

# Advanced Membrane Reactors: Fuel Decarbonisation in IGCC's: H<sub>2</sub> versus CO<sub>2</sub> Separation

Authors: Michiel Carbo, Daniel Jansen, Wim Haije

## Introduction

Reactor modelling studies indicated possible application potential of CO<sub>2</sub> selective Water-Gas-Shift Membrane Reactors (WGS-MR) within Integrated Gasification Combined Cycles (IGCC). Both H<sub>2</sub>- and CO<sub>2</sub>-selective WGS-MR's were assessed with respect to implementation downstream of the gas cleaning section upon dry-fed entrained-flow coal gasification. Several variables were manipulated during modeling to obtain both elevated efficiencies and carbon capture ratios. The simulation results will serve to continue or stop the development of CO<sub>2</sub>-selective membranes.

## Modelling & Results

AspenPlus was applied for the simulations, suited with a dedicated Fortran based membrane model developed by ECN and the exergy analysis tool 'Exercom'.

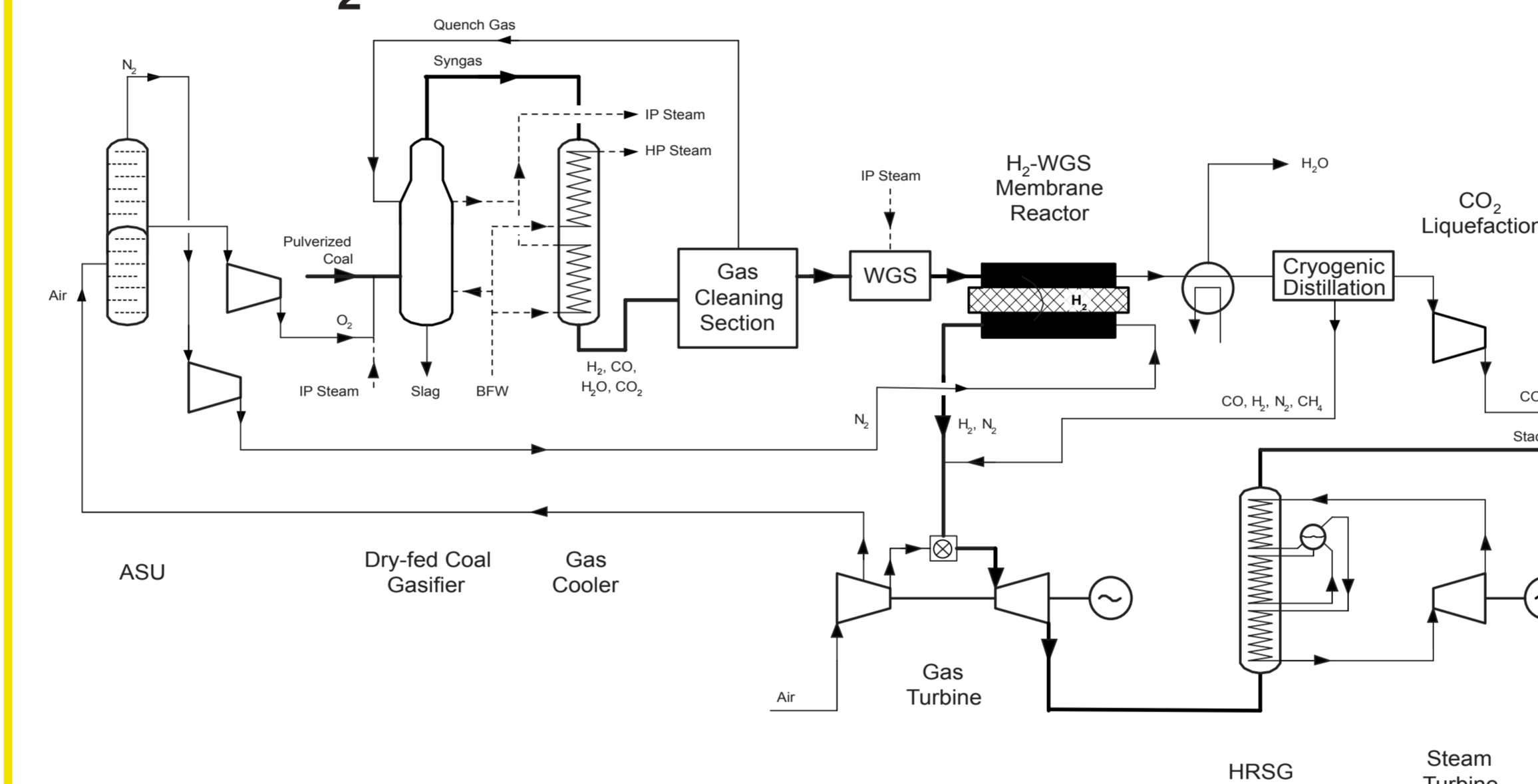
The membrane permeation was set at  $2.0 \times 10^{-6} \text{ mol m}^{-2} \text{ s}^{-1} \text{ Pa}^{-1}$  for both cases; this value serves as target for H<sub>2</sub>-selective membranes.

Key design variables:

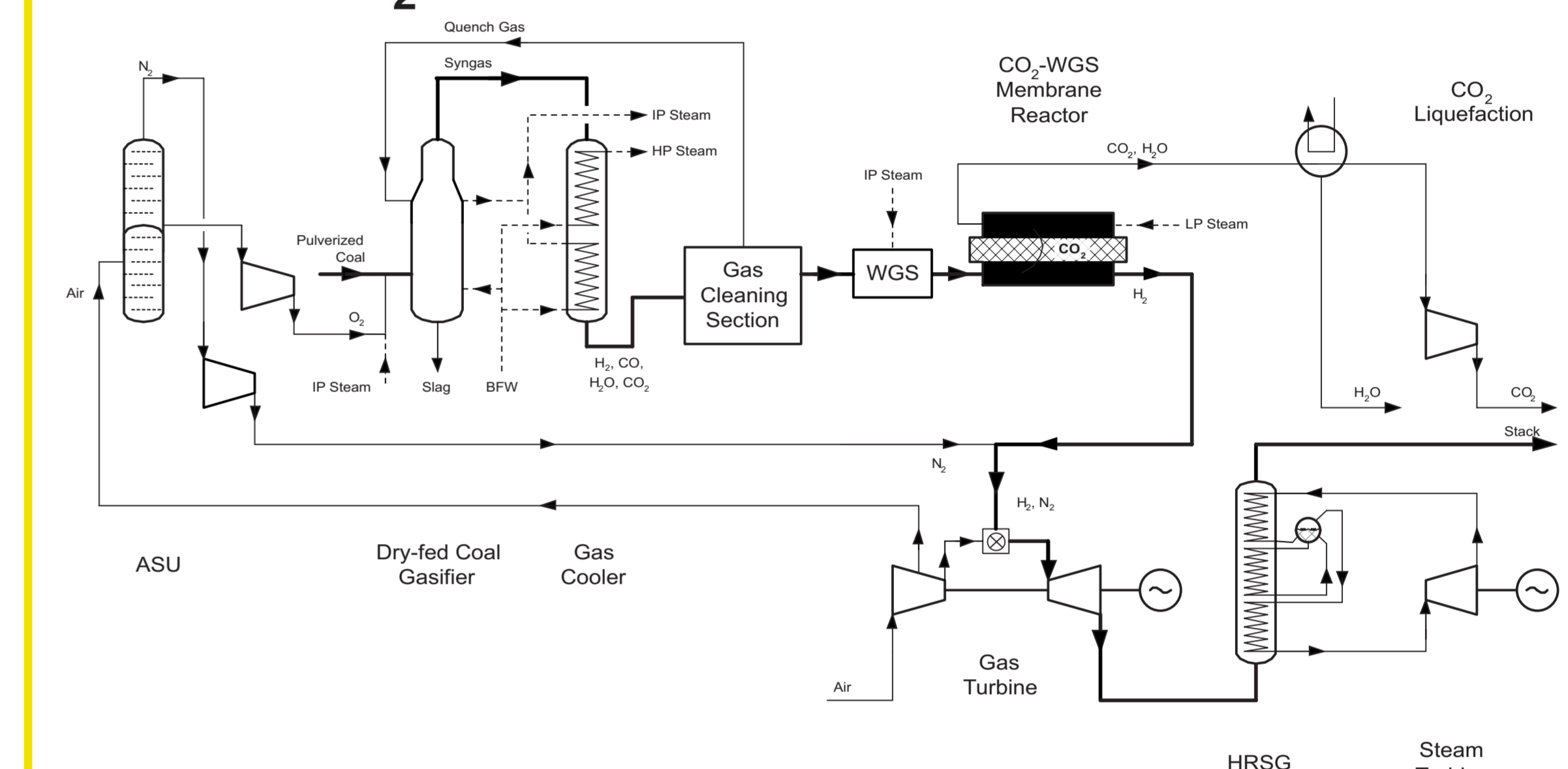
- Steam/CO<sub>2</sub>-ratio: 1.3 – 2.0 (molar basis)
- Membrane Surface: 5,000 – 30,000 m<sup>2</sup>
- Sweep Pressure: 3.0 – 23.0 bara (H<sub>2</sub> WGS-MR)
- Sweep Flow: 13.0 – 56.0 kg/s (CO<sub>2</sub> WGS-MR, 6 bara, 175 °C)

Case	Output [MW <sub>e</sub> ]	Efficiency [-]	Carbon Capture [-]	Membrane Area [m <sup>2</sup> ]	Sweep Steam [kg/s]
IGCC Base Case	500	47.9	-	-	-
IGCC Selexol (HT- & LT-WGS)	417	39.9	91.7	-	-
IGCC H <sub>2</sub> -selective WGS-MR	425	40.7	84.8	15000	-
IGCC CO <sub>2</sub> -selective WGS-MR	398	38.1	85.5	22500	55.6

## IGCC with H<sub>2</sub>-selective WGS Membrane Reactor

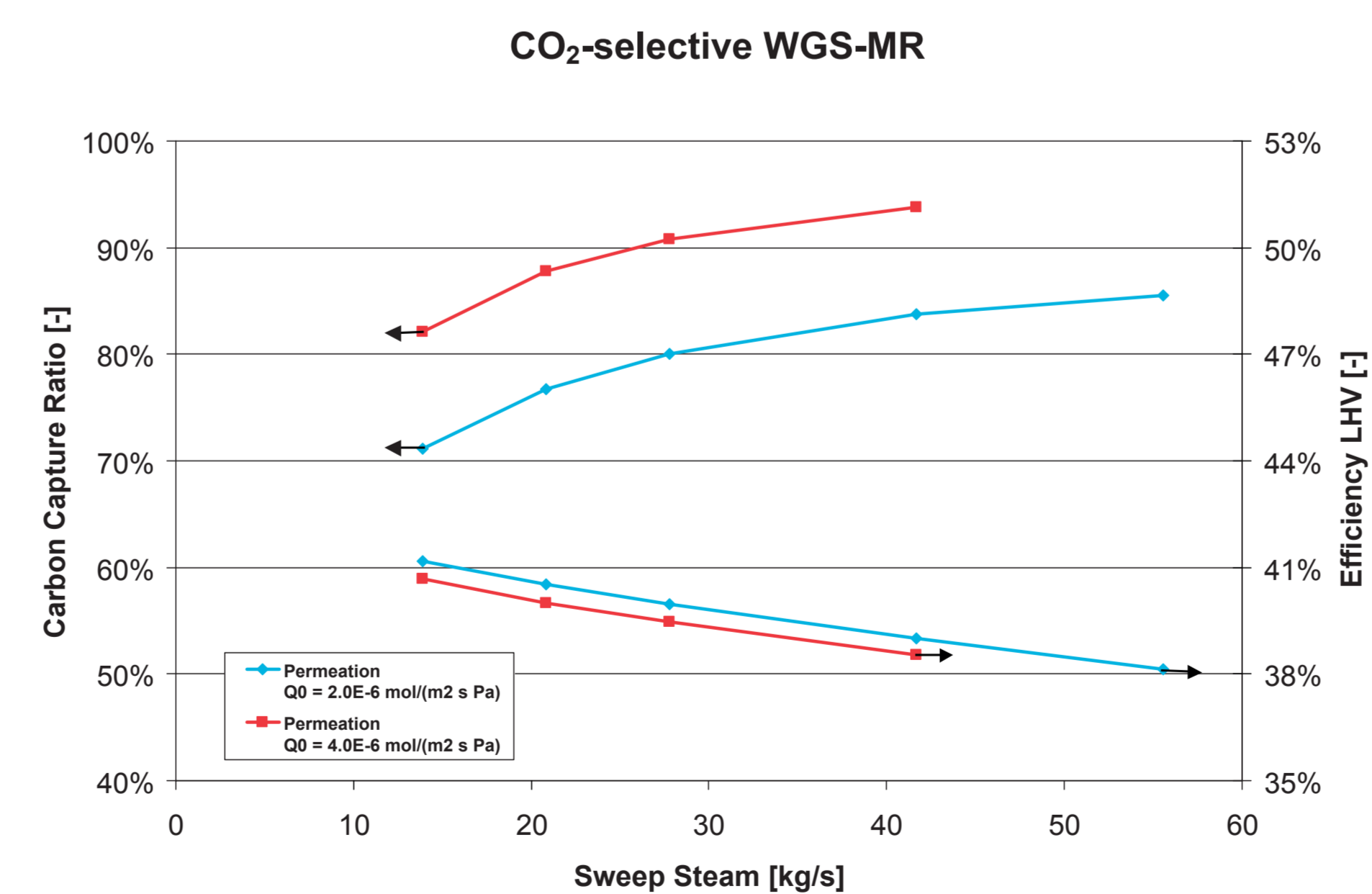


## IGCC with CO<sub>2</sub>-selective WGS Membrane Reactor



## Sensitivity Analysis

The subsequent sensitivity analysis demonstrated that doubling the permeation of CO<sub>2</sub>-selective WGS-MR, reduces the sweep steam flow by a factor 4 at an efficiency of 40.7%



## Conclusions and Recommendations

Coal gasifiers always produce H<sub>2</sub>/CO<sub>2</sub>-ratios higher than unity, resulting in higher H<sub>2</sub> partial pressures, which are beneficial in membrane permeation. The steam sweep flow applied in CO<sub>2</sub>-selective WGS-MR results in higher efficiency penalties than H<sub>2</sub>-selective WGS-MR, when similar carbon capture ratios are pursued.

Doubling the permeation target for CO<sub>2</sub>-selective WGS-MR offers potential for development of CO<sub>2</sub>-selective membranes.

The authors gratefully acknowledge the GCEP sponsors for financial support.

