KAUST VIRTUAL RESEARCH CONFERENCE 2021

Enabling CO_2 Geological Storage within a Low-Carbon Economy

A new enhanced gas recovery scheme using carbonated water and supercritical CO_2

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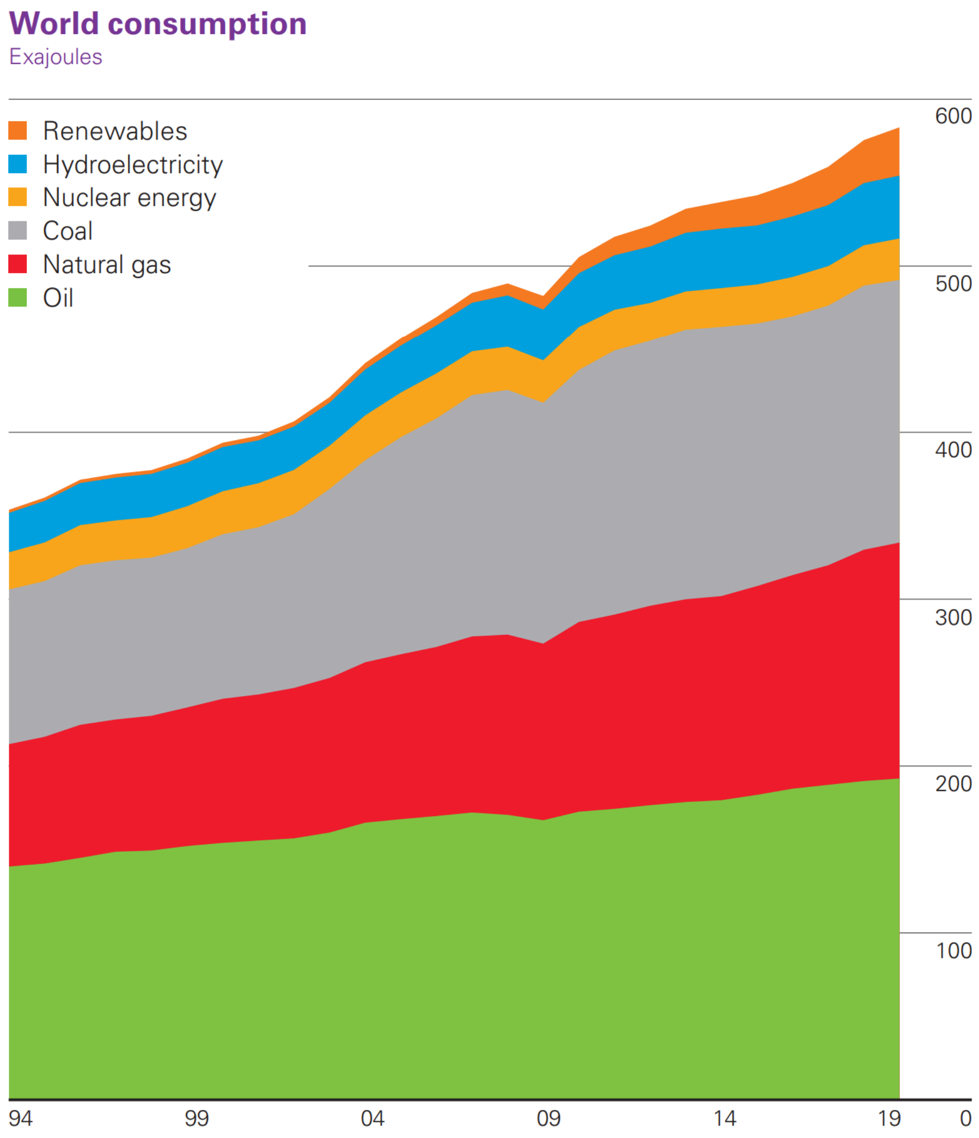
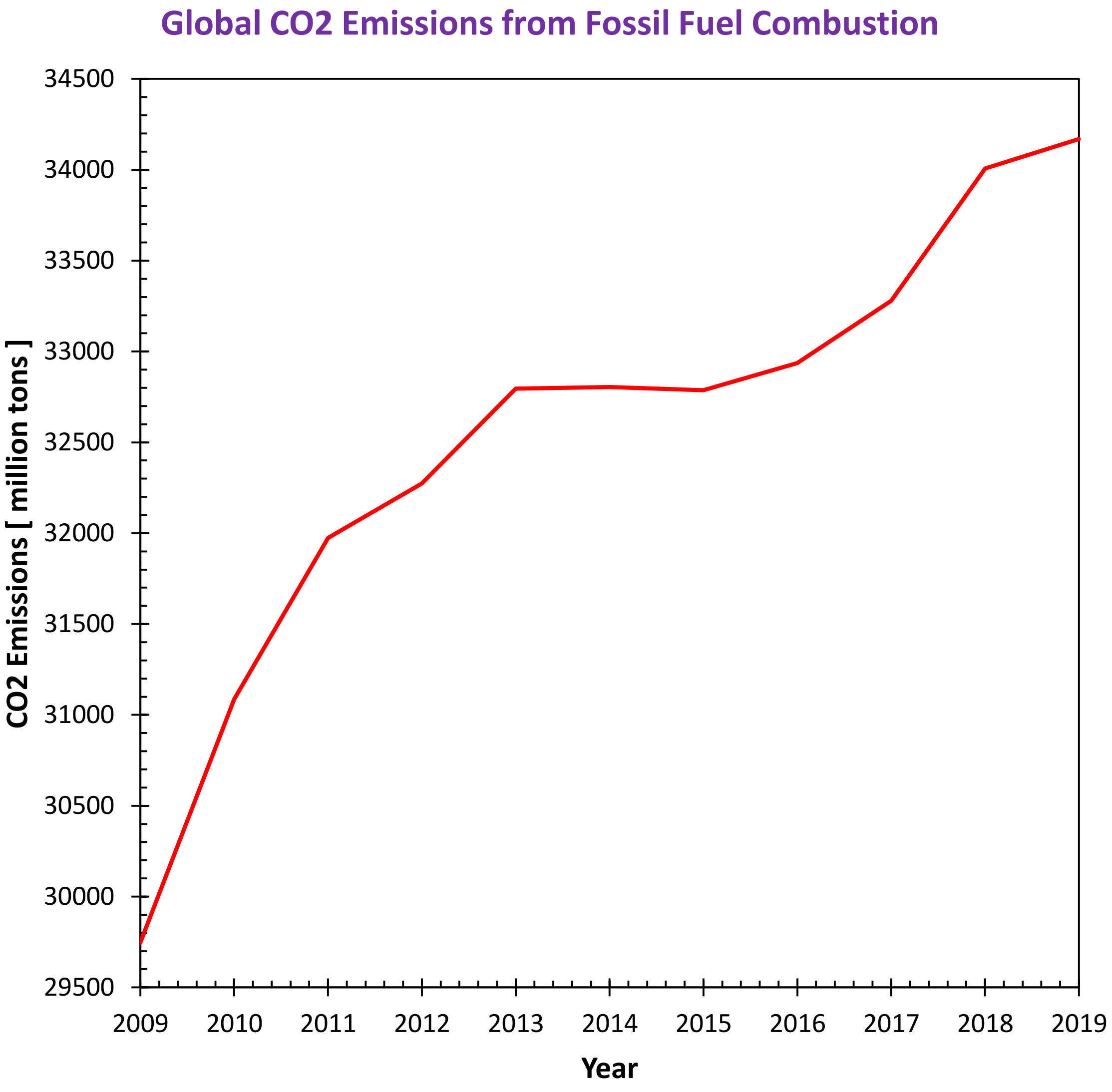
Motivation





BP Statistical Review of World Energy (2020)

CO_2-based Enhanced Gas Recovery (EGR)

- Improving gas recovery from mature reservoirs
- CO_2 entrapment in subsurface reservoirs

Problem Statement

- EGR
  - CO_2-based EGR

Mature technology/technique

Drawbacks

- CO_2-gas mixing
- Early CO_2 breakthrough (low density, viscosity)

- Gas recovery inefficiency
- Increased CAPEX & OPEX

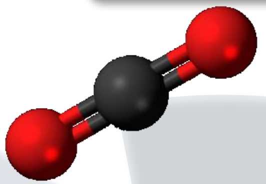
Proposed solution?

2-stage hybrid CO_2-based EGR

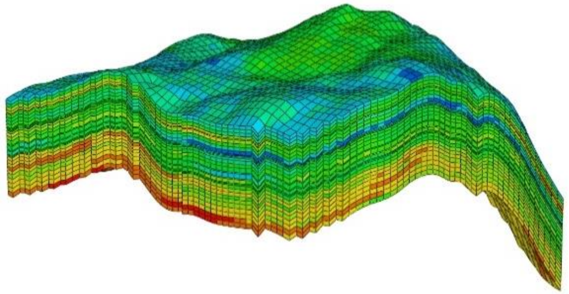
1. Injection of a slug of carbonated water
   - Reservoir pressure initially low
   - Reservoir pressure gradually rises
2. Injection of pure CO_2
   - Higher reservoir pressure
   - CO_2 denser and more viscous
   - Better sweep and displacement efficiency
   - Delayed CO_2 breakthrough

Project Workflow

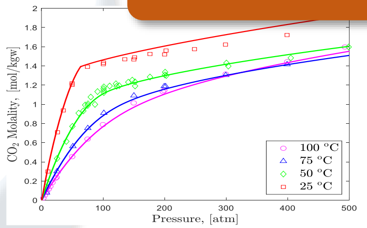
Problem Definition



- CO_2-gas mixing
- Early breakthrough
- Proposed solution

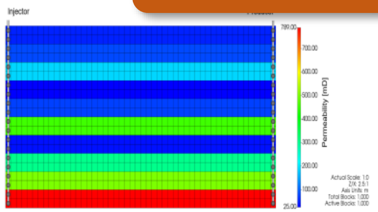


Simulator Validation



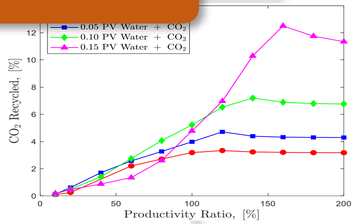
- Solubility
- Density
- Water vaporization

Mechanistic Simulation



- Continuous CO_2 injection
- Hybrid water/CO_2 injection

Optimization

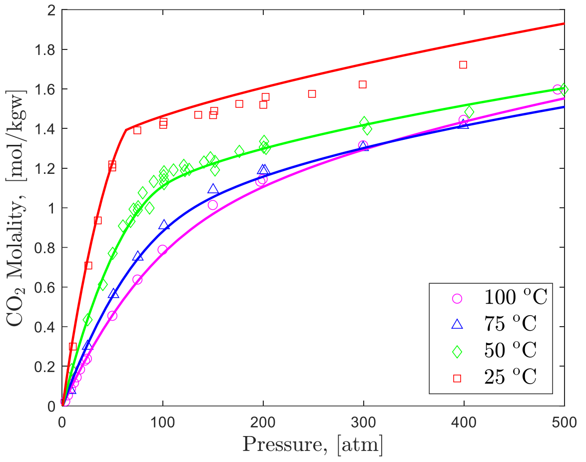


- Methane recovery factor
- CO_2 storage
- CO_2 recycling

Results

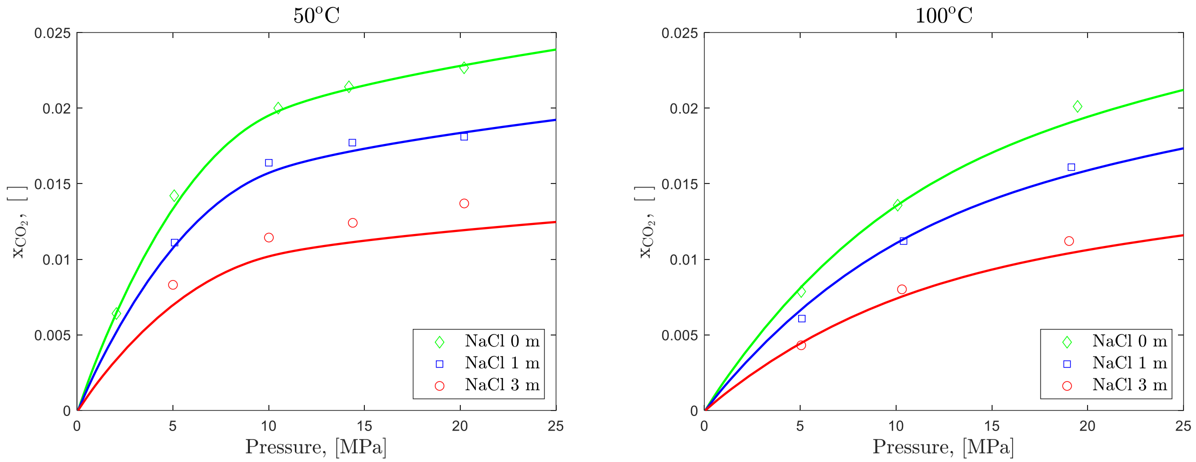
Results – Simulator Validation (CMG-GEM)

CO_2 solubility in pure water [1]



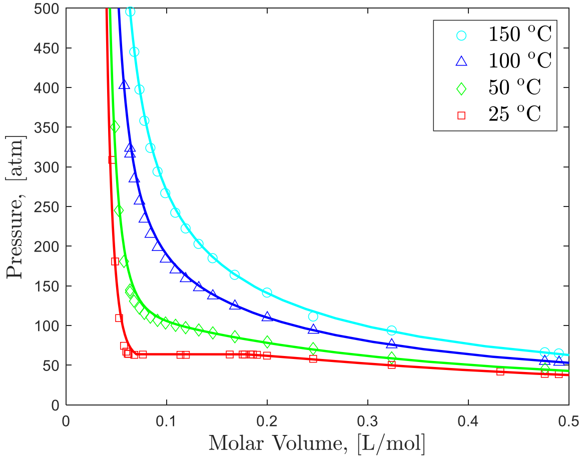
Henry's law

CO_2 solubility in saline water [2]



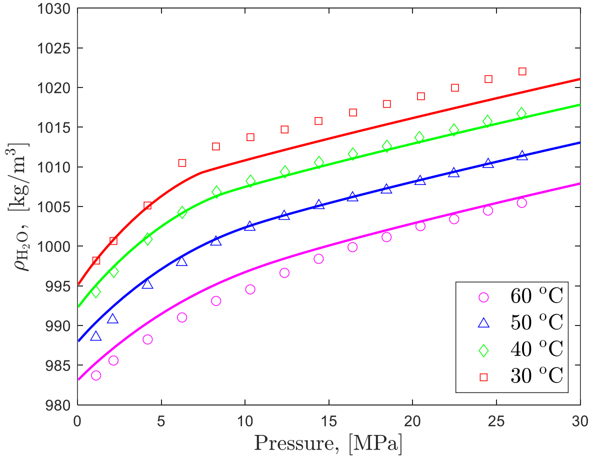
Li and Nghiem Scaled Particle Theory Method for Henry's law constants

CO_2 molar volume [3]



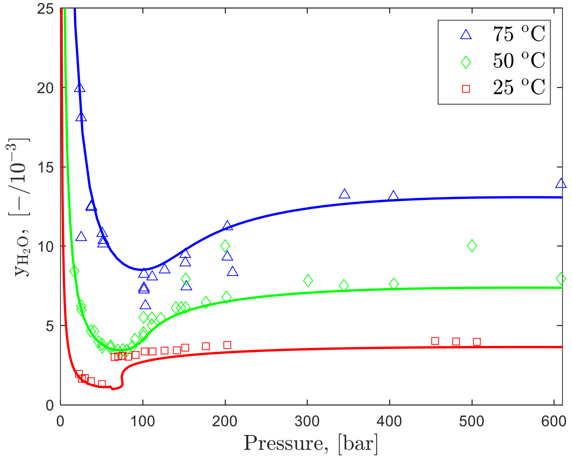
Peng-Robinson EOS

CO_2-saturated water density [4]



Rowe-Chou correlation

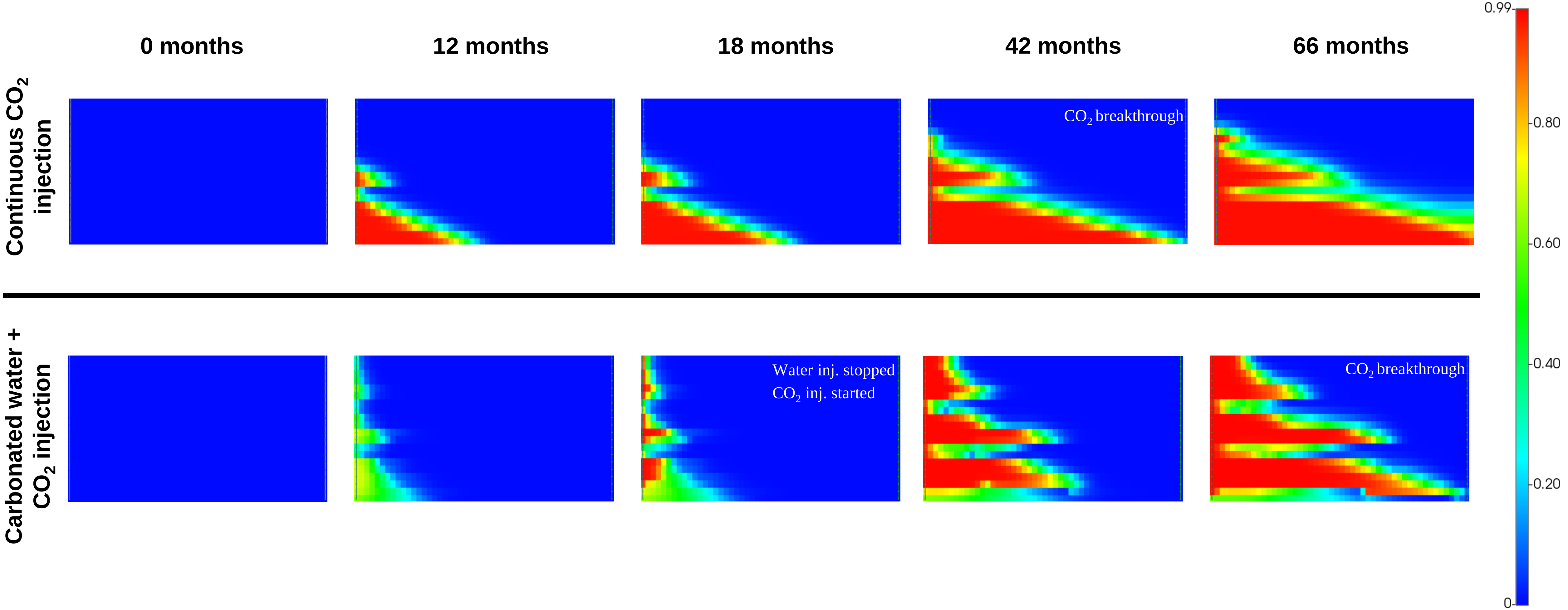
Water vaporization [5]



1: Appelo et al. (2014), Henry (1803) 2: Koschel et al. (2006), Li & Nghiem (1986) 3: Appelo et al. (2014), Peng & Robinson (1976) 4: Hebach et al. (2004), Rowe & Chow (1970) 5: Appelo et al. (2014)

Results – Mechanistic Simulations

Global CO_2 mole fraction



Results – Optimization

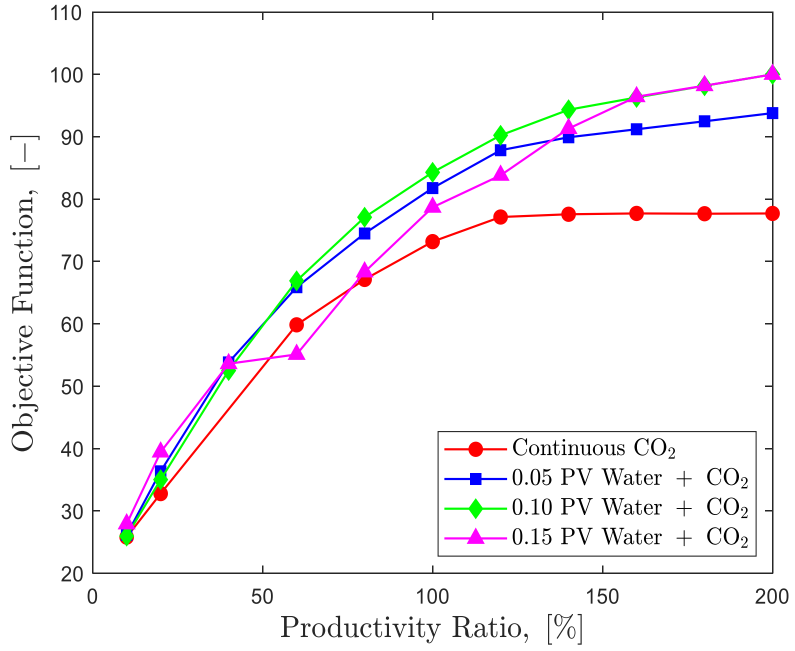
Objective Function

$$\mathrm{OF} = \mathrm{a}X_1 + \mathrm{b}X_2 + \mathrm{c}X_3$$

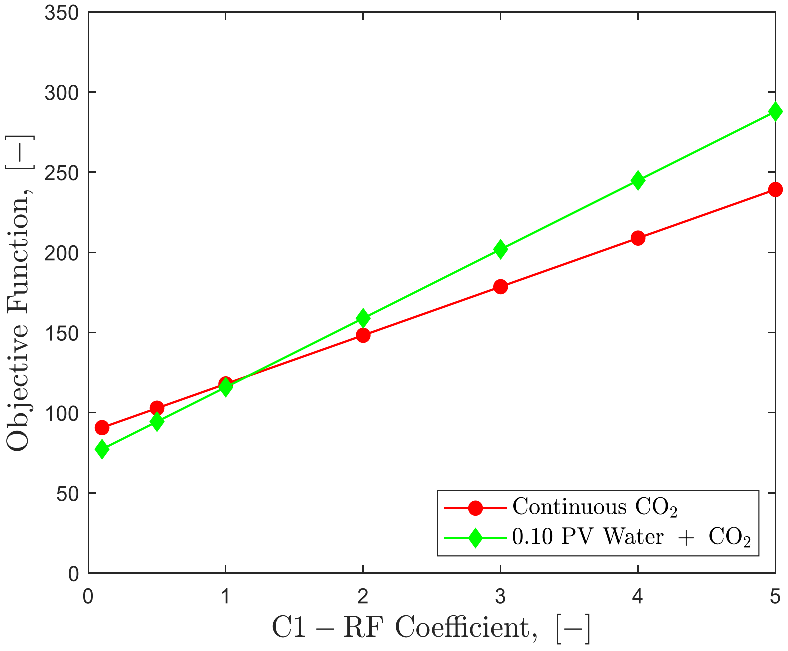
a, b, c : weighting coefficients
X_1 : methane recovery factor
X_2 : total CO_2 stored
X_3 : CO_2 recycled

Goal: Maximization

a = 10, b = 1, c = 1



Objective Function Coefficient Sensitivity



$$0.1 \leq \mathrm{a} \leq 5$$

Conclusions

CO_2-based EGR:

- Improving gas recovery
- CO_2 disposal in the subsurface

Drawbacks:

- Early breakthrough of CO_2
- CO_2-gas dilution
- Increased CAPEX/OPEX

Proposed hybrid water-CO_2 co-injection:

- Delayed breakthrough of CO_2
- Improved natural gas recovery
- Overall significant benefit considering recovery and storage

Future Work

- Sensitivity analysis on more parameters (reservoir pressures, temperature, injection rates etc.)
- Probabilistic analysis on our defined objective function
- High resolution simulations on real reservoir models

Acknowledgements

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3. Prof. Volker Vahrenkamp

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Thank you for your attention!