Hydrogen Mixing Dynamics during Underground Storage in Depleted Gas Reservoirs

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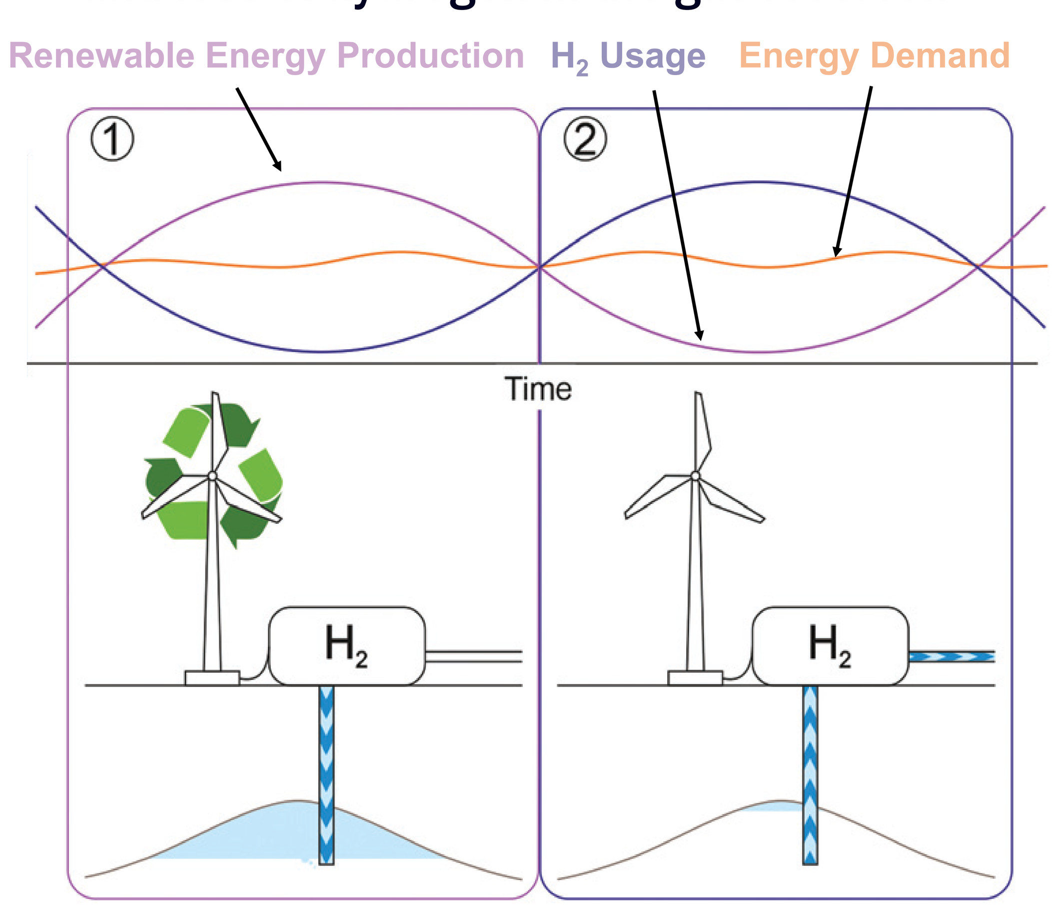
INTRODUCTION

- ❖Underground hydrogen storage (UHS) is a feasible solution to store excessive renewable energy resources
- ❖Depleted gas reservoir is suggested as a suitable geological site for UHS operation
- ❖Cushion gas is pre-injected for pressure and deliverability maintenance
- ❖Gas mixing between in-situ gas and injected cushion gas can lead to the contamination and loss of hydrogen in the gas reservoir



(Heinemann et al, 2021, *Energy and Environmental Science*)

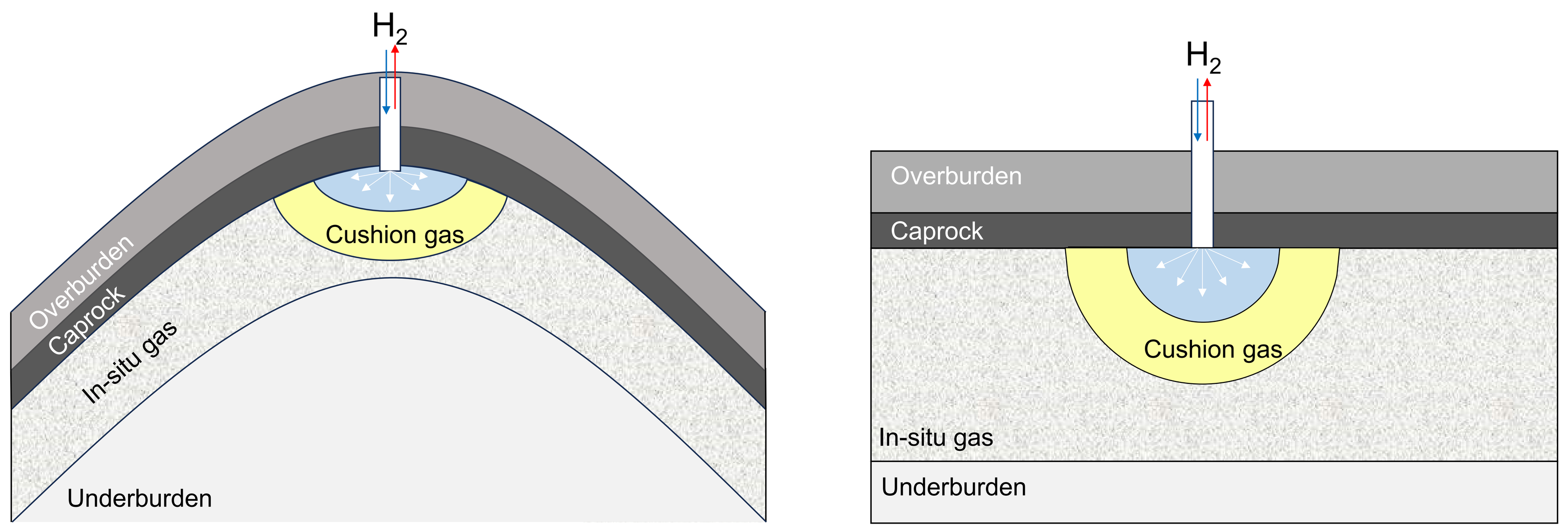
OBJECTIVES

- ❖H_2 mixing with in-situ gas and cushion gas can be influenced by:
  - ➢In-situ gas amount
  - ➢Cushion gas amount
  - ➢Hydrodynamic dispersion (HD)
  - ➢Formation Geometry
- ❖ Investigating the H_2 mixing dynamics and the impacts of the influencing factors on produced H_2 purity and recovery factor (RF) using numerical simulation

METHODS

Conceptual Model & Assumptions

- ✓ Single gas phase
- ✓ Isotropic and homogeneous formation
- ✓ Impermeable boundary
- ✓ No chemical and microbial activities
- ✓ Isothermal condition



Governing Equations

Mass conservation for chemical species

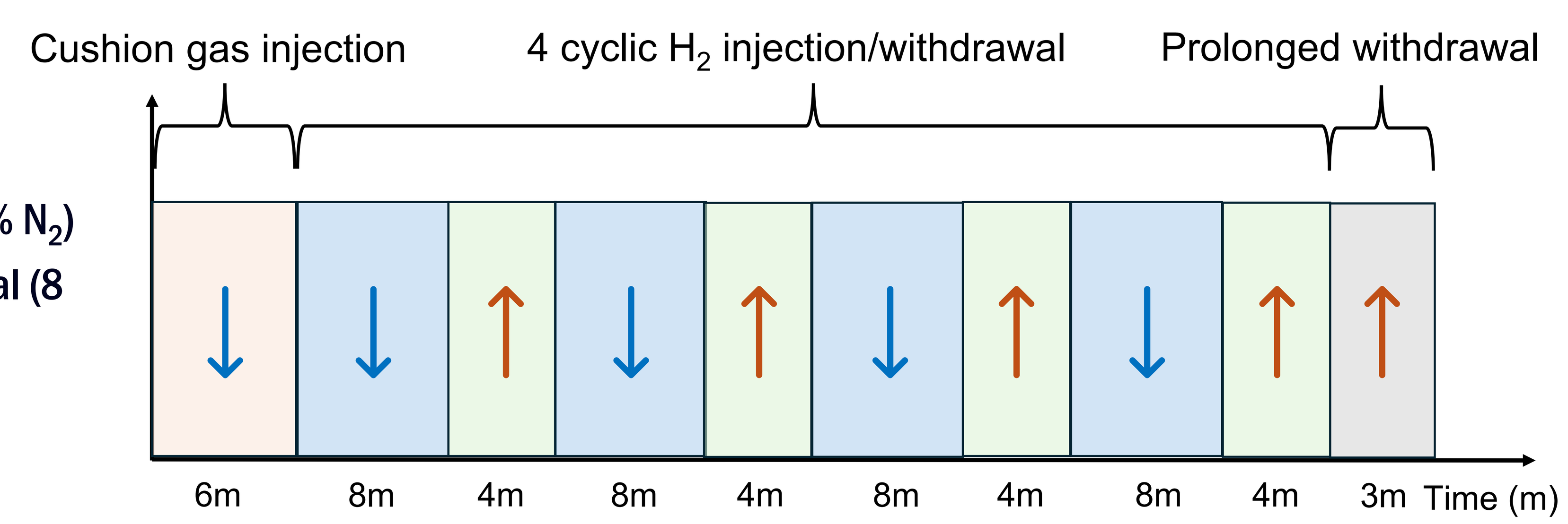
$$\phi\rho\frac{\partial(\omega_i)}{\partial t}+\rho(\boldsymbol{u}\cdot\nabla)\omega_i+\nabla\cdot\boldsymbol{j}_i=R_m$$

GERG-2008 equation of state (EOS)

$$\alpha(\delta,\tau,\bar{x})=\alpha^o(\rho,T,\bar{x})+\alpha^r(\delta,\tau,\bar{x})$$

General Working Schedule

- ✓ 6-month pre-injection of cushion gas (100% N_2)
- ✓ 4 cyclic injections (4 months) and withdrawal (8 months)
- ✓ 3-months prolonged withdrawal



RESULTS

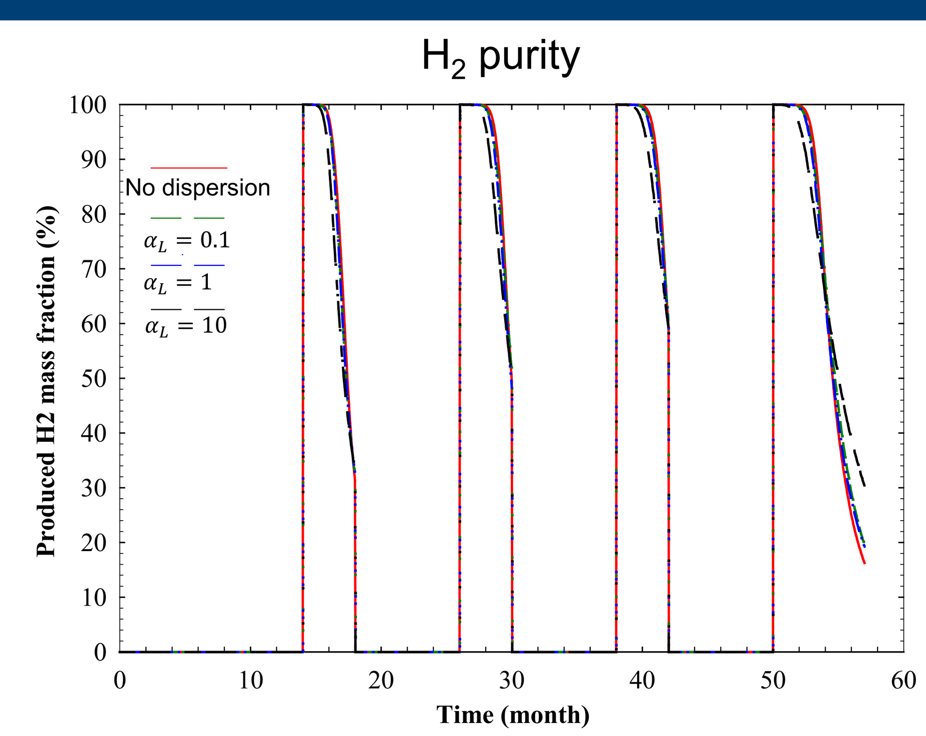
➢ **In-situ Gas & Cushion Gas Amount**

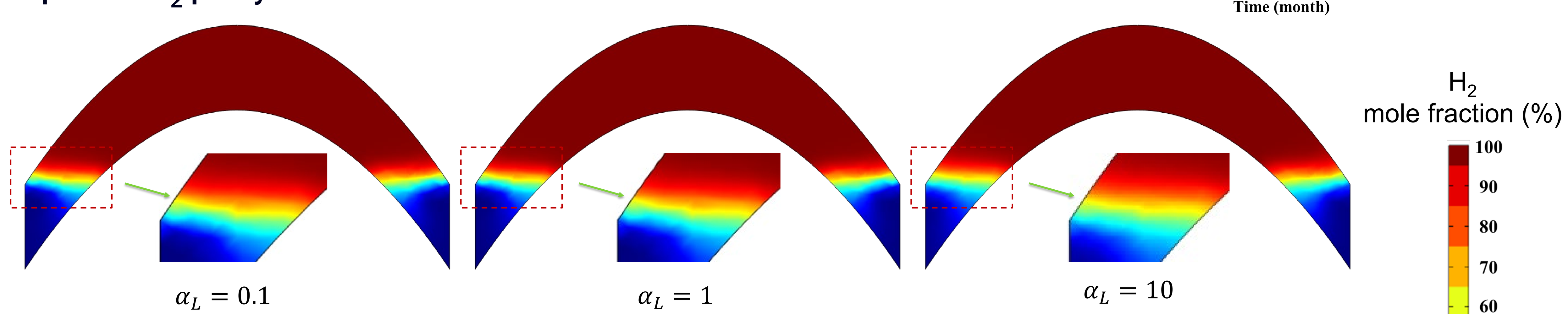
H_2 purity and RF both decrease with the increasing amount of in-situ gas and cushion gas

➢ **Hydrodynamic Dispersion (HD)**

The gas mixing region is amplified with the increasing longitudinal dispersivity (α_L)

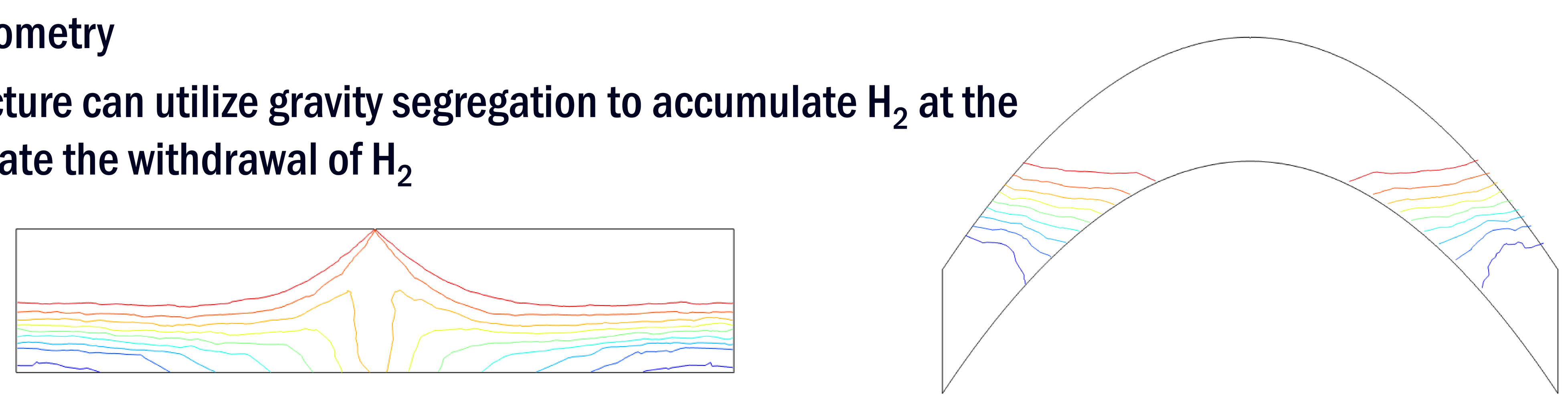
When Longitudinal dispersivity is at 10^1 order, HD has a notable impact on H_2 purity and RF





➢ **Formation Geometry**

Anticline structure can utilize gravity segregation to accumulate H_2 at the top and facilitate the withdrawal of H_2



CONCLUSIONS

We conducted numerical simulations to investigate several influencing factors and H_2 mixing dynamics during UHS:

- ❖ Under the same molar composition, in-situ gas (CH_4) can provide a slightly better H_2 RF (0.5 - 1.4%) than cushion gas (N_2)
- ❖ Hydrodynamic dispersion leads to a notable reduction in H_2 purity and H_2 RF will decrease up to 6% when formation dispersivity is at 10^1 order
- ❖ Horizontal trap significantly decreases the H_2 purity and H_2 RF will reduce up to 23% in each cycle, gravity segregation can facilitate the withdrawal of H_2

REFERENCES

Li, Dexuan, and Hamid Emami-Meybodi. "Hydrogen Mixing Dynamics in Depleted Gas Reservoirs." Paper presented at the SPE Annual Technical Conference and Exhibition, New Orleans, Louisiana, USA, September 2024.

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