The Transportation and Geological Storage of Hydrogen (G576)

Tutor(s)

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Overview

The course will focus on the need for geological storage of hydrogen, introducing the geological storage options available for the secure storage and withdrawal of hydrogen from these different geological stores. The main body of the course will explore the key considerations involved in geological hydrogen storage, including hydrogen flow processes and thermodynamics; geomechanical responses to rapid injection and withdrawal cycles; geochemical and microbial interactions during storage; and the operational considerations and monitoring of hydrogen storage sites that may impact storage integrity, withdrawal rates and hydrogen purity.

Duration and Logistics

Classroom version: A 1.5-day course comprising a mix of lectures, case studies and exercises. The manual will be provided in digital format and participants will be required to bring a laptop or tablet computer to follow the lectures and exercises.

Virtual version: Three 4-hour interactive online sessions presented over three days. Digital course notes and exercise materials will be distributed to participants before the course. Some exercises may be completed by participants off-line.

Level and Audience

Advanced. The course is largely aimed at geoscientists, but engineers will also find the course instructive. Intended for sub-surface scientists, with an emphasis on geoscience topics. Participants will probably have a working knowledge of petroleum geoscience.

Objectives

You will learn to:

1. Describe the different geological storage options available and their capacity and spatial constraints.
2. Understand hydrogen as a fluid in the subsurface, including its thermodynamic and transport properties.
3. Characterize the geomechanical considerations for storage integrity and associated risks, including caprock sealing considerations.
4. Appreciate the impact of geochemical and microbial interactions in subsurface hydrogen stores and the relevant monitoring and management tools.
5. Describe the operational engineering considerations and monitoring of hydrogen storage sites.

Course Content

Part 1: Options for the geological storage of hydrogen

Lectures

- Existing experience in underground gas storage operations
    - natural gas
    - hydrogen
- Subsurface silos
    - technology description
    - design requirements (including geological requirements)
    - sealing / subsurface silos and groundwater control
    - hydrogen injection and withdrawal operational procedures / considerations
    - costs and safety considerations
- Engineered rock caverns
    - technology description
    - design requirements (including geological requirements)
    - hydrodynamic sealing design principles
    - cavern construction and groundwater control
    - hydrogen injection and withdrawal operational procedures / considerations
    - hard rock cavern rock types / distribution / inventory
    - costs and safety considerations
- Salt caverns
    - technology description
    - design requirements (including geological requirements)
    - cavern construction
    - hydrogen injection and withdrawal operational procedures / considerations
    - salt cavern rock types / distribution / inventory
    - costs and safety considerations
- Porous rock storage – aquifers
    - technology description
    - design requirements (including geological requirements)
    - hydrogen injection and withdrawal operational procedures / considerations
    - aquifer storage distribution / inventory
    - costs and safety considerations
- Porous rock storage – depleted gas fields
    - technology description
    - design requirements (including geological requirements)
    - hydrogen injection and withdrawal operational procedures / considerations
    - aquifer storage distribution / inventory
    - costs and safety considerations
- Global UHS projects and their integration with existing and future energy systems
    - global UHS pilot projects in the pipeline
    - integration with energy system (renewable / curtailed wind / electricity / gas)

Activities

- Calculating volumetric capacities/energy densities of hydrogen under the different storage options
- Using EU and global geological map viewers, geographical locations for the various hydrogen storage opportunities will be explored and evaluated within the context of existing energy infrastructures, renewable energy and industrial centres.

Part 2: Hydrogen flow and geomechanics

Lectures

- Thermodynamic and transport properties of hydrogen / Hydrogen P-T phase diagram
- Thermodynamic and transport properties of hydrogen mixtures (water, CO2, N2, CH4 and natural gas)
- Hydrogen transport properties (all storage types)
    - porosity (primary / secondary)
    - permeability and its influence on hydrogen injection and flow
        - absolute and effective permeability
        - permeability isotropy and anisotropy
        - homogeneity and heterogeneity
    - relative permeability
    - capillary entry pressure
        - pore size
        - interfacial tension
        - contact angle
        - wettability
    - advection
    - molecular diffusion
    - dispersion
    - diffusion
    - viscous fingering
- Geomechanical considerations for storage integrity during cyclic injection
    - temperature changes during injection / withdrawal
    - pressure changes during injection / withdrawal
    - reservoir deformation
- Caprock sealing potential
    - capillary pressure column height conversion
    - diffusive losses
    - stress / strain and hysteresis
        - injection / withdrawal pressures
        - stress state in the subsurface
        - failure mechanics
        - formation damage
        - faults and leakage risk
        - fractures and microfractures

    - drainage / imbibition
        - residual trapping

Activities

- Hydrogen column height calculations
- Hydrogen caprock diffusion calculations; Injection rate calculations for varying permeability.

Part 3: Impact of geochemical and microbial interactions

Lectures

- Hydrogen solubility and impact of pressure, temp, Ph and salinity
- Geochemistry
    - range of minerals that may react with hydrogen and their associated lithology, e.g. pyrite / pyrrhotite, anhydrite, hematite, clays, calcite etc.
    - mechanisms and kinetics of redox reactions
    - kinetics of precipitation and dissolution
    - mineral reaction rates
    - reactions with well cements and casing
    - impact of geochemical activities
        - gas composition changes
        - dissolution of minerals and change in reservoir properties
        - souring and H2S
        - steel corrosion
    - geochemical impacts from experiences of hydrogen underground storage
- Risks associated with microbial activities
    - microbes in the subsurface (what and where)
    - environmental parameters for microbial life
    - microbial hydrogen consumption processes
    - impact of microbial activities
        - gas composition changes
        - souring and H2S
        - microbial induced plugging or clogging
        - steel corrosion
        - dissolution of minerals and change in reservoir properties
        - impact of H leakage on soil and groundwater microbial communities
    - microbial activity impacts from experiences of hydrogen underground storage sites
    - microbial effects in salt caverns
    - recommendations on design, monitoring and management tools to manage microbial risks

Activities

- Classification of storage sites in terms of risks of mineral dissolution
- Classification of storage sites in terms of risks of microbial consumption of hydrogen.

Part 4: Operational considerations and monitoring of hydrogen storage sites

Lectures

- Optimization of injection-withdrawal strategies
- Cushion gas
    - role of cushion gas
    - implications of using different types of cushion gas on the effectiveness of storage operations
- Analyses and assessments of potential interactions with existing (sub)surface usage and
- resources
- Integrity of surface facilities and wells
    - evaluation of storage facility lifecycle
    - well cement integrity
    - suitability of materials for wells and surface facilities
    - storage facility operational parameters
    - safety and monitoring concepts
- Risk of leakage through abandoned wells
    - abandonment completion assessments
    - leakage assessment
- Risk of micro seismicity during cyclic injection and production operations
- Monitoring strategies
    - geophysics: seismic / microseismic, electrical resistivity etc.
    - monitoring wells
    - conventional monitoring: annulus pressure, radioactive tracer survey, casing inspection log, pressure test on the casing, neutron log, sonic detection, cement bond log, temperature log, spinner survey, pump and plug test, and camera inspection, etc.
- Public perception

Activities

- Risk assessment of hydrogen leakage; Assessment of re-purposing depleted gas field for hydrogen storage.