Fluid Thermophysical Properties of CO_2-rich Streams in the Carbon Capture and Storage (CCS) Processes

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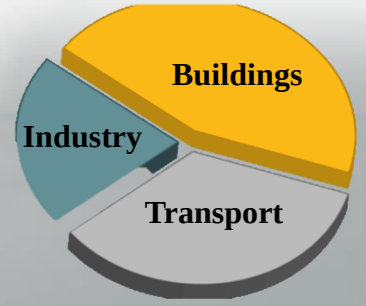
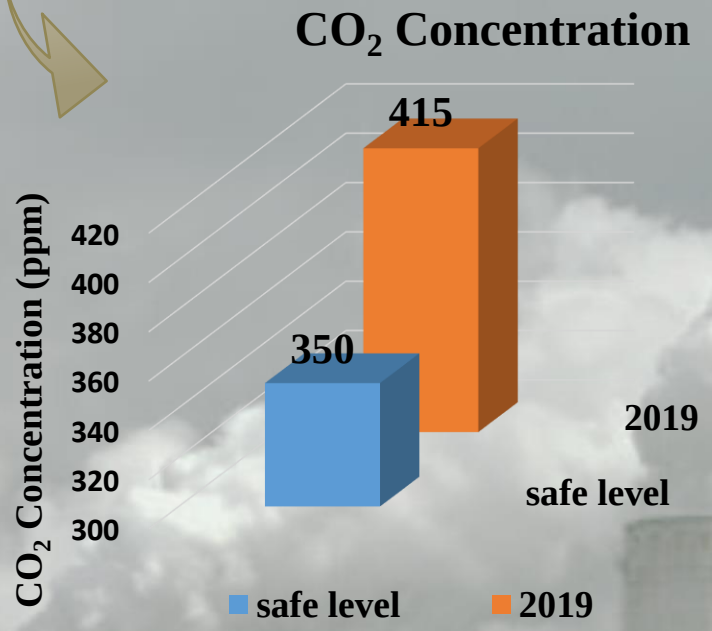
CO_2 Emissions, Capture, and Storage

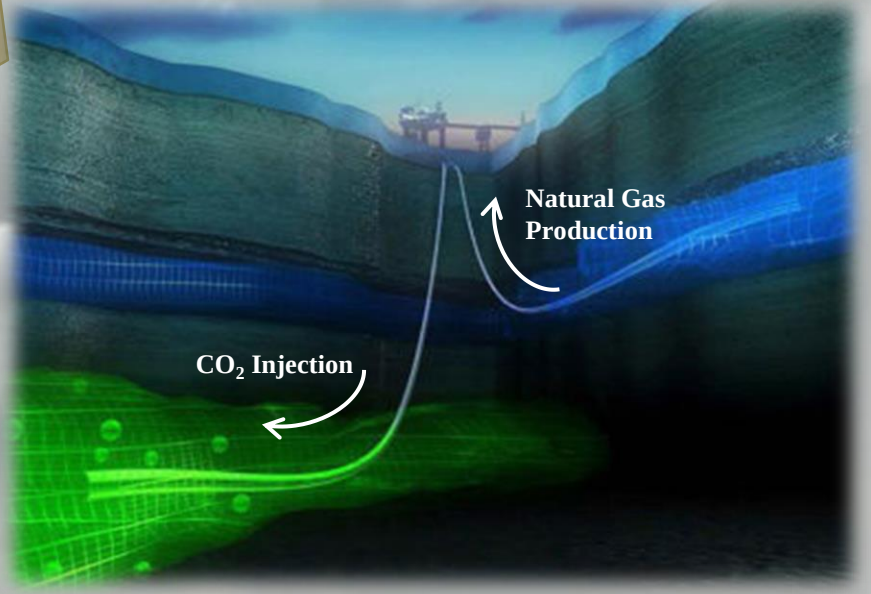


CO_2 Emissions by Sector

Capture CO_2 Safely → Biomimicry → Transportation and Storage in Subsurface Reservoirs



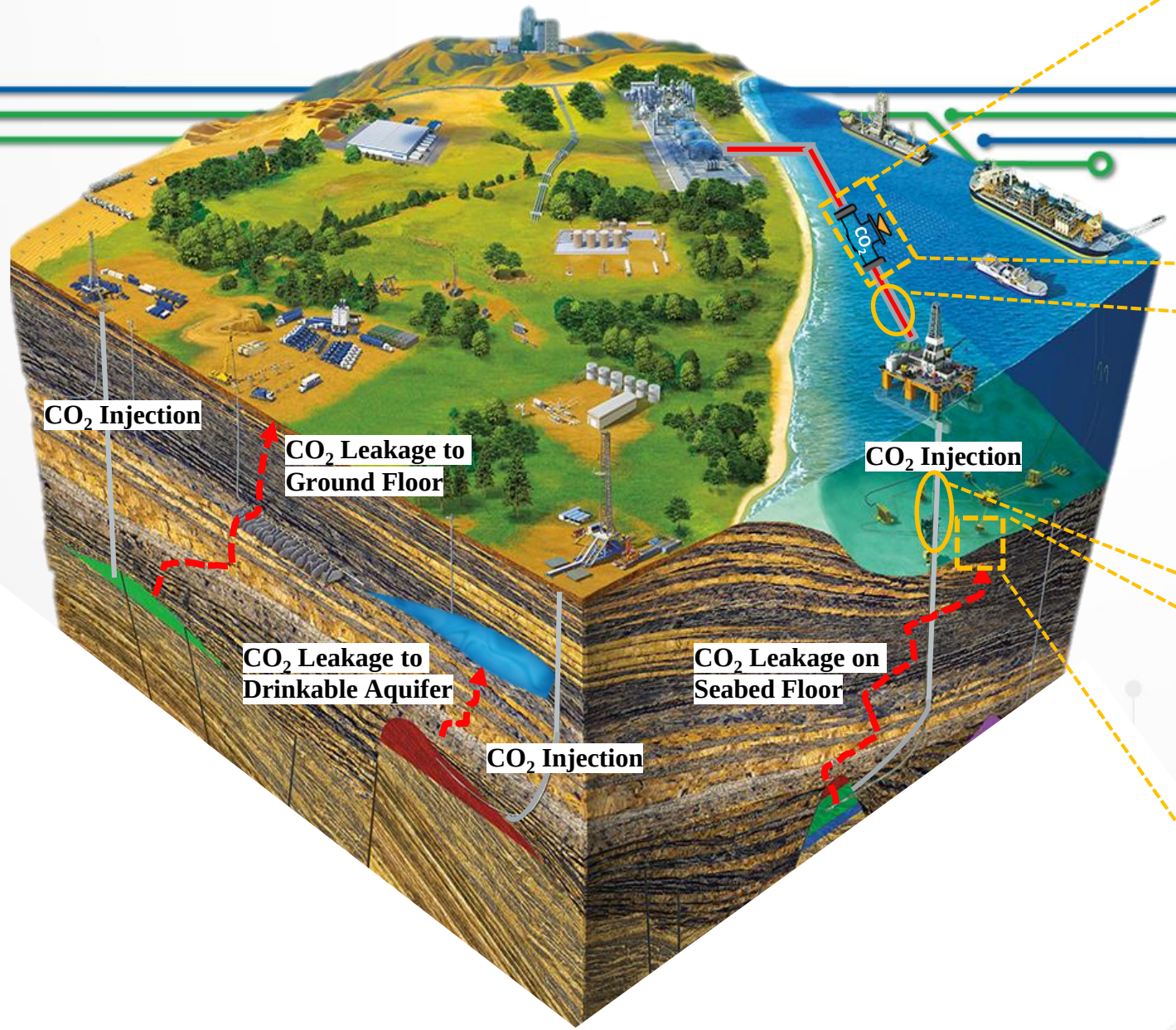
CCS

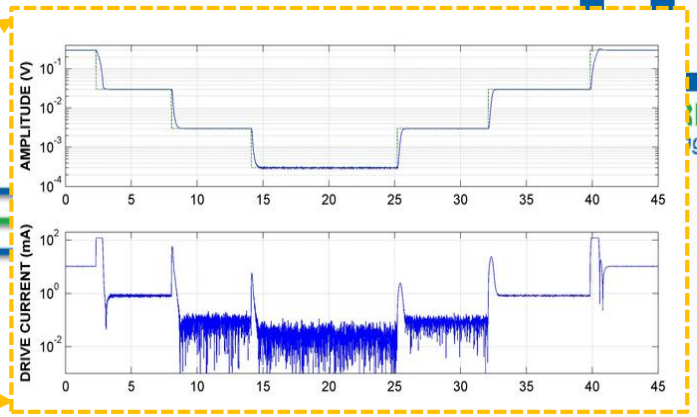


Agenda

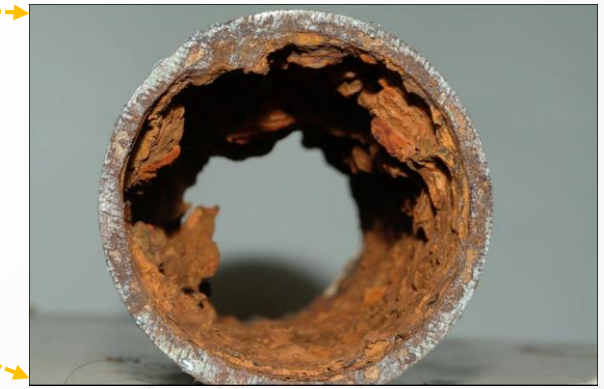
- Step 1: How is a CCS system like?
- Step 2: What are the problems in this system?
- Step 3: Thermodynamics & Theory
- Step 4: What is the solution?

Reusing Oil & Gas Infrastructure for CCS Applications; The Big Challenges!

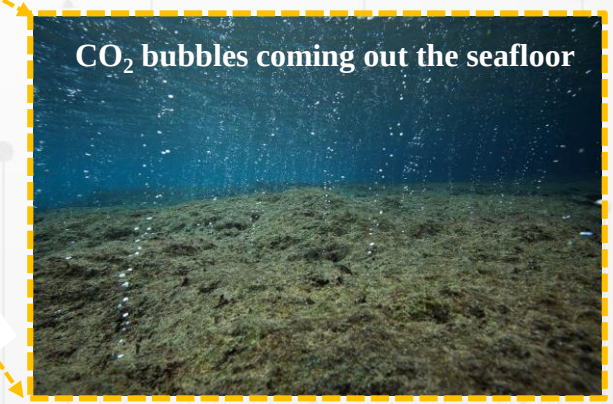




Errors in CO_2 flow measurement!

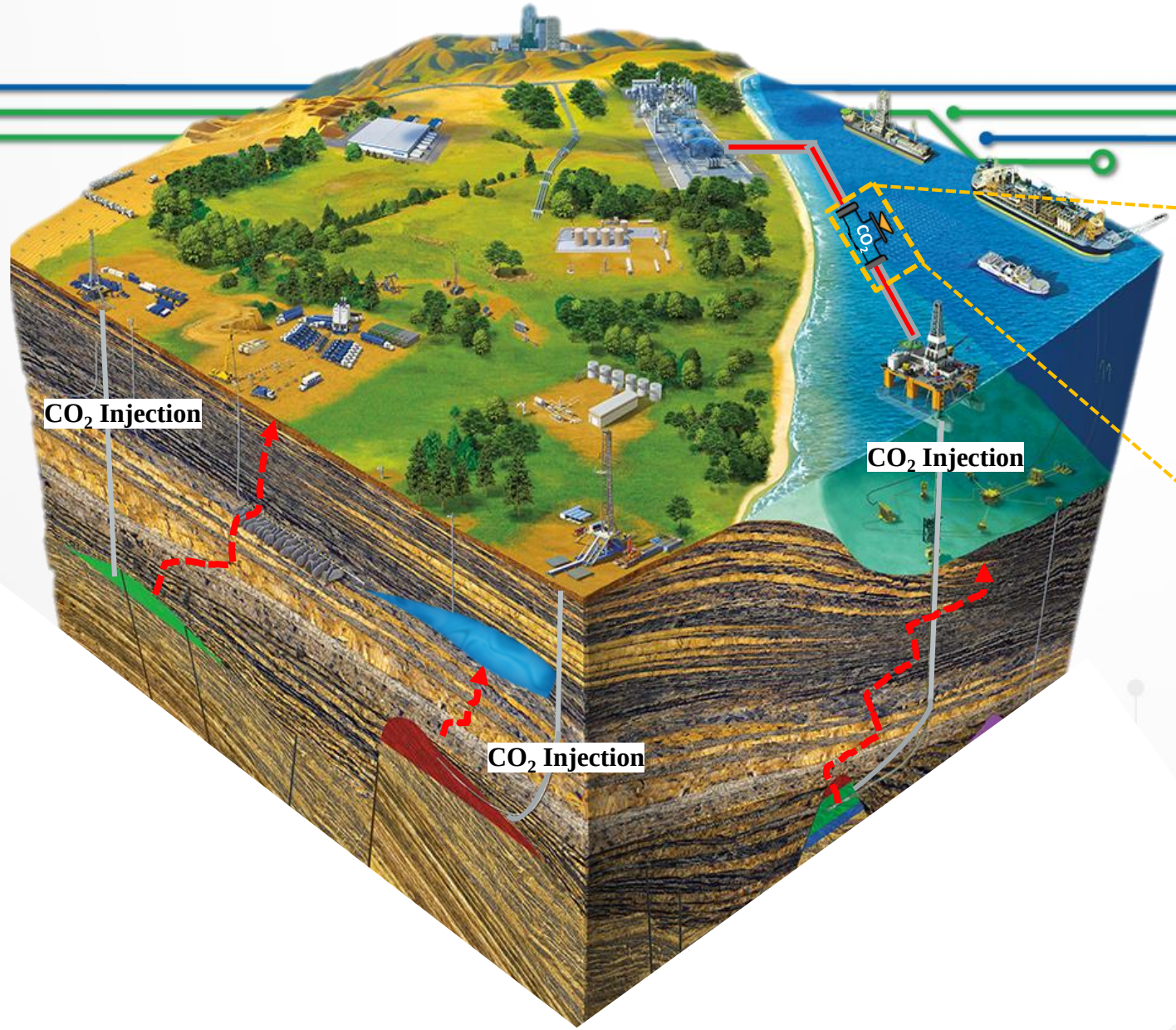


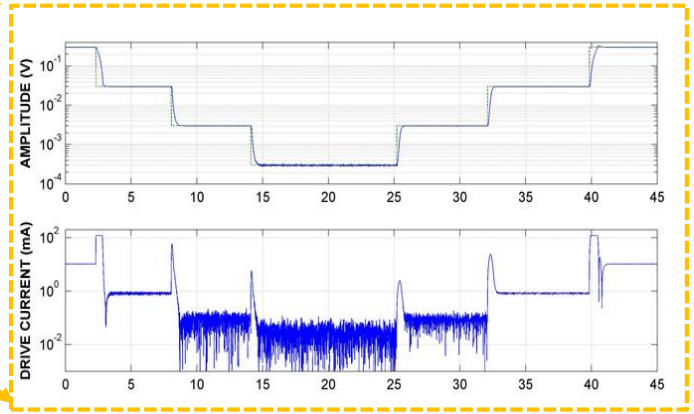
Corrosion Problem!



CO_2 rock dissolution and associated leakage challenge!

1st Problem: CCS Flow Measurement

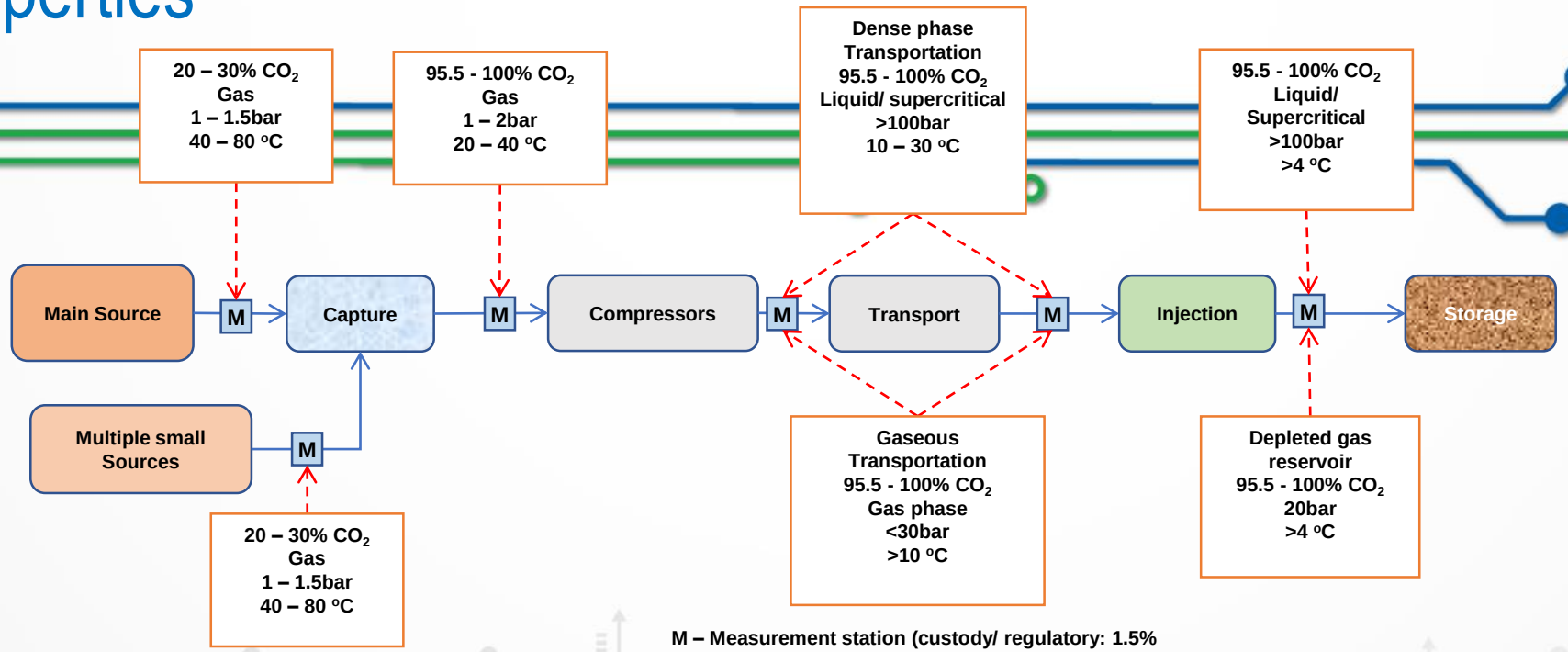




Errors in CO_2 flow measurement!

How can we reduce errors in CCS flow metering?

CCS Flow Metering and Significant Role of Thermodynamic Properties

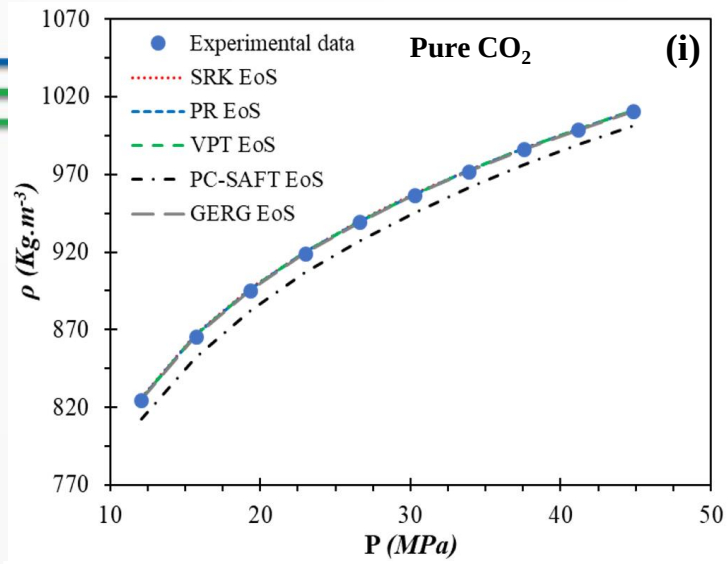


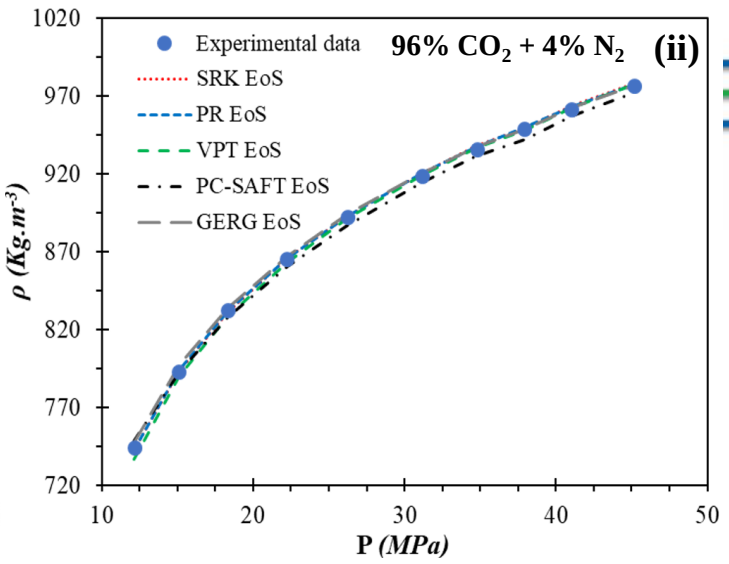
M – Measurement station (custody/ regulatory: 1.5% uncertainty)

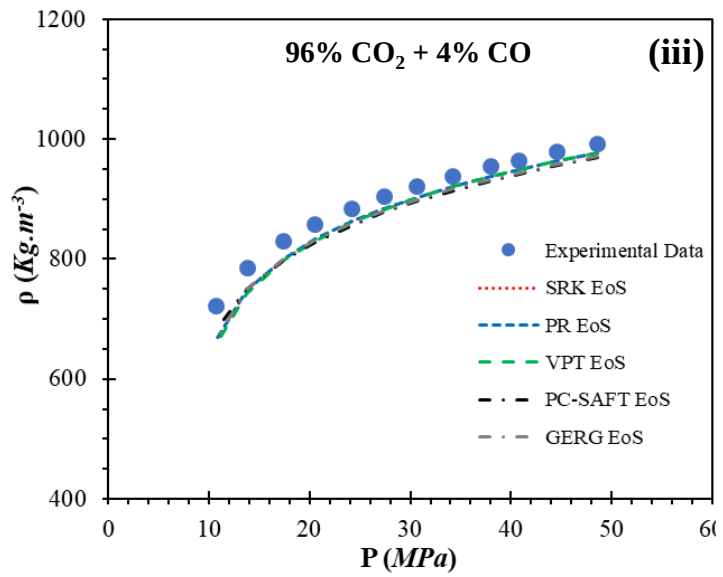
- **Ultrasonic Flow Meter**
  - Could be a good potential candidate
  - Number of difficulties with CO_2 measurement
  - **Accurate Speed of sound (SoS) for CO_2 streams?**

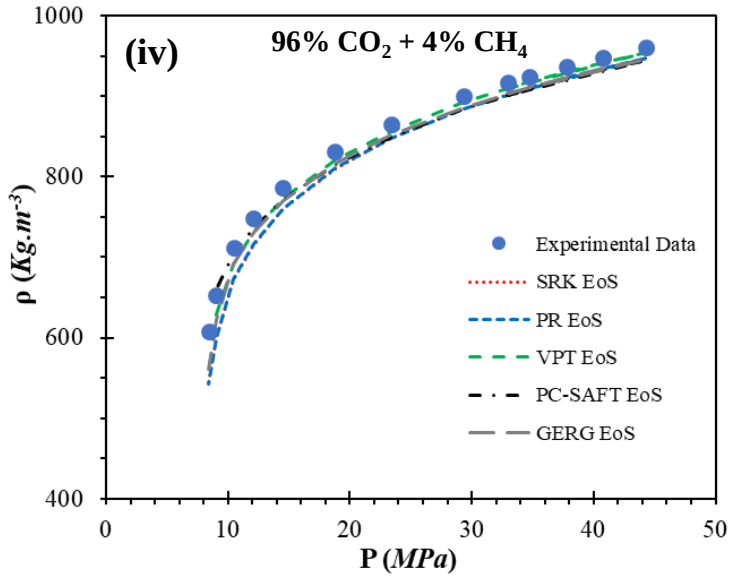
- **Coriolis**
  - Used in CCS trials
  - **Two phase flow – though not accurate.**
  - **Density of CO_2-rich streams?**

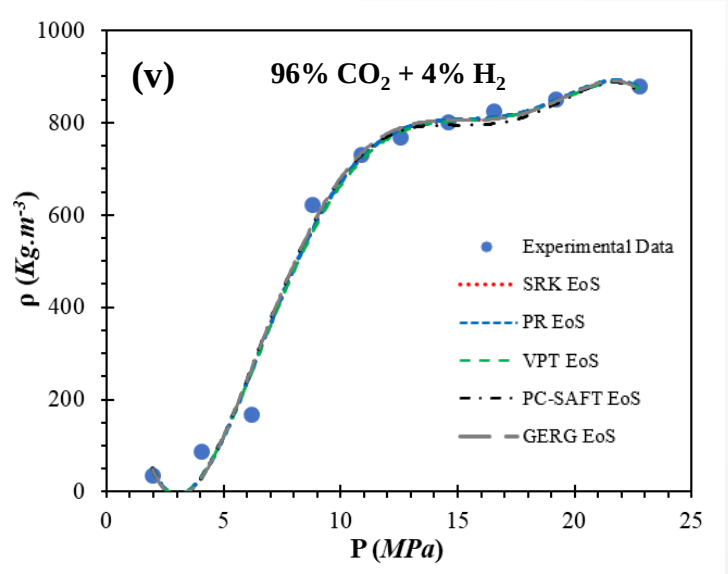
Densities of CO_2-rich Streams (with N_2, H_2, CH_4, and CO Impurities)





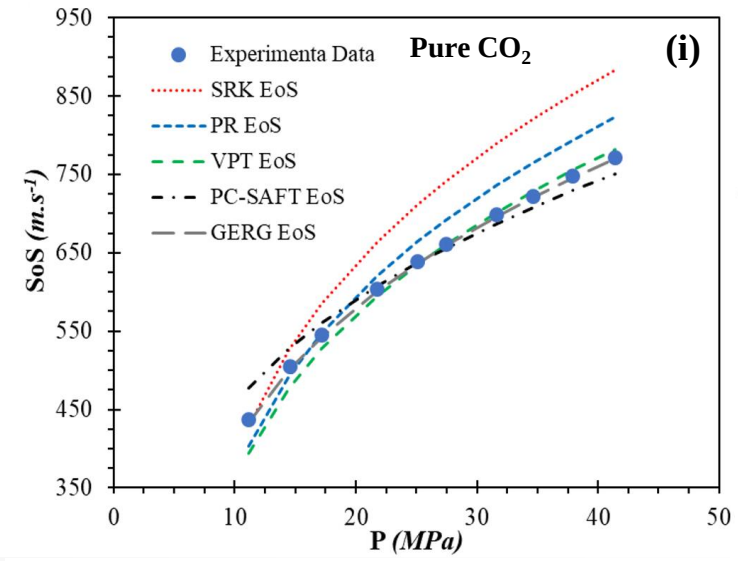


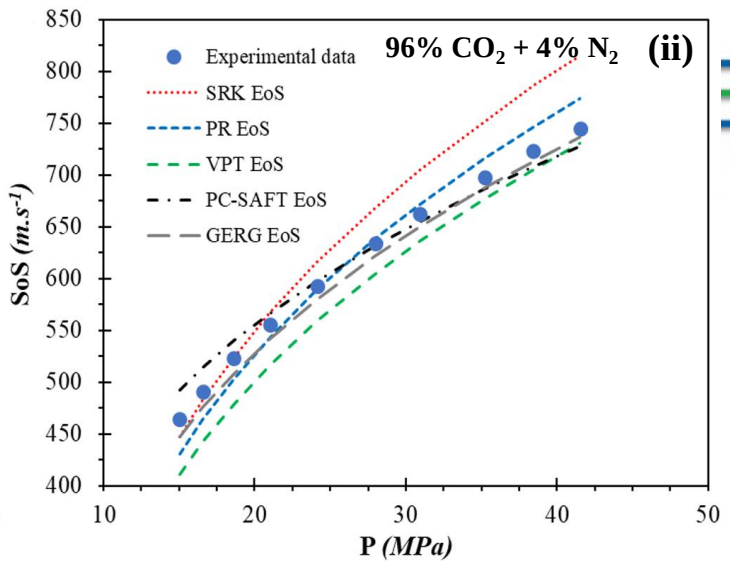


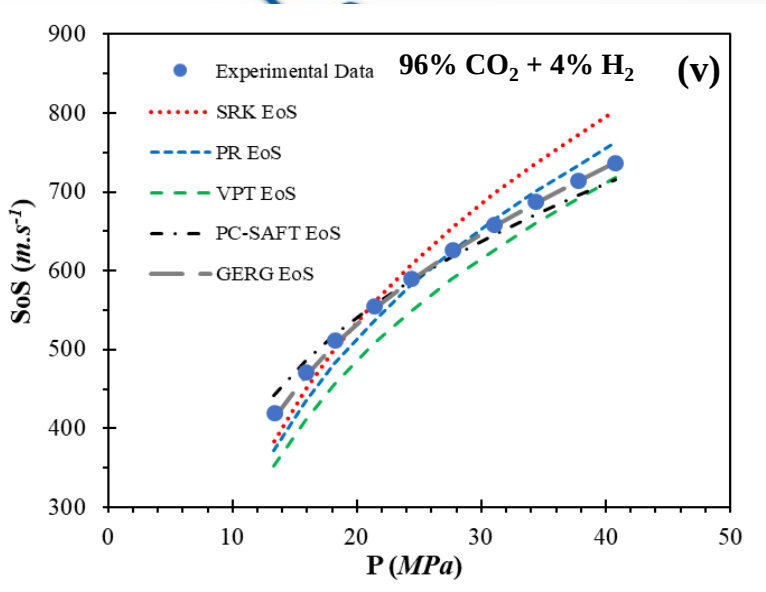


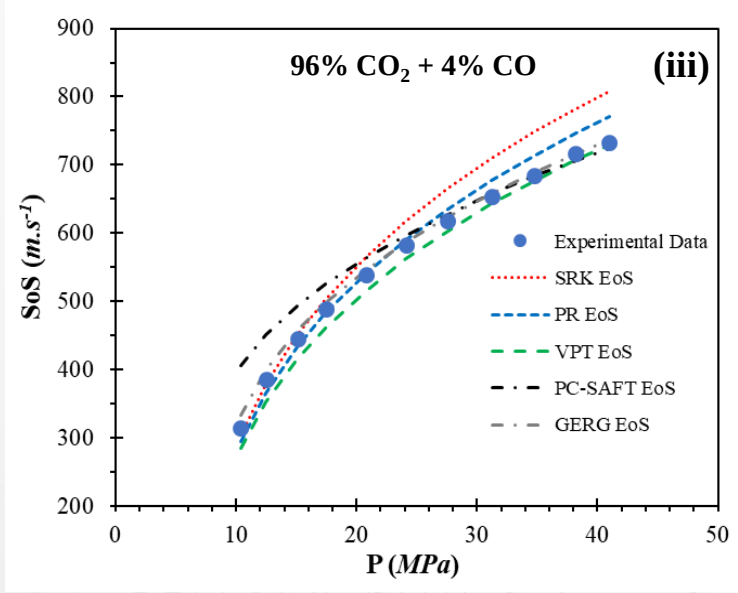
- ✓ **Order of density values:**
  (i) > (ii) > (iii) > (iv) > (v)
- ✓ **All the models could successfully predict all the trends!**

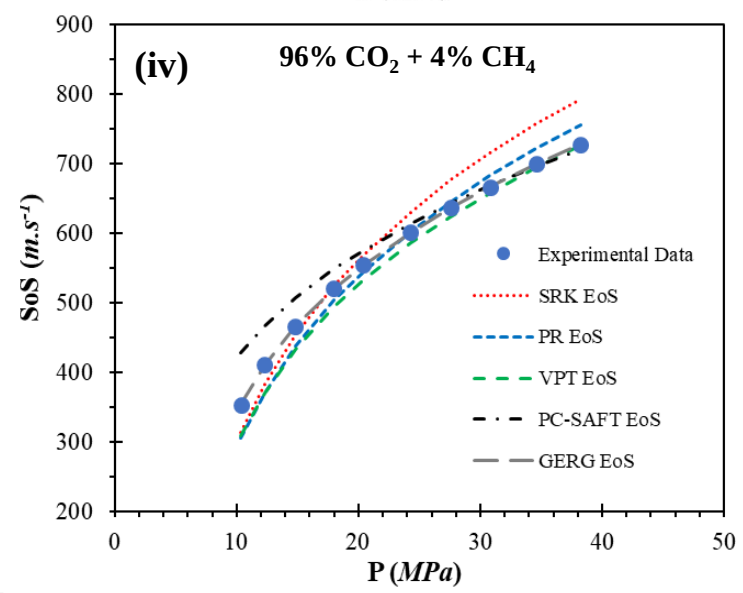
Speed of Sound (SoS) of CO_2-rich Streams (with N_2, H_2, CH_4, and CO Impurities)





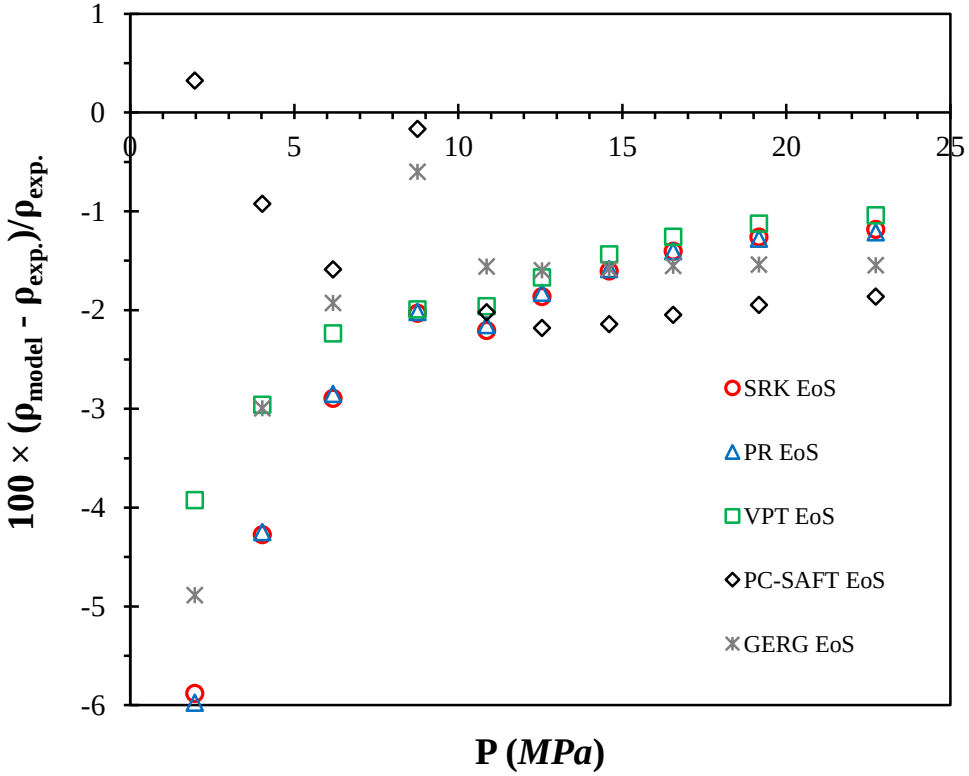


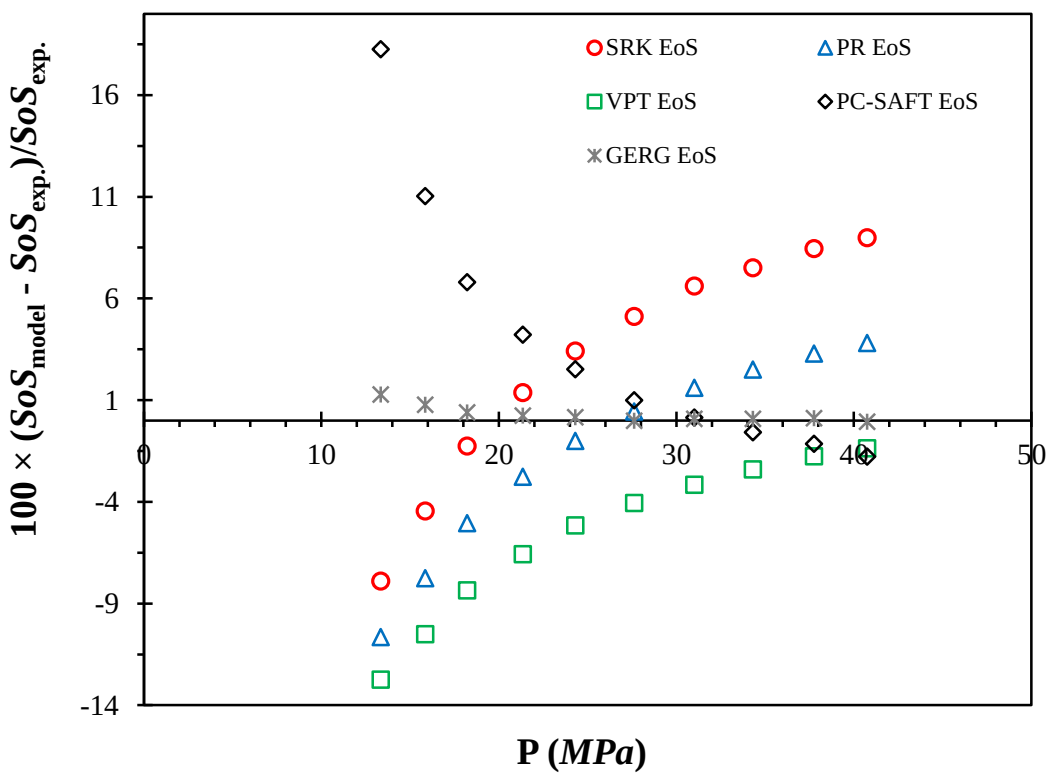




- ✓ **Order of SoS values:**
  (ii) > (v) > (i) > (iv) > (iii)
- ✓ **All the models could successfully predict all the trends!**

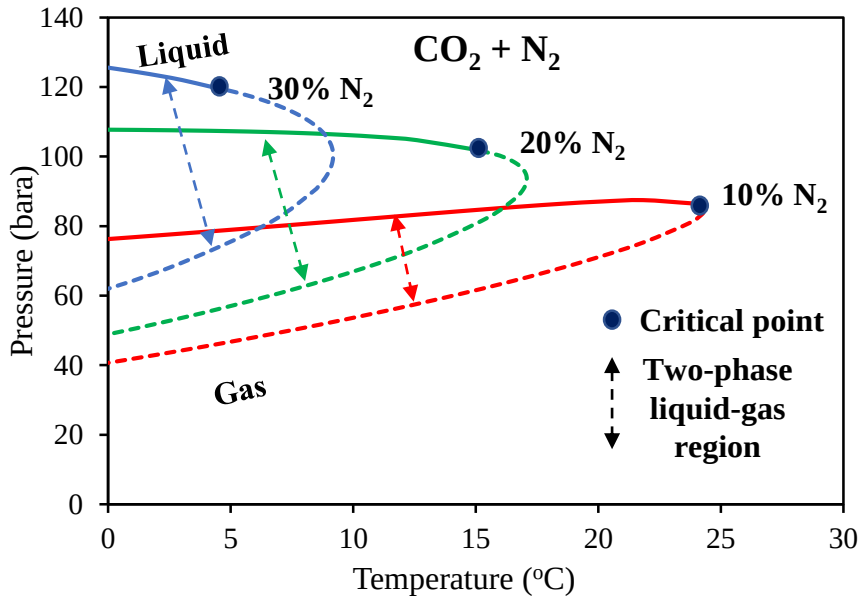
Model validation: Experimental vs Modelling data

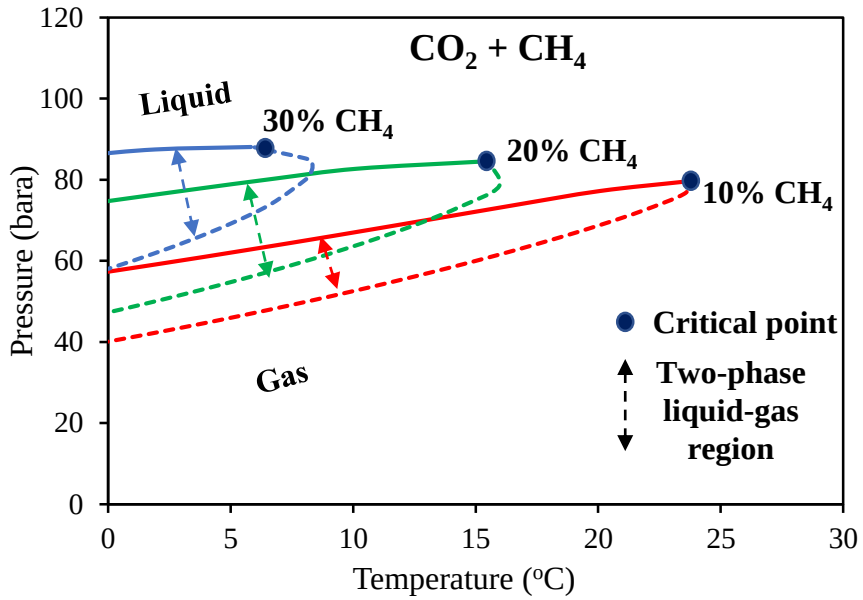


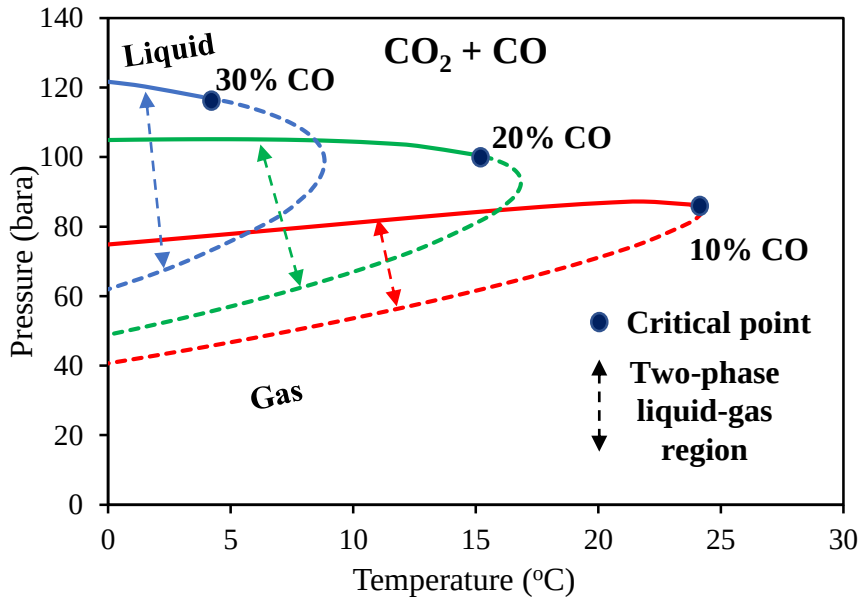


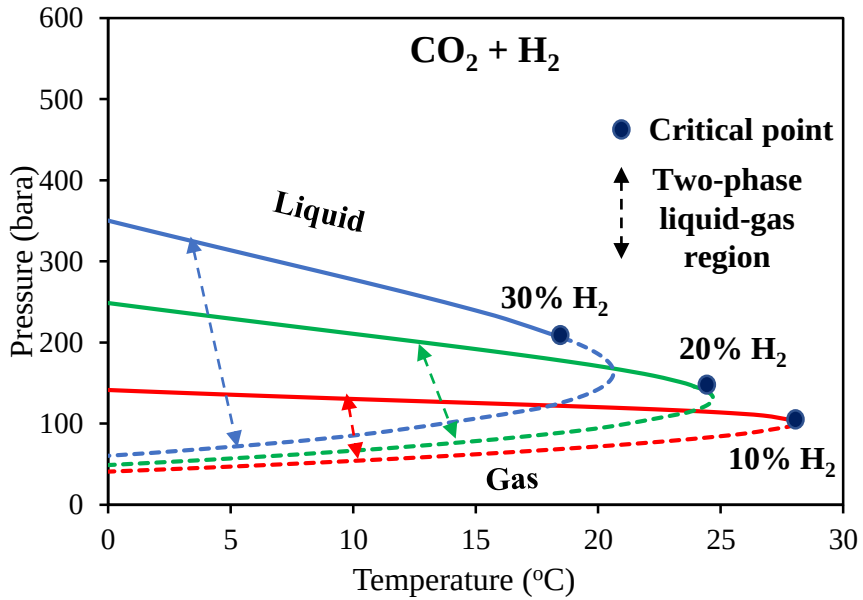
✓ **GERG EoS is the most accurate model**

The Effect of Two Phase Region on Fluid Flow Measurement



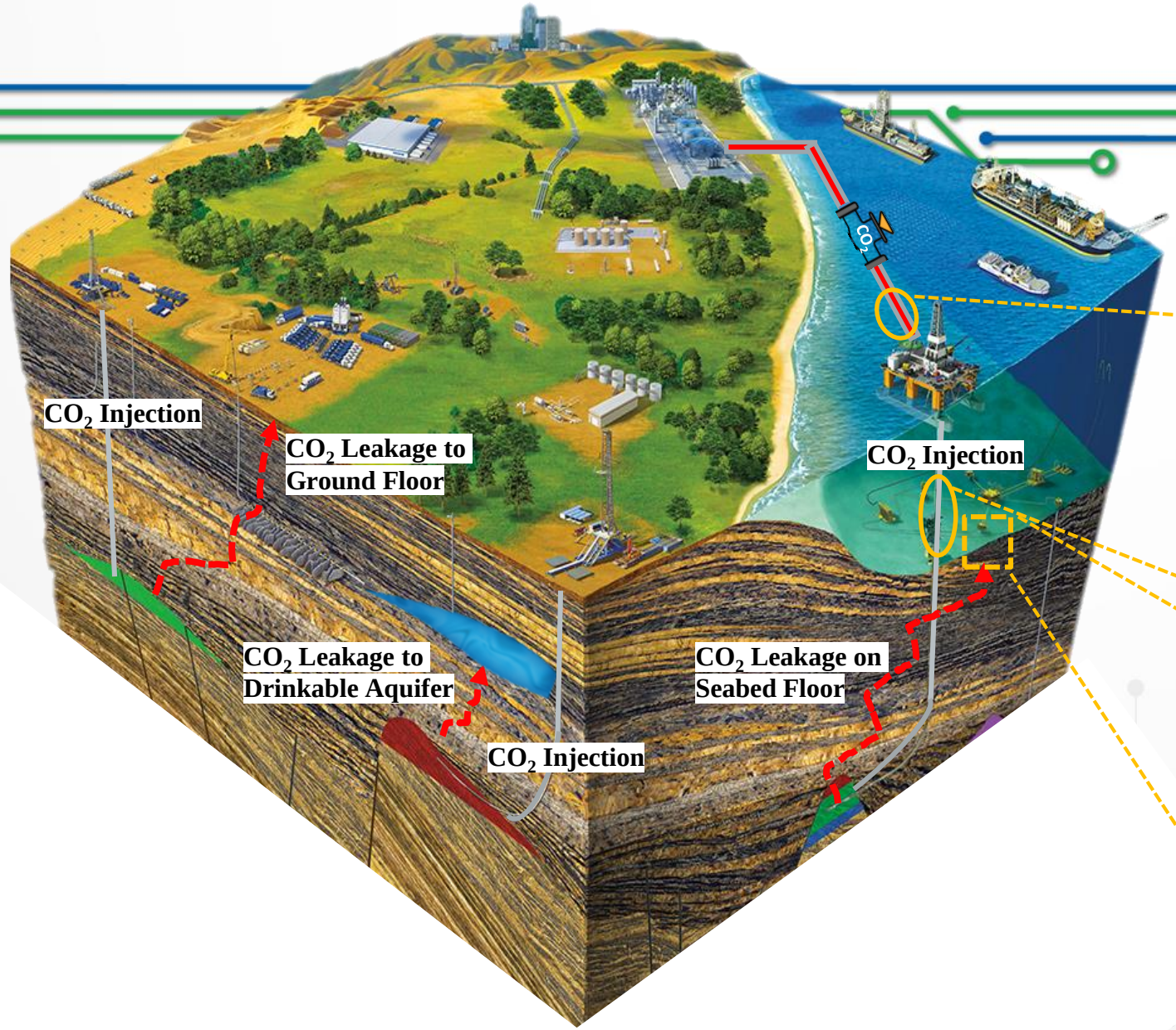




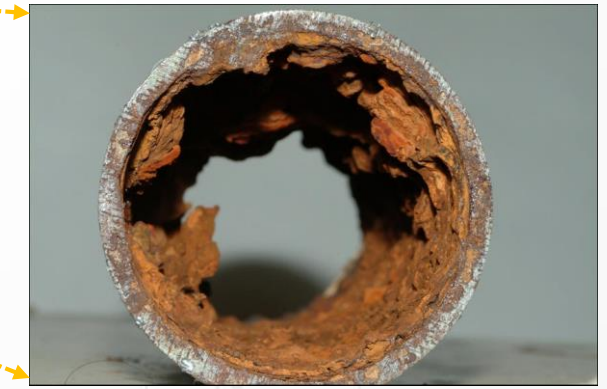


✓ Is it better to operate in the **single phase** regions?

2nd and 3rd Problems: Corrosion and Rock Dissolution Induced Leakage



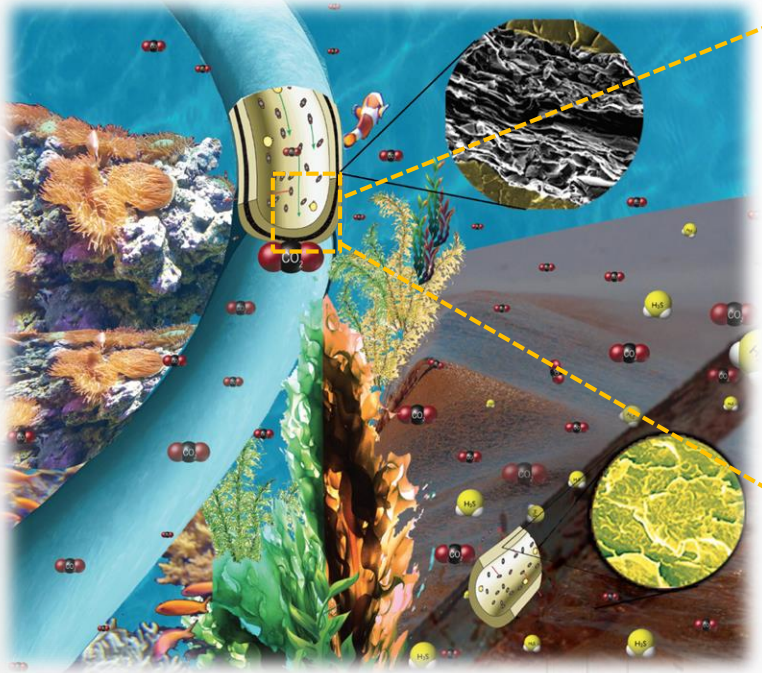
How can we avoid significant corrosion and leakage problems?

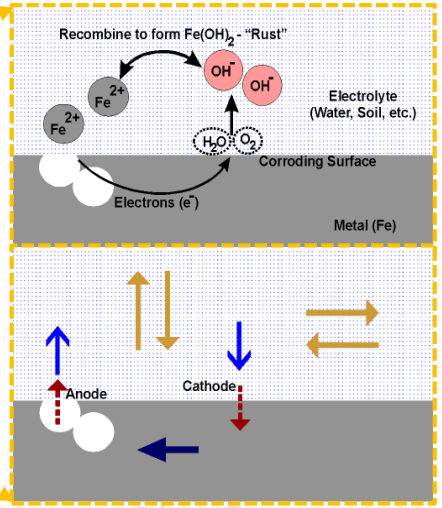


Corrosion Problem!

CO_2 rock dissolution and associated leakage challenge!

What is the main driver of corrosion and reservoir rock dissolution challenges? “pH”



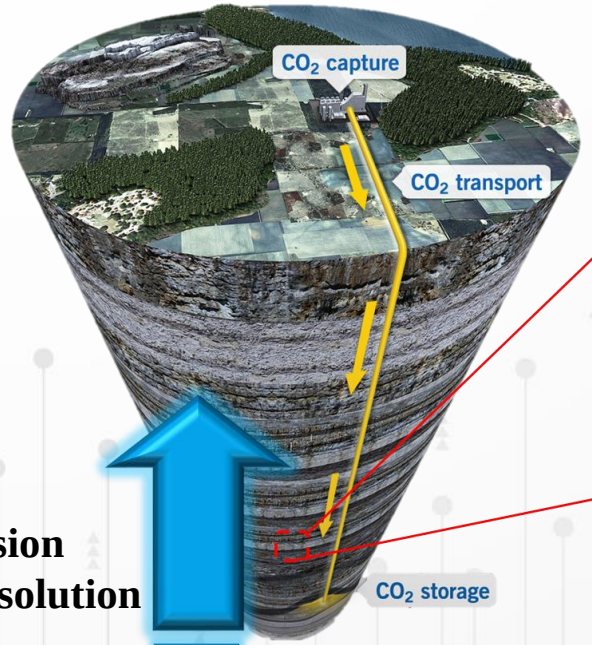


Anode reaction: $2Fe \rightarrow 2Fe^{2+} + 4e^-$

Cathode reaction: $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

Pipeline Corrosion
Reservoir Rock Dissolution

Safety and Security of CCS Processes

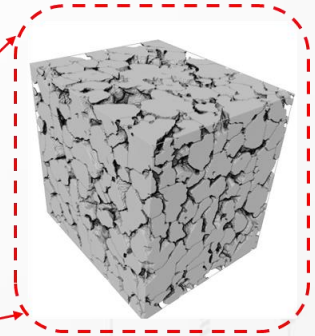


High – Pressure

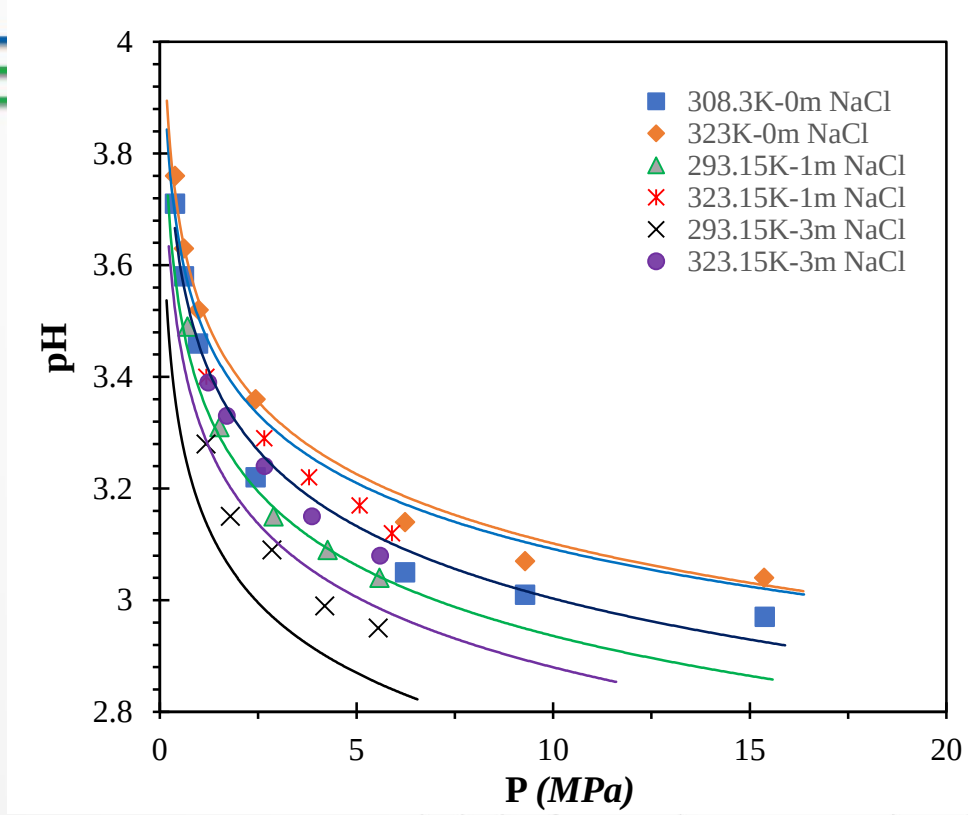
$$CO_{2(aq)} + H_2O \rightarrow H_2CO_3$$

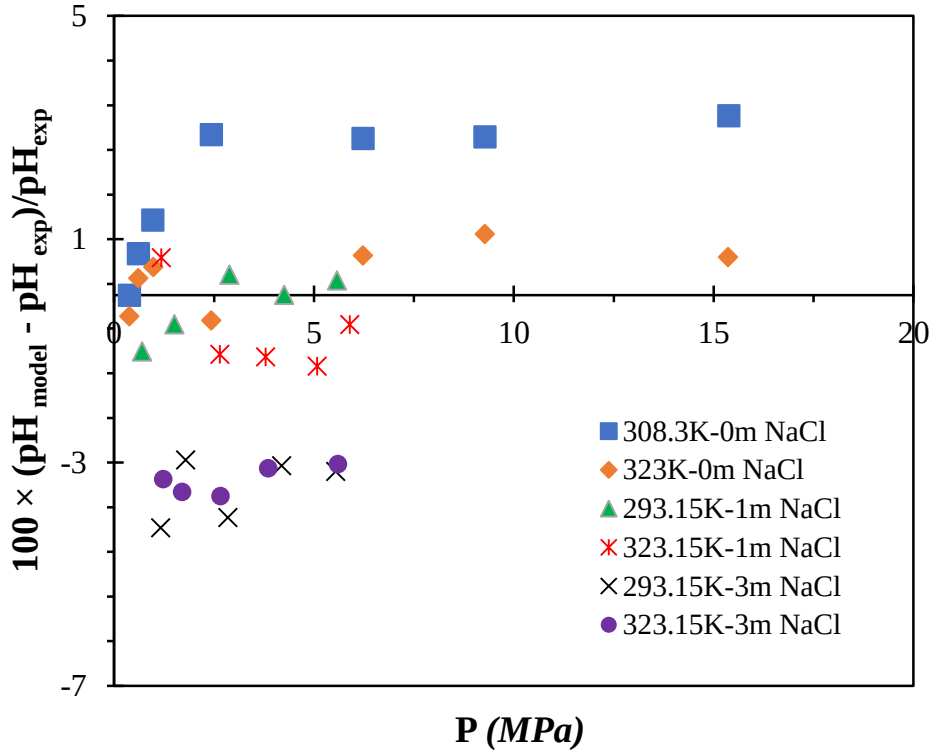
$$H_2CO_3 \rightarrow H^+ + HCO_3^-$$

Porous Media



Experimental and thermodynamic modelling data of pH variations for CO_2-Brine Systems

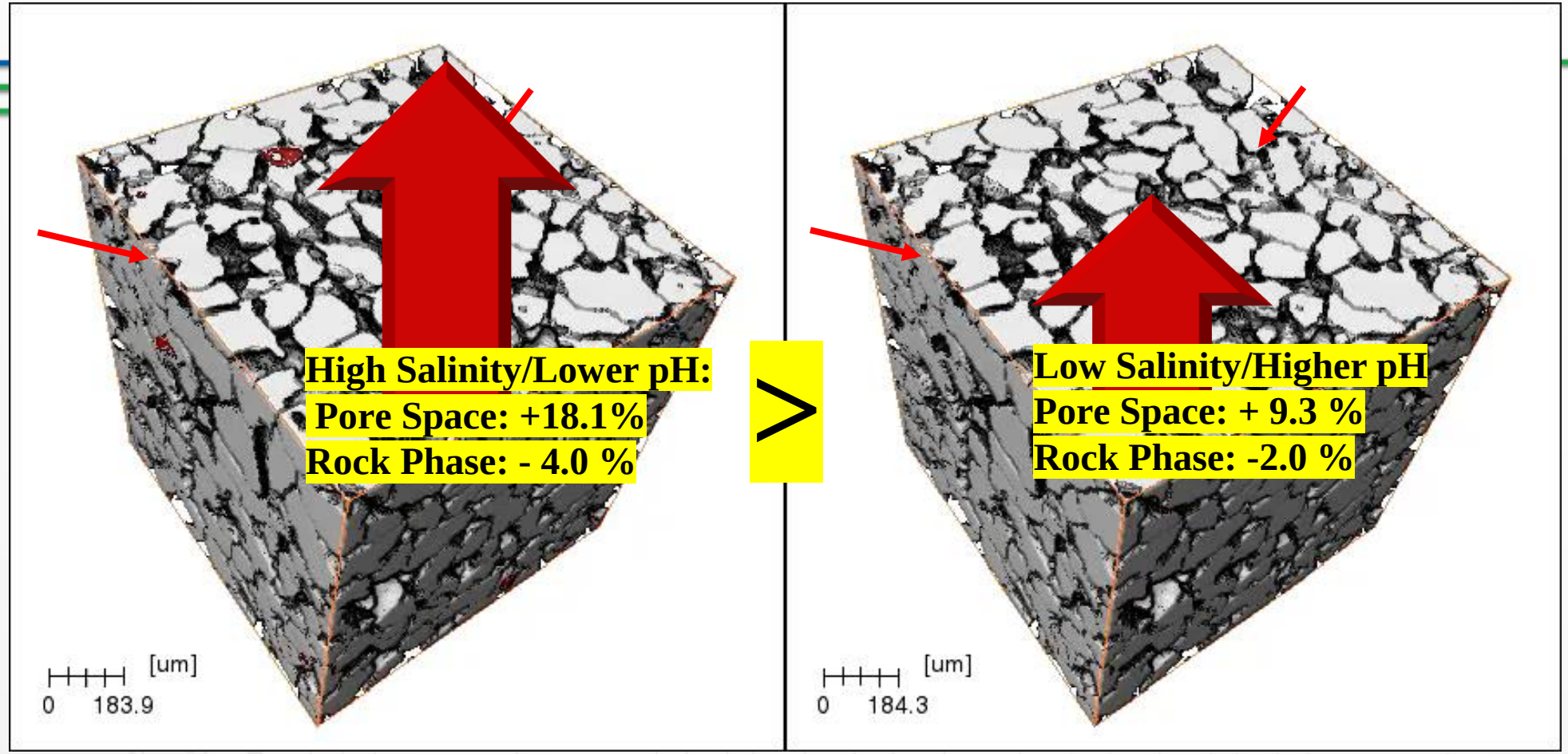




Ionic Strength/Salinity ↑ → γ_{H^+} ↑ → pH ↓ ⇒ Increase the risk of reservoir rock dissolution and corrosion problems

✓ Our model could successfully predict the trends/behaviour

Visual Observation of Rock Dissolution due to the pH Changes



Before **After**

Pore Spaces **Rock grains** **Dissolved Grains**

Wrap up

Problems

- Errors in CCS flow measurement
- Corrosion in pipelines and reservoir rock dissolution

Solutions

- Understanding of theory and thermodynamics of the whole CCS process
- Development of an adequate model for predictions of thermophysical properties of CCS streams and respective phase behaviour

Significance

- Having more accurate CCS flow metering technologies
- Avoiding the conditions which lead to pipeline corrosions and reservoir rock dissolution challenges
- Preventing CO_2 leakage from transportation pipelines and/or geological formations to the atmosphere/environment

NORTH SEA FLOW MEASUREMENT WORKSHOP

measuring for the energy transition

Thanks for your time and attention!

National Engineering Laboratory

Contact Us

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