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Monitoring Techniques/Technologies required or in use for CCUS projects

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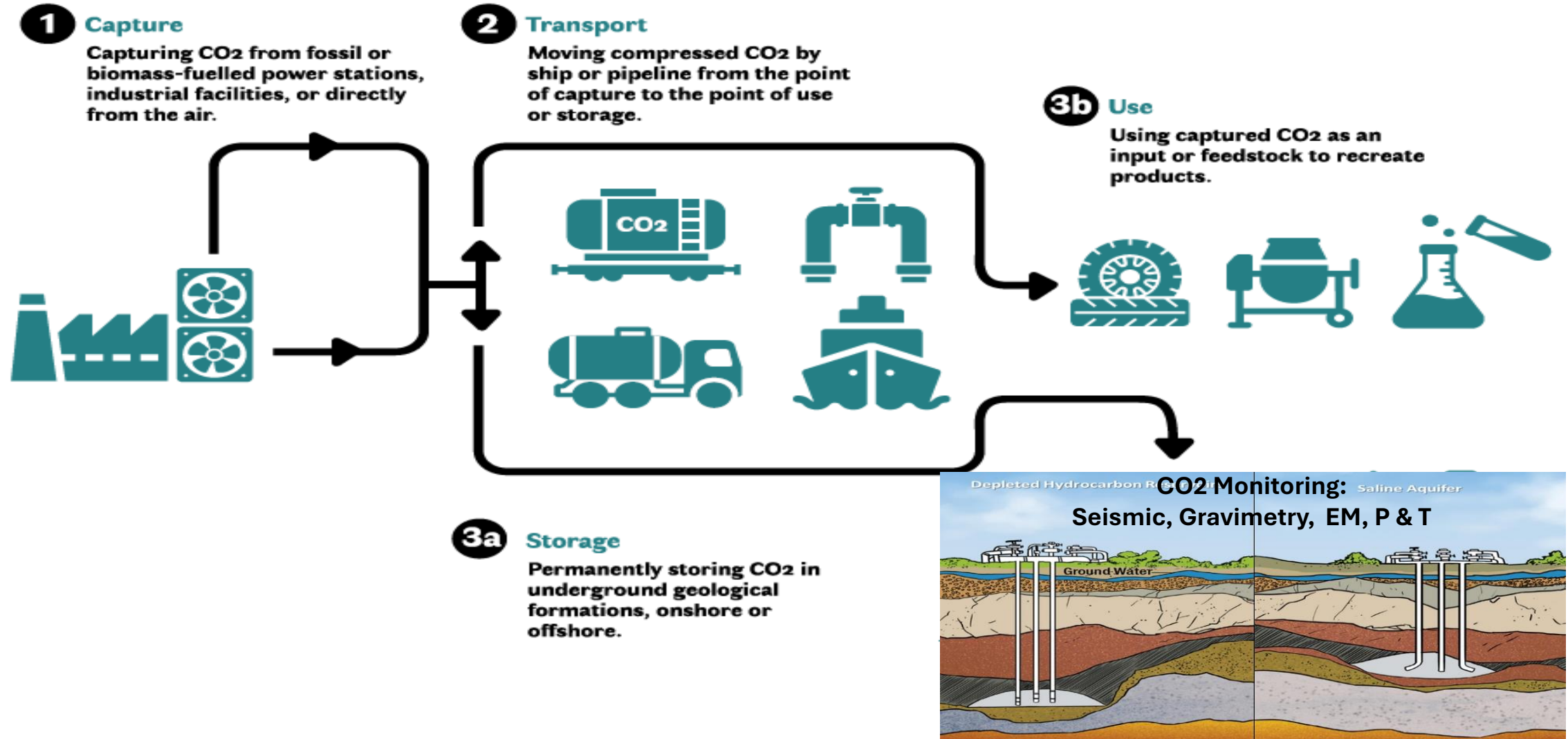
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Overview of the presentation



- **Background – CCUS and Monitoring**
- **Fundamentals of Monitoring Method**
- **Monitoring Techniques and Applications**
- **Global Outlook of CCUS Projects**
- **Next Generation Monitoring Tool for UGS**
- **CCUS for Sustainable Energy Transition**
- **Concluding Remarks**

Background - Overview of CCUS and Monitoring



Fundamentals of Monitoring – UGS



Definition:

- Underground gas storage (UGS) monitoring system identifies and verifies developing and existing issues by comparing actual and expected storage parameters using analytics and then reports the health condition of the reservoir.
- The required data for an issue are derived from the pressure and temperature monitored by the sensor.
- The system classifies issues into two major groups: known and unknown. Known issues then fall into other subgroups. Unknown issues are investigated in detail.

Basics of Monitoring – UGS

Objectives:

The main goals of the UGS monitoring system are to monitor (1) health, safety, and environment (HSE), (2) emission trading system (ETS), operational and informational.

Classification of Monitoring

Based on application, function, and stage of development, the CO₂ Monitoring techniques can be categorized into three. There are primary, secondary and additional.



Global CCUS Operational Projects



Continent	Country	Total No of CCS Project (EOR 68%, Saline Aquifer 24%, Other 8%)	Total (50)
Africa (Middle East)	Saudi Arab	1 (EOR)	3
	Qatar	1 (Saline Aquifer)	
	UAE	1 (EOR)	
Asia	China	14 (EOR 12, Saline Aquifer 1, Not mentioned 1)	14
Europe	Hungary	1(EOR)	5
	Iceland	2 (EOR 1, Mineral Carbonation 1)	
	Norway	2 (Saline Aquifer 2)	
North America	Canada	7 (EOR 5, Saline Aquifer 2)	27
	USA	19 (EOR 12, Saline Aquifer 5, Mineral Carbonation 1, Not mentioned 1)	
South America	Brazil	1 (EOR)	
Oceania	Australia	1 (Saline Aquifer)	1

Common CO2 Monitoring Techniques and Applications



Monitoring Methods	CO2 Migration (Issue)	Fine-scale process	Leakage (Issue)	Quantification
Seismic	Primary	Primary	Primary	Primary
Gravimetry	Secondary	Secondary		
Electromagnetic (EM) / Electric	Primary & Secondary	Secondary	Secondary	
Sonar Bathymetry		Primary		
Geochemical		Secondary	Primary	Secondary
Remote sensing	Primary		Primary	Secondary
Geophysical		Primary		Secondary
Pressure / Temperature			Primary	Secondary
Tiltmeters	Secondary	Secondary		

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Monitoring Techniques in Use for CCUS Projects



Project	Monitoring Techniques	Ref.
CO₂CRC Otway Project, Victoria, Australia, 2004	➤ Seismic monitoring, ➤ Soil gas sampling, ➤ Atmospheric measurements	(Urosevic, M. et al. 2011)
Gorgon CO₂ Injection Project, Western Australia	➤ Pressure and Temperature Monitoring, ➤ Groundwater Monitoring ➤ Microseismic Monitoring	(Trupp, M. et al. 2013)
Tomakomai CCS Demonstration Project, Tomakomai City, Hokkaido, Japan	➤ 3D Seismic Surveys ➤ Pressure and Temperature Monitoring ➤ Microseismic Monitoring ➤ Seafloor Monitoring ➤ Environmental Baseline Monitoring	(Tanaka et. Al, 2017; Ltd. Japan CCS Co., 2018; Meckel et. al, 2019)

Monitoring Techniques in Use for CCUS Projects



Project	Monitoring Techniques	Ref.
Tundra Carbon Capture Project, Richardton, North Dakota, USA	➤ Seismic Imaging ➤ Pressure and Temperature Monitoring ➤ Groundwater Sampling ➤ Well Integrity Monitoring	(Arctic Contaminants Action Program, 2019; U. Environmental Protection Agency, 2022)
Weyburn-Midale Canada	Geophysical ➤ Time-lapse 3D seismic ➤ Microseismic ➤ Electrical resistivity imaging <u>Geochemical</u> ➤ Groundwater sampling ➤ Soil gas surveys	(Rostron and Whittaker, 2011)

Monitoring Techniques in Use for CCUS Projects



Project	Monitoring Techniques	Ref.
Sleipner CCS, Norway	➤ 4D (time-lapse) seismic, high-resolution 2D seismic ➤ Seabed gravity, seabed-controlled source electromagnetic (CSEM) ➤ Seabed imaging and bathymetry ➤ Continuous monitoring - Wellhead pressure and flow rate.	(Alnes et al., 2011).
In Salah, Algeria	➤ Time-lapse 3D seismic, microseismics, InSAR measurements, ➤ Tiltmeter data, groundwater sampling , surface flux/soil gas measurements, microbiology surveys, ➤ Wireline logging and sampling, Wellhead/annulus sampling and tracer injection	(Mathieson et al., 2011).



UGS Meta Monitoring - Potential Leakage Pathways



Caprocks (a):

- Caprock integrity is the strategic point for CO₂ monitoring. Proper characterization of caprock (thickness, strength, lateral distribution and sealing properties) facilitates safe and efficient storage of CO₂.
- Potentially weak spots of caprocks could provide leakage pathways. Selecting suitable sites and parameters is critical for the early detection of such potentially diffuse leakage.

Faults (b):

- Permeable faults in caprocks may provide pathways to migrate CO₂ to the surface.
- Some faults act as barriers and reduce storage capacity. So, faults are crucial points for monitoring.

UGS Meta Monitoring - Potential Leakage Pathways



Boreholes (c):

- Boreholes, especially from improperly installed and/or abandoned wells, may provide direct leakage pathways between reservoirs, groundwater, and the surface.
- Older boreholes are more problematic due to less information on well cementing and logging. Thus, monitoring of older, plugged wells has to be considered first in monitoring plans.

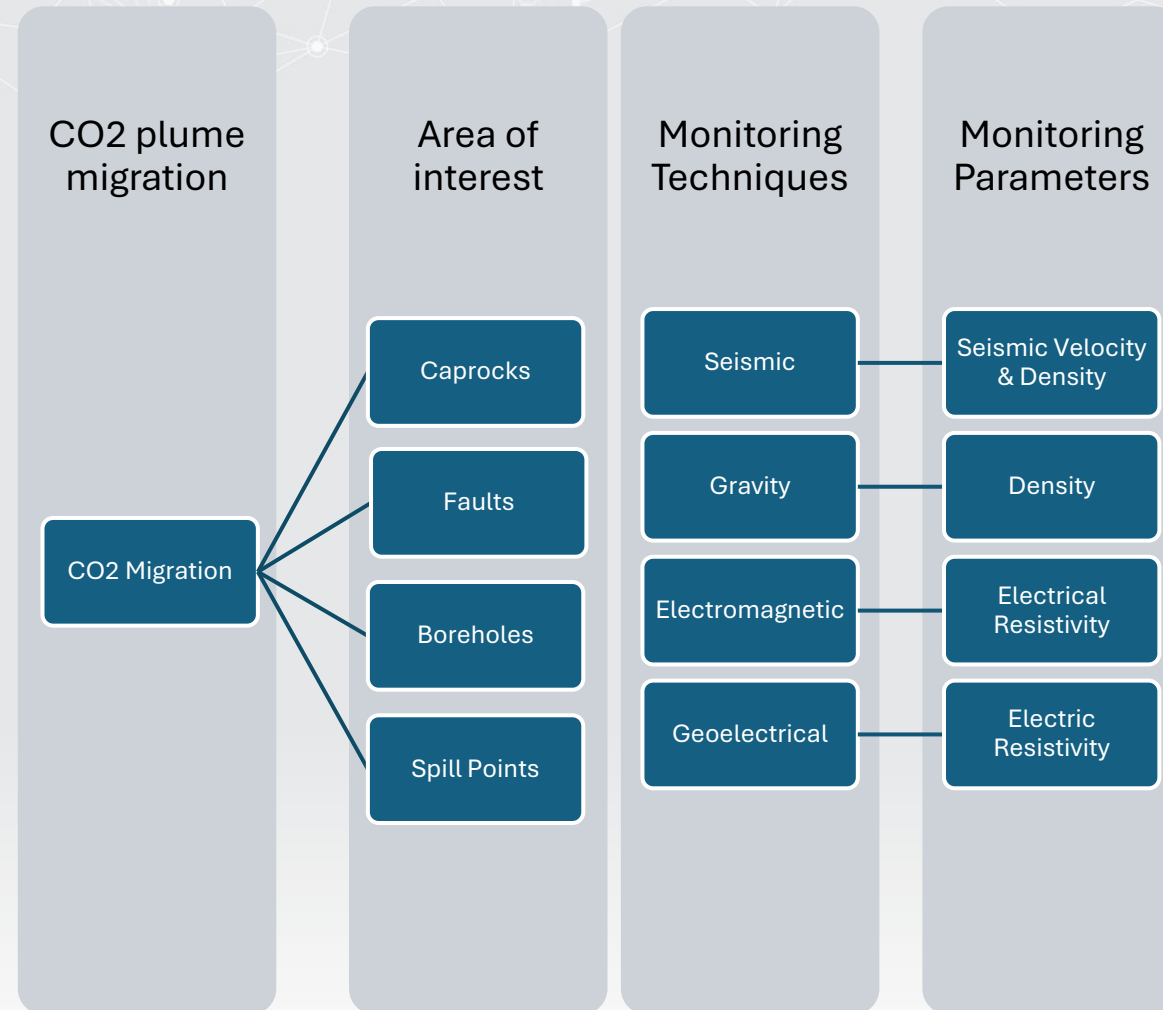
Spill Points (d):

- Spill points of structural traps are crucial areas for monitoring the movement of CO₂ plumes in saline aquifers. It may be difficult to map in gently inclined structures.
- Spill points may be the starting points of leakage pathways. If a CO₂ plume expands beyond spill points, it has to be carefully monitored.

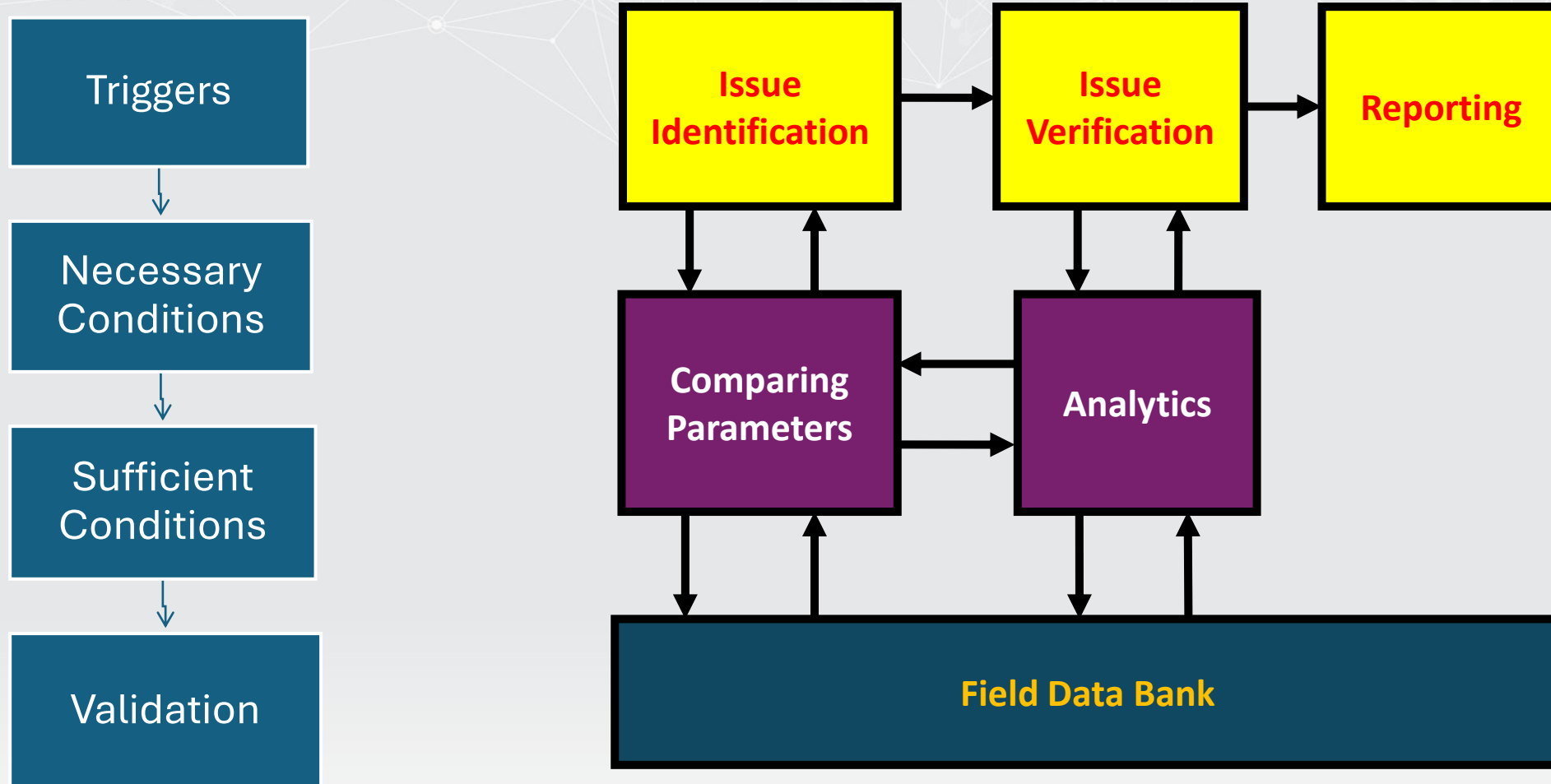
CO2 Monitoring Techniques



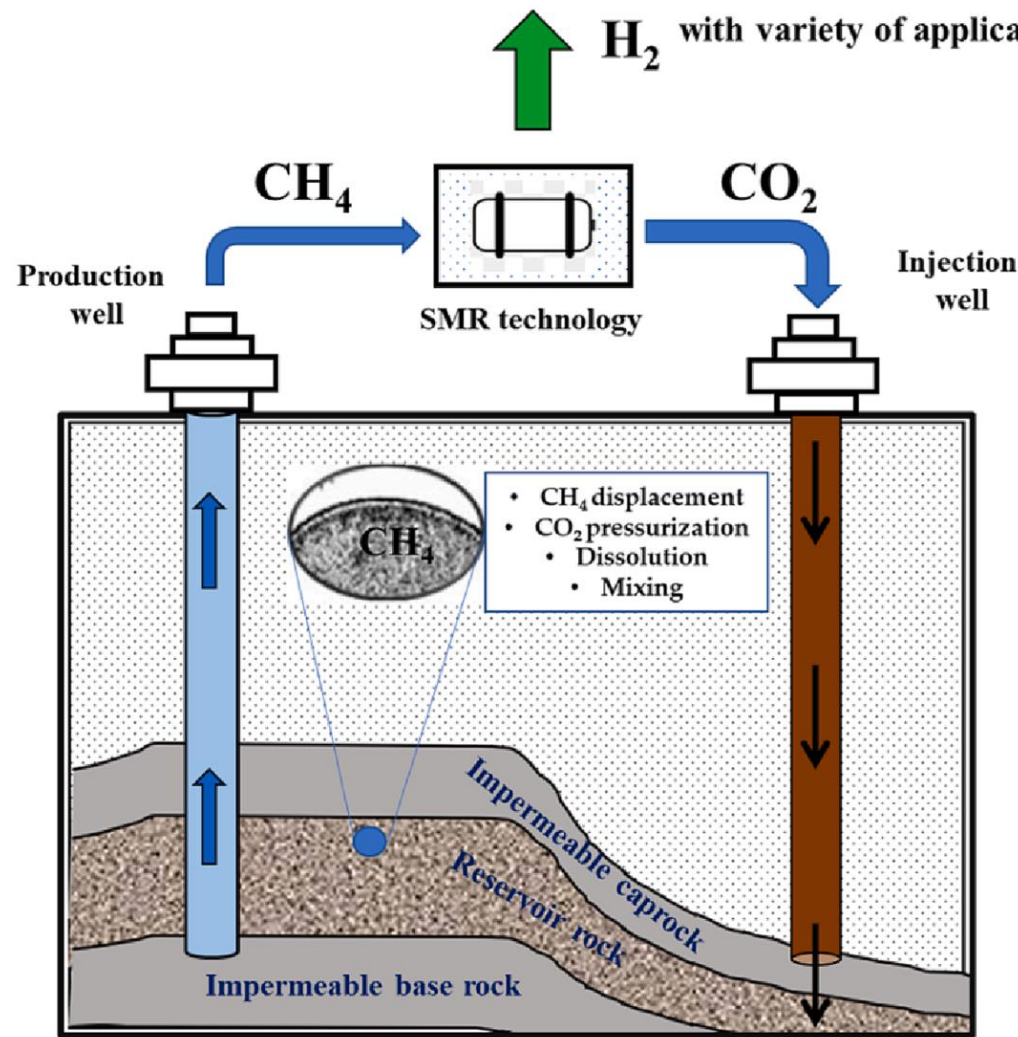
The common monitoring techniques are to monitor CO2 injection and follow the migration of the H2 plume.



Next Generation UGS Meta Monitoring Tool



CCUS for Sustainable Energy Transition



In building for heating and cooling

In Industries for refining and steel production

In transportation for cars, tracks and buses

For fuel synthesis e.g., methane and ammonia

For gas grids direct methanation

Substitute fuel in aviation and maritime industries

Concluding Remarks and Recommendations



- Gas reservoirs might be viable options for CO₂ storage.
- Meta-monitoring tool could be a good choice for healthy storage.

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