



CAPABILITIES FOR ENERGY STORAGE IN THE SUBSURFACE

Sandia National Laboratories offers expertise for energy storage in the subsurface:

- **40+ years** of experience with salt cavern storage, including expertise in crude oil and hydrogen storage
- **Partnerships** where unique subsurface capabilities are aligned with fostering success in industry and for sponsored storage system projects (e.g., hydrogen hubs)

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ADVANCING SUBSURFACE STORAGE THROUGH SANDIA GEOTECHNICAL, ENGINEERING, AND RESEARCH & DEVELOPMENT CAPABILITIES

Geosciences

Geochemistry analysis

- Subsurface materials analysis for major and trace elements, sulfur content, density, surface area, pore size distributions, and other characteristics related to product loss and purity
- Characterization tools, including X-Ray diffraction, X-Ray fluorescence, Fourier-transform infrared spectroscopy, Raman spectroscopy, and mass spectrometry
- Hydrogen-induced reaction testing at elevated temperatures and pressures to replicate subsurface environment conditions

Geomechanical analysis

- Permeability testing to confirm the state of specific subsurface materials in operational settings at variable temperatures and confining pressures using core-size samples with nanodarcy accuracy
- Testing to collect compressive and tensile strength measurements from geologic samples
- Ability to recreate in situ states of stress in the subsurface;
- Constant mean stress tests to true triaxial stress tests with three independent stress controls
- Creep testing
- Detailed imaging capability to yield information on rock structures and in situ features

Microbiology facilities and expertise to

- Evaluate the likelihood of growth and survival of hydrogen-metabolizing microbes in the subsurface ecosystem
- Provide genomic classification, quantification, and identification
- Supply metagenomic and transcriptomic sequencing to identify microbes before and after exposure
- Conduct incubations with hydrogen, methane, and/or gas mixtures to amplify and isolate microbial targets

Modeling

Geomechanical modeling

- Analyses of time-dependent stresses occurring in cavern walls, wellbores, and other structural elements of subsurface storage systems for operational decision-making
- High-performance computing for reservoir geometry and associated stresses

Modeling stored gas behavior in storage systems

- Flow, reactive transport, and geochemical modeling
- Reaction modeling and characterization of the pore connectivity of flow pathways
- Reservoir-scale simulation studies on large and complex flow and transport simulations with PFLOTTRAN
- Thermodynamic and kinetic databases for relevant sorption equilibrium constants
- Pore-scale models of relevant gaseous and aqueous adsorption/transport
- Relative permeability, capillary pressure, and saturation modeling
- Multiphase flow reactive transport modeling at pore (or meso) scales to lab scale

Materials Research

Metals and infrastructure components

- Materials testing in hydrogen environments in the world-class Hydrogen Effects on Materials Laboratory to inform design decisions
- Specialized systems that allow structural materials testing under in-service conditions
- Experience developing and establishing test methods for materials, a mechanistic understanding of test outcomes, and performance trends for safety codes and standards

Cement-hydrogen interactions

- Analysis of geochemical interactions between cement mineral phase assemblages and storage gas

Integrity Monitoring

Monitoring salt cavern mechanics

- Use of computational geomechanical models to analyze viscoplastic, or creep, behavior of salt
- Salt creep evaluations to inform cavern operations and safety

Sonar monitoring and leaching modeling

- Sonar monitoring for adverse leaching effects
- Sandia Solution Mining Code, SANSMIC, to model leaching between sonar measurements to account for injected water

Wellbore integrity

- Expertise in oil, gas, and hydrogen or carbon storage and geothermal activities

Systems

System dynamics modeling

- Capturing operational requirements and constraints
- Bracketing costs for key components
- Modeling and analysis for design optimization and control studies

Water resources

- Water resource modeling and analysis expertise at watershed and regional scales for availability, scarcity, and uncertainty
- Multiscale interactions among energy, water, and climate

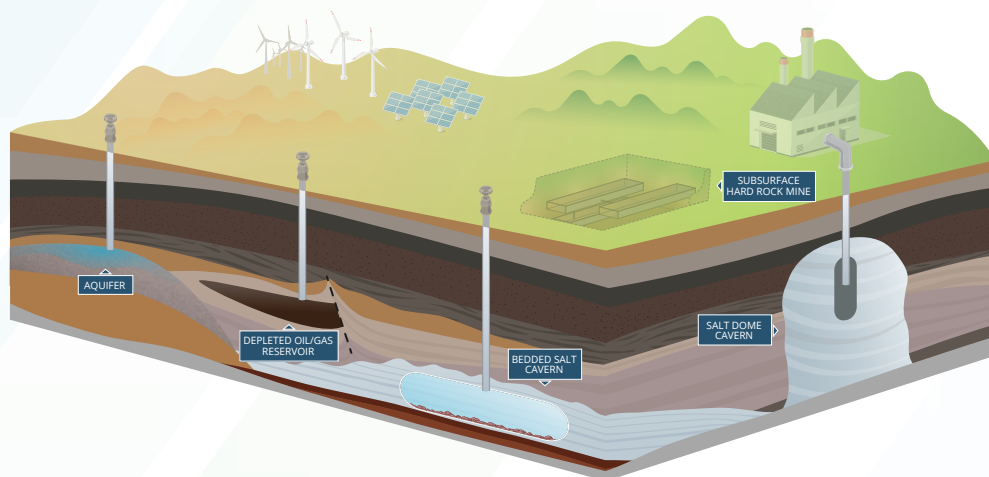
Technoeconomic analysis (TEA) and life cycle assessments (LCA)

- Coupling socioeconomic shifts with energy transition
- Uncertainty characterization
- Systems analysis and dynamics
- Trade-off analyses

Safety codes and standards

- Safety and consequence analysis using tools that tie risk to the scientific basis of hazards and controls

SUBSURFACE STORAGE LOCATIONS



Active projects employing subsurface storage capabilities:

- Strategic Petroleum Reserve
- Subsurface Hydrogen Assessment, Storage, and Technology Acceleration (SHASTA)
- Commercial subsurface storage of hydrogen
- R&D with the U.S. Department of Transportation Pipeline & Hazardous Materials Safety Administration for safe hydrogen storage