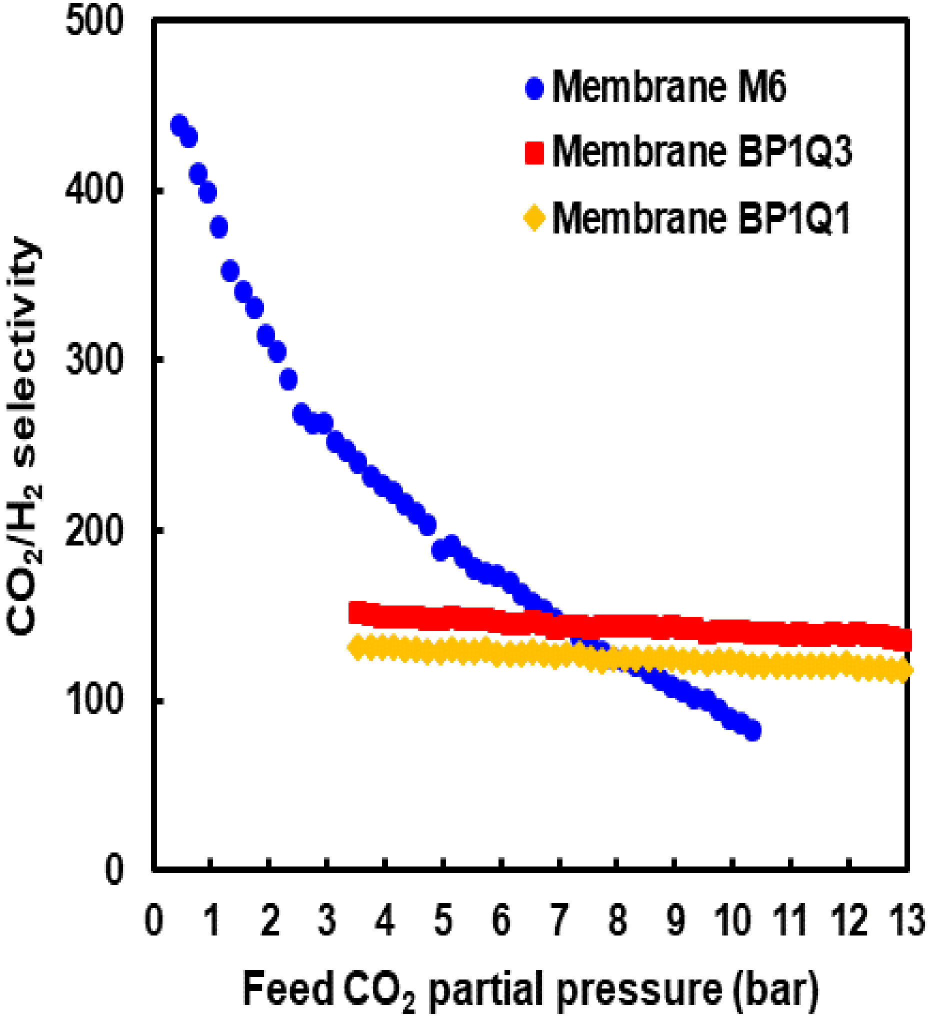
Membrane Performances



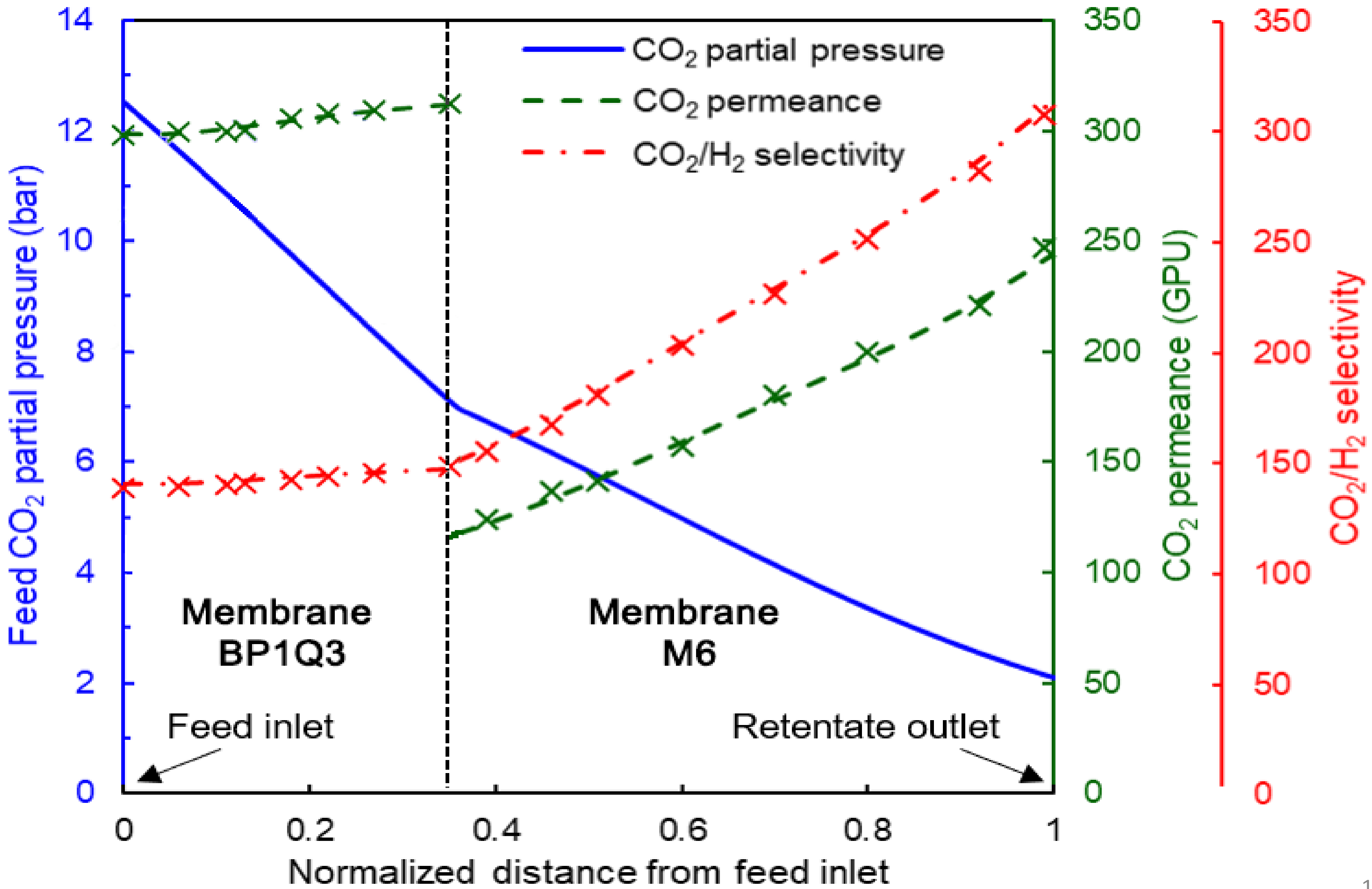
Membrane Performances

Simulated Syngas at 107°C and 31.7 bar

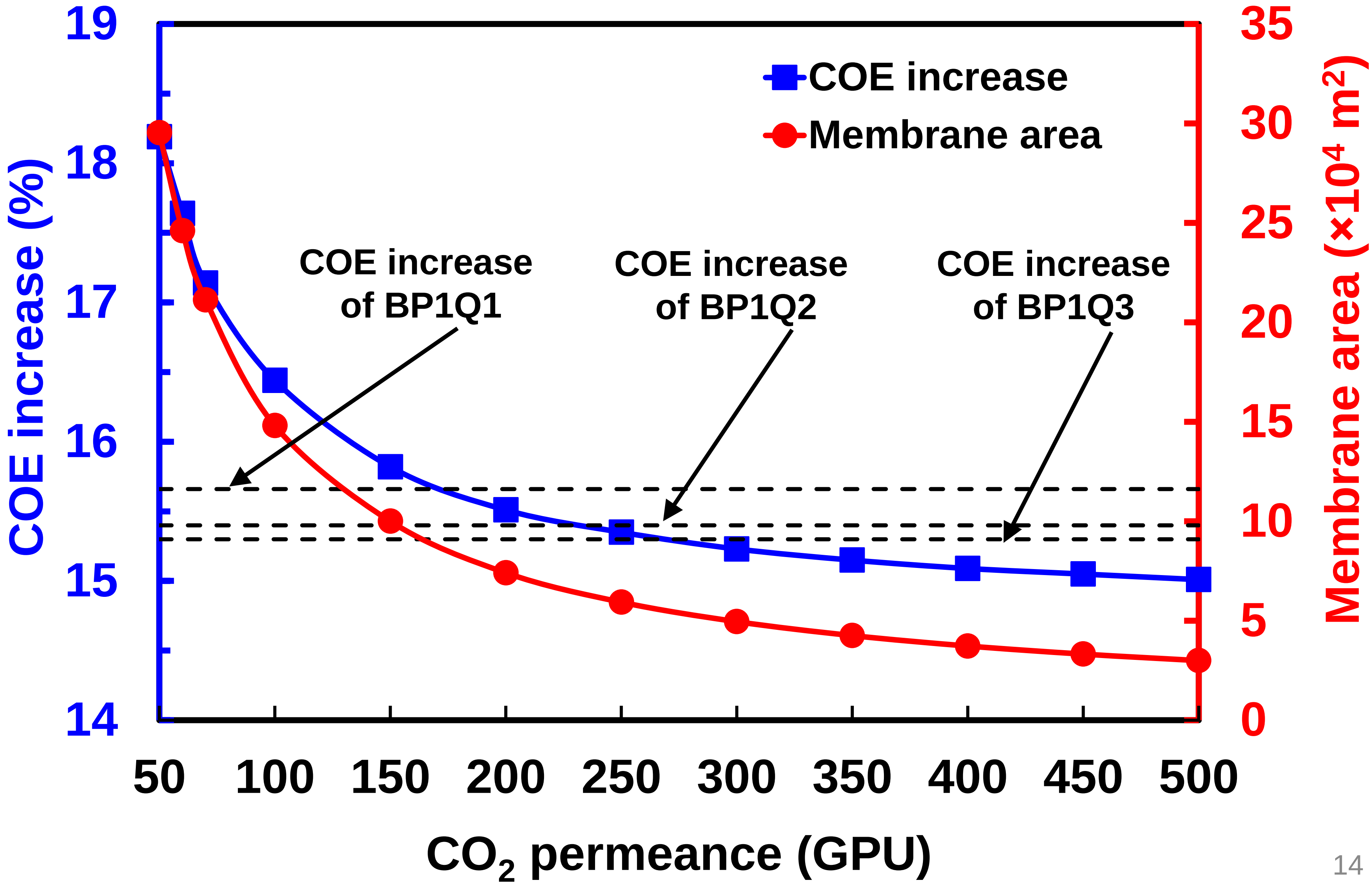




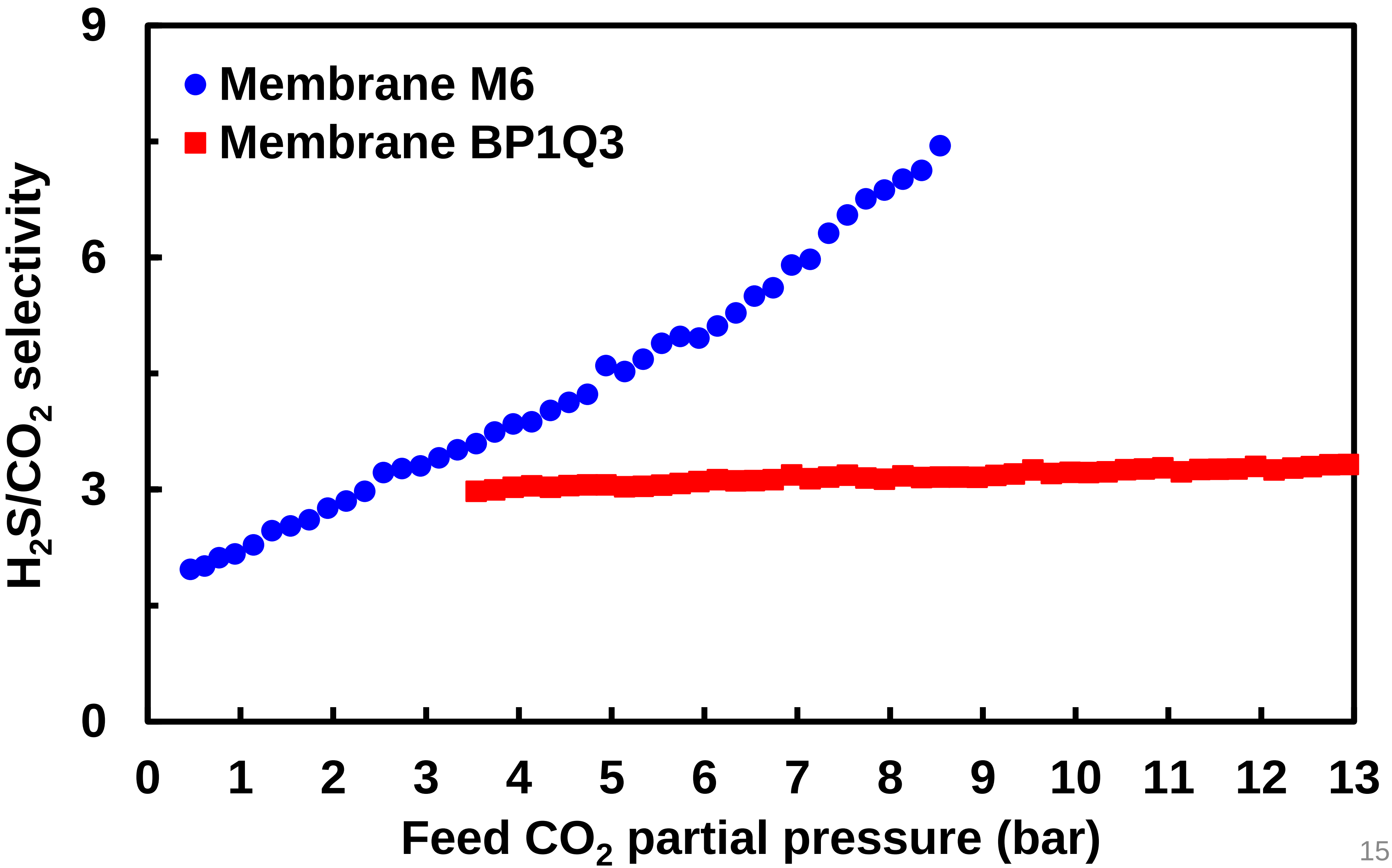
Effect of Carrier Saturation Phenomenon on Performance



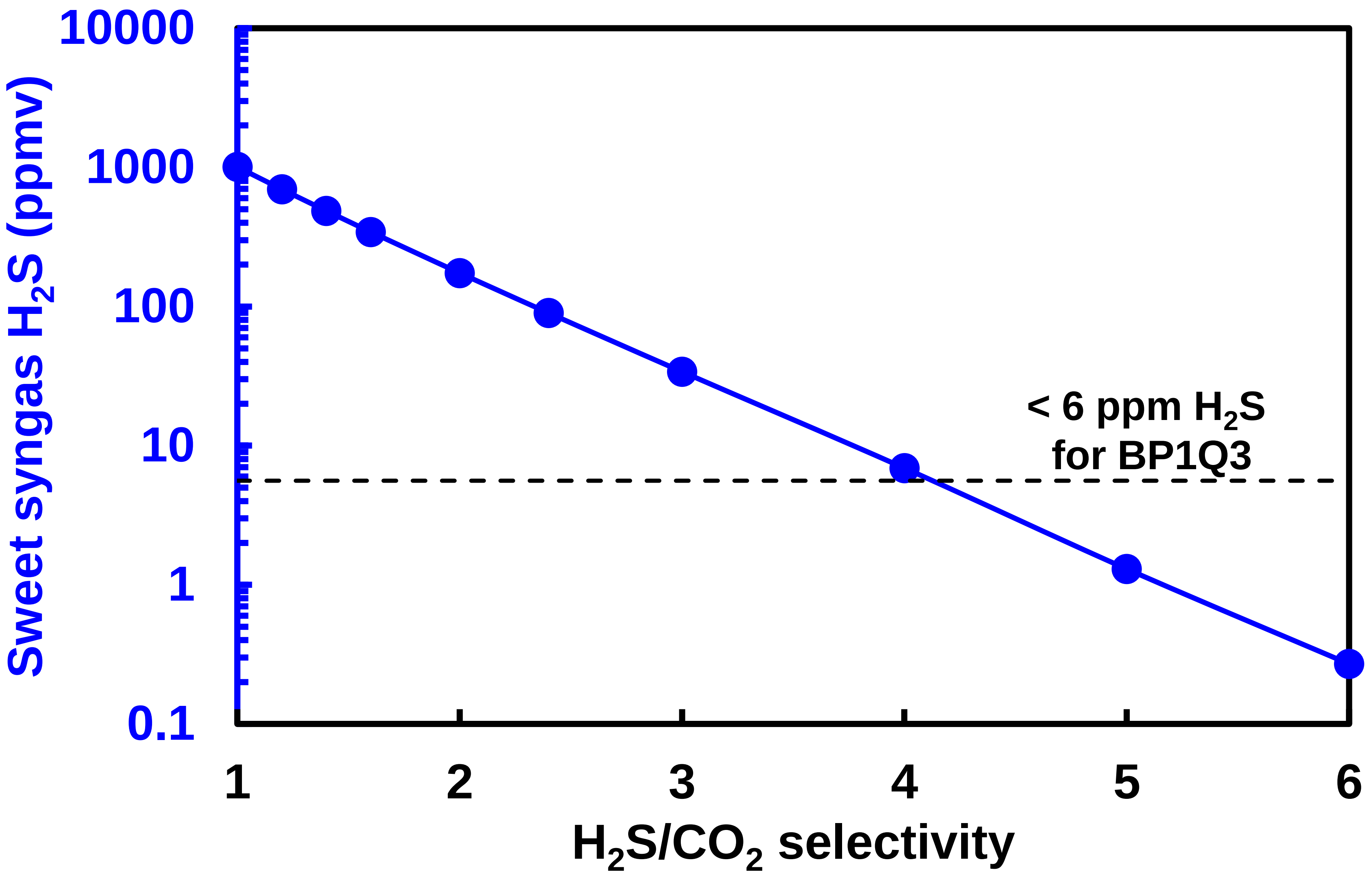
Effect of CO_2 Permeance on Cost of Electricity Increase



Membranes Synthesized with Tuned H_2S/CO_2 Selectivities



Effect of H_2S/CO_2 Selectivity on H_2S Concentration in H_2 Product



Plans for Future Testing/Development

- **Remaining BP1**
  - Increase CO_2 Sorption at High Pressure
  - Enhance Membrane Mechanical Properties
  - Preliminary Techno-Economic Analysis

- **BP2**
  - Membrane Scale-up and Characterization
    - + Continuous roll-to-roll fabrication (14″ wide by 20′ long)
  - Prototype SW Module Fabrication
    - + Fabricate 9 prototype SW modules (800 cm^2 each)
    - + 200-h stability test with simulated syngas
  - Final Techno-Economic Analysis

Acknowledgments

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