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Developing Risk-Based Assurance Monitoring Strategies for Underground Hydrogen Storage

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Summary

To achieve a Net-Zero economy in Canada by 2050, and to transition to cleaner energy production, multiple transformative energy technologies will be required. Hydrogen is an energy carrier with unique properties to be used as an ingredient in alternative fuels for transportation sector, as feedstock for chemicals, and as a storage medium for energy sector. Hydrogen hence requires infrastructure, similar to natural gas, in connecting production facilities with various end-use applications. The infrastructure includes pipeline for distribution and underground hydrogen storage (UHS) for managing supply and demand. Similar to natural gas and hydrocarbon liquid storage, UHS targets include salt caverns and/or porous media such as geological formations and depleted oil and gas reservoirs (Figure 1).

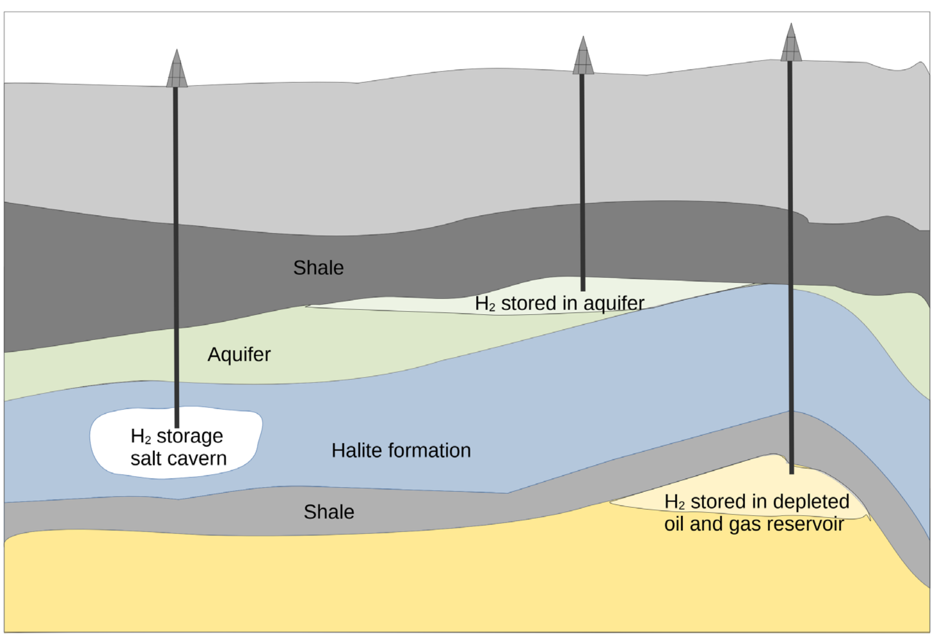

Figure 1: Schematic cross diagram of hydrogen storage in salt caverns, hydrogen stored in aquifers and hydrogen stored in depleted oil and gas reservoirs.

Historically, hydrogen storage projects have existed in Europe, Scandinavia and the U.S. since the 1960s (Miocic et al., 2023). Currently there are some large operational hydrogen storage facilities in the United States (US) and the United Kingdom, where hydrogen is stored in salt caverns (Sambo *et al.*, 2022). These facilities are supply hydrogen to petroleum refineries and chemical plants, respectively. In the Canadian and US context, displacing 1 to 30% of natural gas with hydrogen in existing pipelines is the focus for the gas distribution industry (Duetsch et al., 2022). These pipelines use more than 200 natural gas underground storage facilities in Canada alone (the Dawn Hub). Hence, the immediate need is to assess suitability of underground hydrocarbon storage facilities to take higher concentrations of hydrogen. The long-term need is the ability to store higher concentration or pure hydrogen underground to provide storage capacity for excess/surplus electricity from a provincial grid.

However, the challenges associated with the storage of hydrogen are quite different due to the physical and chemical properties of the gas and interactions with minerals, fluids and microbial activity (Muhammed *et al.*, 2022; Minougou *et al.,* 2023). In order to effectively operate and monitor hydrogen storage at any particular site, hydrogen behavior during storage and potential leakage pathways must be identified, prioritized and an appropriate risk-based monitoring system established.

Our research program focusses on salt cavern and reservoir storage in two field areas across Canada including Alberta and Ontario. We are developing conceptual models of each study area (*e.g.* geography, geology, hydrology, geological structure, well penetrations, surface and subsurface infrastructure among other features) to enable the identification of potential leakage pathways from an underground hydrogen storage facility. Core samples (salt horizons, overlying and underlying formations, non-salt interbeds), aquifer and soil samples from these sites are being characterized to study hydrogen-rock interactions, microbiology, lithogeochemistry of rock matrix, geomechanical integrity of salts and other factors relevant to H_2 leakage and migration. Hydrogen leakage and transport through aquifers, groundwater and soils is being simulated at bench- and pilot scale to improve our understanding of leakage behaviour and to develop risk-based monitoring strategies for such facilities.

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