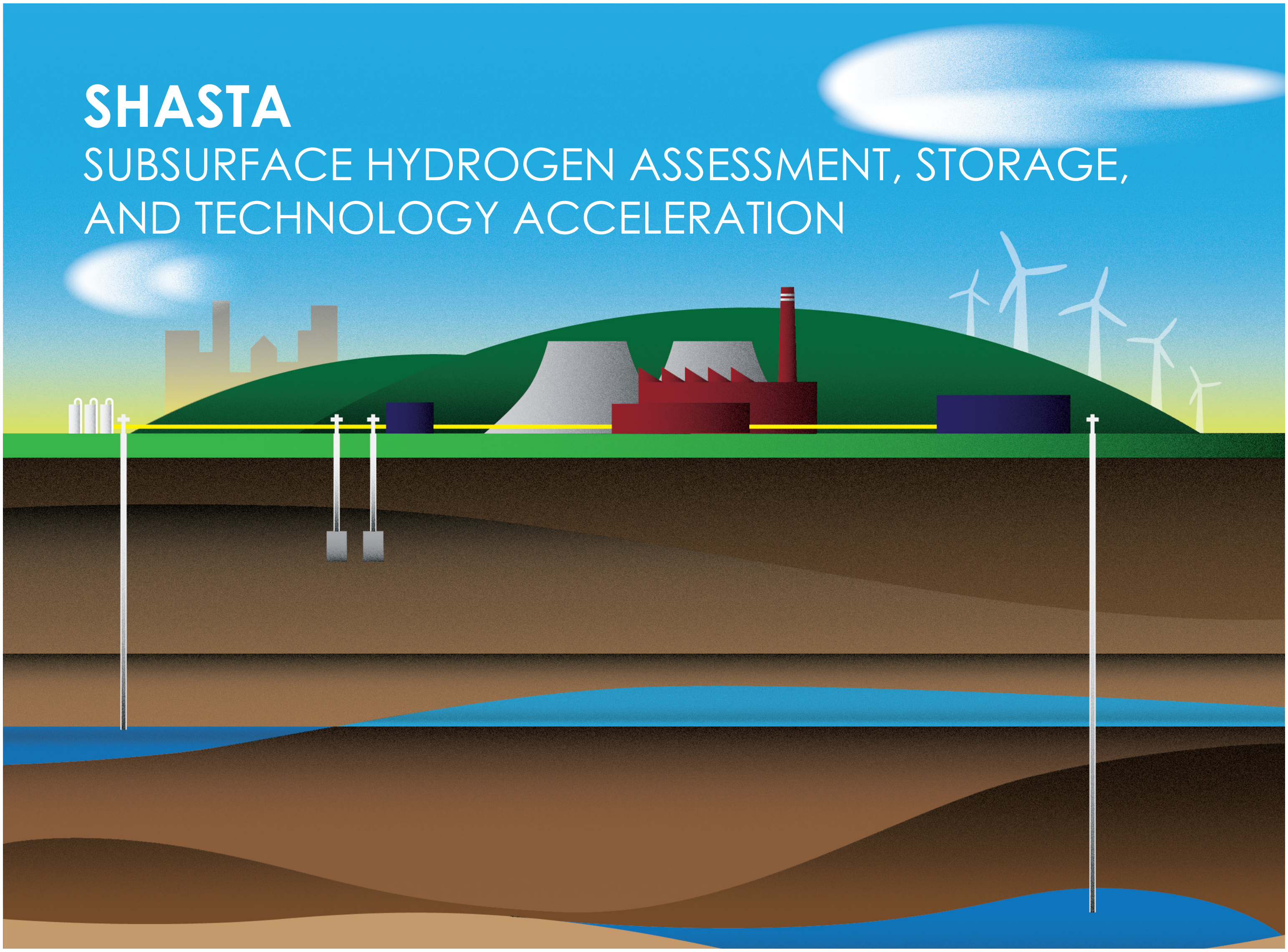
SHASTA

SUBSURFACE HYDROGEN ASSESSMENT, STORAGE, AND TECHNOLOGY ACCELERATION



NETL
NATIONAL ENERGY TECHNOLOGY LABORATORY

SHASTA
Subsurface Hydrogen Assessment, Storage, and Technology Acceleration

OVERVIEW

The DOE's Office of Fossil Energy and Carbon Management (FECM) is leveraging the unique capabilities and demonstrated expertise of three national laboratories — NETL, Pacific Northwest National Laboratory (PNNL) and Lawrence Livermore National Laboratory (LLNL) — to determine the viability, safety, and reliability of storing pure hydrogen or hydrogen-natural gas blends in subsurface environments.

Hydrogen is emerging as a low-carbon fuel option for transportation, electricity generation, manufacturing applications, and clean energy technologies that will accelerate the United States' transition to a low-carbon economy. However, a key challenge is to ensure the safe and effective storage of hydrogen. Large-scale storage of H_2 can be achieved by utilizing underground resources similar to how natural gas (NG) has been stored for the past century. Underground hydrogen storage (UHS) has the potential to provide the storage capacity required for the future hydrogen energy market.

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Recent studies have concluded that UHS is less costly than storage in above-ground vessels. Although there is much experience in underground storage of natural gas, there are significant technical challenges that must be addressed to store H_2 economically and safely at the commercial scale. NETL is addressing the following challenges:

- Hydrogen storage efficacy for a variety of underground systems such as depleted hydrocarbon reservoirs, saline aquifers, and salt caverns.
- Effect of hydrogen low mass density, volumetric energy density and viscosity on gas storage behavior.
- H_2 loss through biogeochemical reactions such as methanogenesis, sulfate reduction and iron reduction.
- Effect of small H_2 molecular size on risk of loss of containment from the storage reservoir through caprock, faults or fractures, or leaky wells.
- Development of real-time monitoring technology to assess gas migration, potential leakage, microbial activity, and well integrity.
- Support from key stakeholders as well as public acceptance.
- Delineating expected regulatory environment .

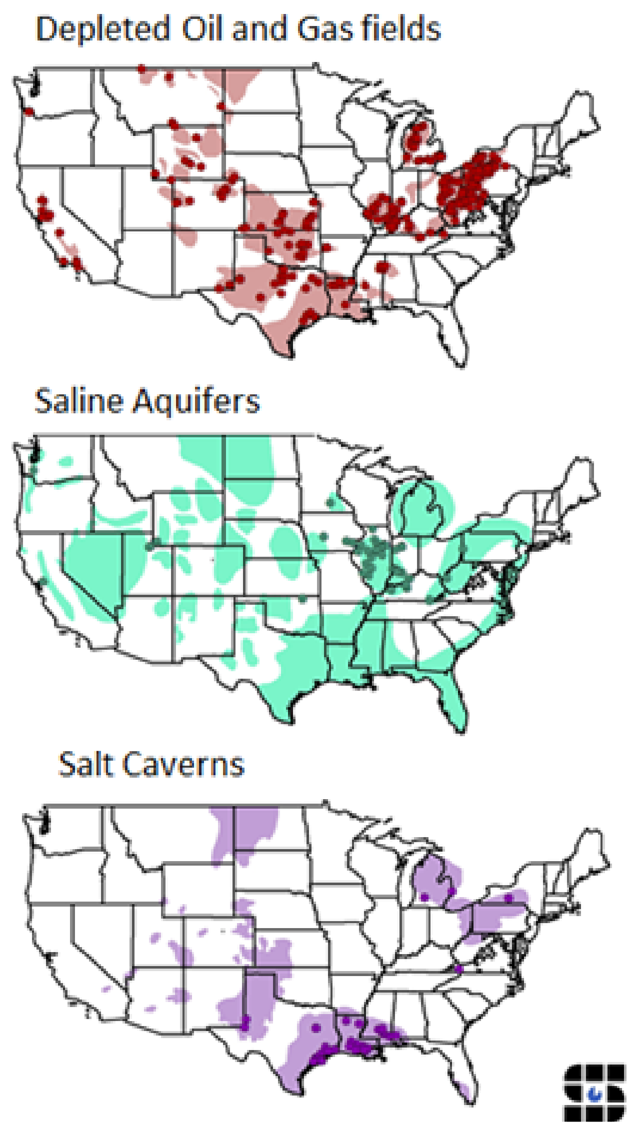
UNIQUE FACILITIES

World class facilities at three labs, NETL, PNNL, and LLNL are currently being used to drive innovation in SHASTA. Laboratory work conducted at NETL builds on existing subsurface capabilities designed to study high pressure high temperature reactor studies that simulate wellbore and subsurface reactions, assess the geochemistry and microbiology of reservoir types targeted for H_2/CH_4 storage, and develop optic fiber sensors capable of measuring H_2, CH_4, and pH. Specific equipment include the following: gas and ion chromatography, x-ray diffraction, scanning electron microscopy, various mass spectrometry techniques, qPCR and DNA sequencing capabilities, optical fiber sensor design and fabrication, chemical sensor layer synthesis, automated high temperature high pressure reactors, Brunauer-Emmett-Teller surface area and pore size analysis, TOUGH reservoir simulation, statistical analysis and python coding.

Laboratory work conducted at PNNL will leverage capabilities and expertise within the Earth Systems Science Division specifically related to subsurface flow and transport, and biogeochemistry. Specific locations will be the biogeochemistry lab and subsurface science lab. Each of these labs hold the requisite equipment to conduct microbial analysis and flow through tests. The project can also leverage capabilities available at PNNL's Environmental Molecular Sciences Laboratory. For computer simulations, PNNL researchers have access to world-class computing facilities, including the Constance system.

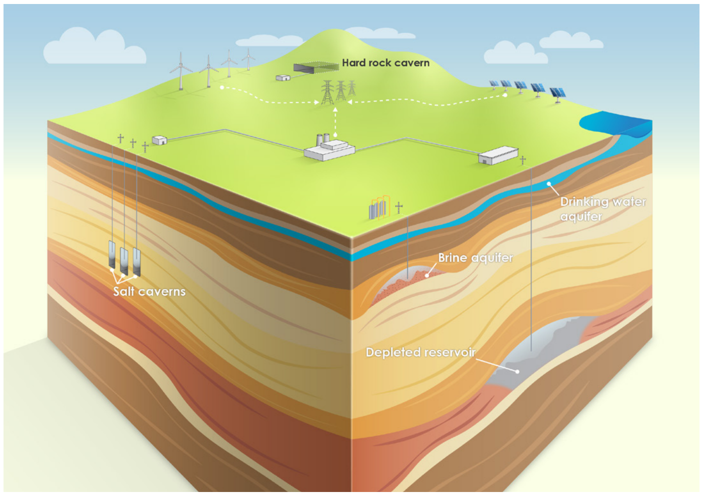
Laboratory work conducted at LLNL builds from expertise in rock-water-CO_2 interactions in batch and flowing systems. Specific lab locations include the experimental geochemistry facilities equipment necessary for batch exposure experiments. Additional LLNL capabilities co-located in these same buildings include gas and ion chromatography, various mass spectrometry techniques, nuclear magnetic resonance facilities, scanning electron microscopy, X-ray tomography, profilometry, and X-ray diffraction and fluorescence.

For computer simulations, LLNL researchers have access to several TOP500 system through the Livermore Computing Center.

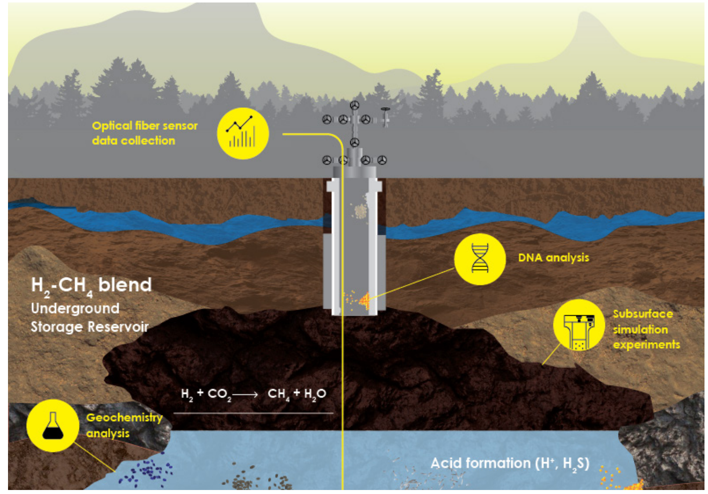


Three main types of underground natural gas storage (USG) in service are: depleted oil and gas fields, saline aquifers, and salt caverns.

SHASTA-SUBSURFACE HYDROGEN ASSESMENT AND TECHNOLOGY ACCELERATION



Underground storage of H_2 is less costly than storage in above-ground vessels but significant technical challenges must be addressed to store H_2 economically and safely at the commercial scale. SHASTA research focuses on quantifying materials compatibility, investigating core- and reservoir-scale performance and characterizing microbial interactions.



Research on the challenges of storing pure hydrogen or hydrogen-natural gas blends in subsurface environments include securing data on DNA analysis, subsurface simulation experiments and geochemistry analysis. SHASTA uses analytic capabilities in combination with optical fiber sensors and modeling to collect data to advance research.

The National Energy Technology Laboratory is a U.S. Department of Energy national laboratory that drives innovation and delivers technological solutions for an environmentally sustainable and prosperous energy future. Through its world-class scientists, engineers and research facilities, NETL is ensuring affordable, abundant and reliable energy that drives a robust economy and national security, while developing technologies to manage carbon across the full life cycle, enabling environmental sustainability for all Americans, advancing environmental justice and revitalizing the economies of disadvantaged communities.

The Pacific Northwest National Laboratory advances the frontiers of knowledge, taking on some of the world's greatest science and technology challenges. Distinctive strengths in chemistry, Earth sciences, biology, and data science are central to our scientific discovery mission. PNNL's research lays a foundation for innovations that advance sustainable energy through decarbonization and energy storage and enhance national security through nuclear materials and threat analyses.

For more than 60 years, the Lawrence Livermore National Laboratory has applied science and technology to make the world a safer place. Livermore's defining responsibility is ensuring the safety, security and reliability of the nation's nuclear deterrent. Yet LLNL's mission is broader than stockpile stewardship, as dangers ranging from nuclear proliferation and terrorism to energy shortages and climate change threaten national security and global stability. LLNL responds with vision, quality, integrity, and technical excellence to the nation's most challenging security problems.

U.S. DEPARTMENT OF ENERGY
Fossil Energy and Carbon Management

NATIONAL ENERGY TECHNOLOGY LABORATORY

Pacific Northwest NATIONAL LABORATORY

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