Team explores the subterranean storage of hydrogen

April 9 2024

Matthew Paul, a Sandia National Laboratories geosciences engineer, works on a gas adsorption system in a fume hood as part of a project to see if depleted petroleum reservoirs can be used for storing carbon-free hydrogen fuel. Credit: Craig Fritz

Imagine a vast volume of porous sandstone reservoir, once full of oil and natural gas, now full of a different carbon-free fuel—hydrogen. Scientists at Sandia National Laboratories are using computer simulations and laboratory experiments to determine whether depleted oil and natural gas reservoirs can be used for storing this carbon-free fuel.

Hydrogen is an important clean fuel: It can be made by splitting water using solar or wind power, it can be used to generate electricity and power heavy industry, and it could be used to power fuel-cell-based vehicles. Additionally, hydrogen could be stored for months and used when energy needs outpace the supply delivered by renewable energy sources.

"Hydrogen would be good for seasonal and long-term storage," said Sandia chemical engineer Tuan Ho, who is leading the research. "If you think of solar energy, in the summer, you can produce a lot of electricity, but you don't need a lot for heating. The excess can be turned into hydrogen and stored until winter."

However, hydrogen contains much less "bang" in a set volume than carbon-based fuels such as natural gas or propane, and is much more difficult to compress, Ho said. This means storing huge amounts of hydrogen in metal tanks on the surface is just not feasible, he added.

Hydrogen can be stored underground in salt caverns, but salt deposits are not widespread across the U.S., said Don Conley, the manager for Sandia's underground hydrogen storage work. Therefore, Ho's team is studying whether hydrogen stored in depleted oil and gas reservoirs will get stuck in the rock, leak out, or become contaminated.

Ho's team recently shared their findings in a paper published in the *International Journal of Hydrogen Energy*.

Leaky rocks or secure storage

First, the team studied whether hydrogen would get stuck in the sandstone or shale that forms the body and seal around many oil and gas reservoirs, or leak out. Sandstone is composed of sand-sized grains of minerals and rocks that have been compressed over eons; sandstone has a lot of gaps between particles and thus can store water in aquifers or form oil and gas reservoirs. Shale is mud compressed into rock and is made up of much smaller particles of clay-rich minerals.

Thus, shale can form a seal around sandstone and trap it. "You want the hydrogen to stay where you inject it," Ho said. "You don't want it to migrate away from the storage zone and get lost. That's just a waste of money, which is a big concern for any storage facility."

Ho's collaborators at the University of Oklahoma used experiments to study how hydrogen interacts with samples of sandstone and shale. They found that hydrogen does not stay inside sandstone after it is pumped out, but up to 10% of the adsorbed gas got stuck inside the shale sample, Ho said. His computer simulations confirmed these results.

Taking a closer look at a specific type of clay that is common in the shale around oil and gas reservoirs, Ho conducted computer simulations of the molecular interactions between layers of montmorillonite clay, water, and hydrogen. He found that hydrogen does not prefer to go into the watery gaps between mineral layers of that kind of clay.

This means that the loss of hydrogen in clay due to getting stuck or moving through it would be tiny, Ho said. This is quite positive for underground storage of hydrogen. These findings on clay were published last year in the journal *Sustainable Energy & Fuels.*

Additional absorption experiments are being conducted at Stevens

Institute of Technology and the University of Oklahoma to confirm the molecular simulation results, Ho added.

Risks of contamination

Using both experiments and simulation, Ho's team found that residual natural gas can be released from the rock into the hydrogen when hydrogen is injected into a depleted natural gas reservoir. This means that when the hydrogen is removed for use, it will contain a small amount of natural gas, Ho said.

"That's not terrible because natural gas still has energy, but it contains carbon, so when this hydrogen is burned, it will produce a small amount of carbon dioxide," Ho said. "It's something we need to be aware of."

Ho's team, principally Sandia postdoctoral researcher Aditya Choudhary, is currently studying the effects of hydrogen on a depleted oil reservoir and how leftover oil might contaminate or interact with hydrogen gas using both molecular simulations and experiments.

The findings from this research can be used to inform and guide large field-scale tests of underground hydrogen storage, said Conley, the manager for Sandia's portion of the Department of Energy Office of Fossil Energy and Carbon Management's Subsurface Hydrogen Assessment, Storage, and Technology Acceleration (SHASTA) project.

The SHASTA project plans to conduct such a field-scale test in the future to demonstrate the feasibility of depleted oil and natural gas reservoirs for hydrogen storage, he added.

Additional research is needed to understand how microorganisms and other chemicals in depleted petroleum reservoirs might interact with stored hydrogen, Ho said.

"If we want to create a hydrogen economy, we really need widely distributed means of storing large quantities of hydrogen," Conley added. "Storage in salt is excellent where it exists, but it can't be the sole option. So, we're turning to depleted oil and gas reservoirs and aquifers as more geologically distributed means of storing large quantities of hydrogen. It's all in the name of decarbonizing the energy sector."

More information: Tuan A. Ho et al, Nuclear magnetic resonance and molecular simulation study of H2 and CH4 adsorption onto shale and sandstone for hydrogen geological storage, *International Journal of Hydrogen Energy* (2023). DOI: 10.1016/j.ijhydene.2023.11.011

Tuan A. Ho et al, Low hydrogen solubility in clay interlayers limits gas loss in hydrogen geological storage, *Sustainable Energy & Fuels* (2023). DOI: 10.1039/D3SE00363A

Provided by Sandia National Laboratories