Scientists use machine learning to explore effects of cushion gases on underground hydrogen storage

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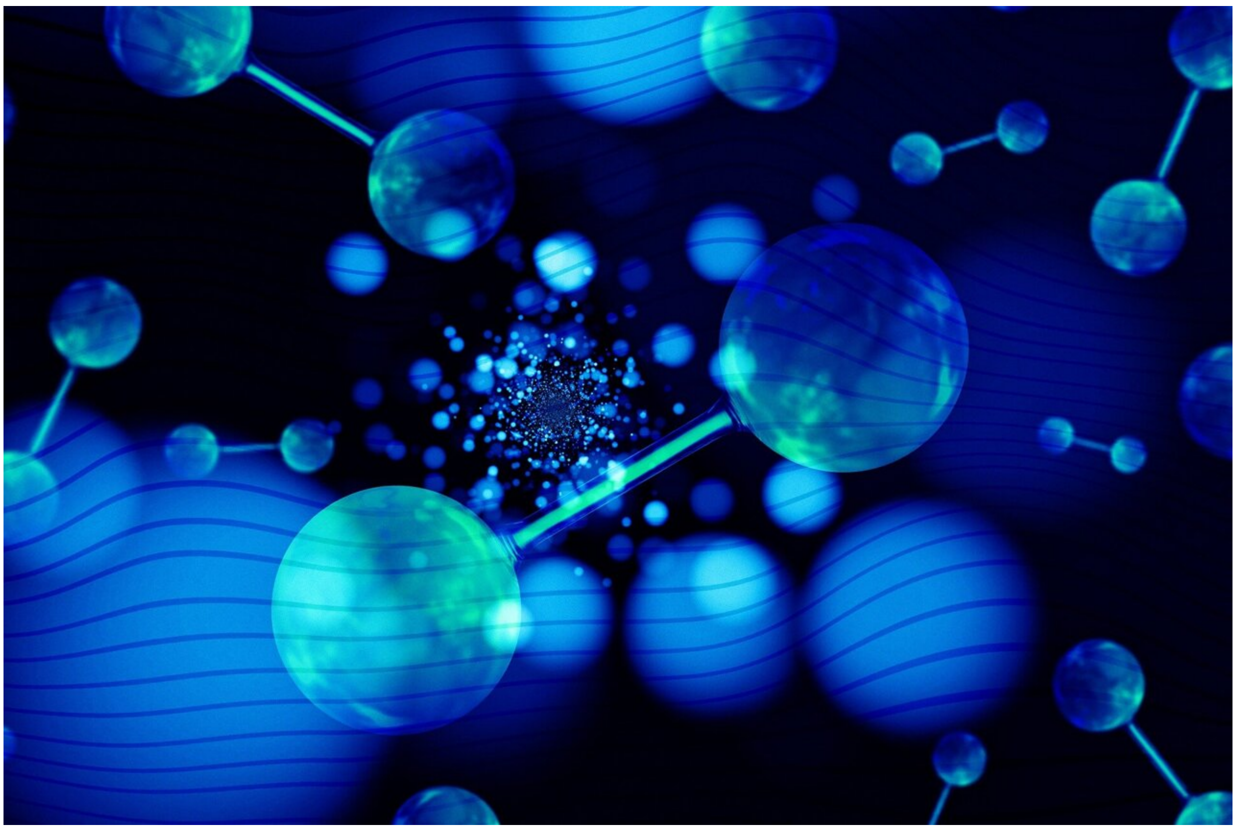

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Los Alamos National Laboratory scientists are developing powerful machine learning models—an application of artificial intelligence—to simulate underground hydrogen storage operations under various cushion gas scenarios. This will play a vital role in the low-carbon economy of the future.

"One of the most practical methods for storing hydrogen is deep saline aquifers, or depleted hydrocarbon reservoirs," said Mohamed Mehana, the team's lead scientist. "But to do this, we first need to inject cushion gases into the reservoir, which displaces existing fluids and provides the pressure support for hydrogen recovery."

Scientists have studied the effects of cushion gases, which are most often methane, carbon dioxide, or nitrogen, on such underground hydrogen storage systems. However, it has never been fully understood how cushion gases would affect the performance of underground hydrogen storage operations.

In a recent paper, published in the *International Journal of Hydrogen Energy*, the Los Alamos team successfully investigated comprehensive cushion gas scenarios, providing key insights into the effects of various cushion gases on underground hydrogen storage performance.

A complicated solution

Scaling the hydrogen economy is an important leg of the nation's effort to decarbonize. And like gasoline, hydrogen gas will need to be produced and stored regionally to power clean-energy semi-trucks, generate electricity directly, and provide resilience for solar power plants during the winter months.

The nation will need to exploit a wide range of underground reservoirs to reach this scale. Previous studies had focused on a single set of geological and operational conditions. But in order to mimic real-world scenarios, the Los Alamos team's model accounted for multiple geological conditions, the presence of water, and the operational impact of several cushion gases.

"Underground hydrogen storage is complex due to hydrogen's unique properties and complicated operational conditions," said Shaowen Mao, a postdoctoral research associate on the Los Alamos team. "We need to maximize hydrogen recoverability and purity during withdrawal stages while mitigating water production risks. Understanding these and other factors is essential to make underground hydrogen storage economically viable."

To accomplish this, the Los Alamos team used a deep neural network machine learning model, which analyzed combinations of geological and operational parameters to mimic the variability of real-world scenarios. In the paper, the team noted key findings, some of which included:

- the technical promise of underground hydrogen storage in porous rocks due to improved storage performance over cycles,
- the advantages and disadvantages of underground hydrogen storage in saline aquifers and depleted hydrocarbon reservoirs, and
- the impact of various cushion gas scenarios on hydrogen recoverability, purity, water production risk, and well injectivity in porous rocks.

A yearslong investigation

This paper builds on years of hydrogen storage research at Los Alamos, one of the first institutions to explore this technology from multiple angles.

Los Alamos scientists have investigated the flow and transport behavior of hydrogen in the subsurface environment, which helps to shed light on the effects of cushion gas on underground hydrogen storage performance.

Another leg of this research, all of which is ongoing, has explored potential hydrogen storage locations in the Intermountain West region, an effort that combines the physics of subsurface geological formations with machine learning-powered simulations.

Yet another research branch has worked toward developing tools that can assess the reliability, risk, and performance of hydrogen storage across a wide range of conditions. This latter work led to OPERATE-H2, the first industry-available software to integrate advanced machine learning for optimizing hydrogen storage.

More information: Shaowen Mao et al, Cushion gas effects on hydrogen storage in porous rocks: Insights from reservoir simulation and deep learning, *International Journal of Hydrogen Energy* (2024). DOI: 10.1016/j.ijhydene.2024.04.288

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