Who we are

GTI ENERGY
solutions that transform

OPEN HYDROGEN INITIATIVE
GTI ENERGY | S&P Global Commodity Insights

VERITAS

LCRI
LOW-CARBON RESOURCES INITIATIVE

UTD
Utilization Technology Development

GTI ENERGY NZIP
Net Zero Infrastructure Program

GTI ENERGY HyRes
Hydrogen Emissions Research Consortium

OTD
Operations Technology Development

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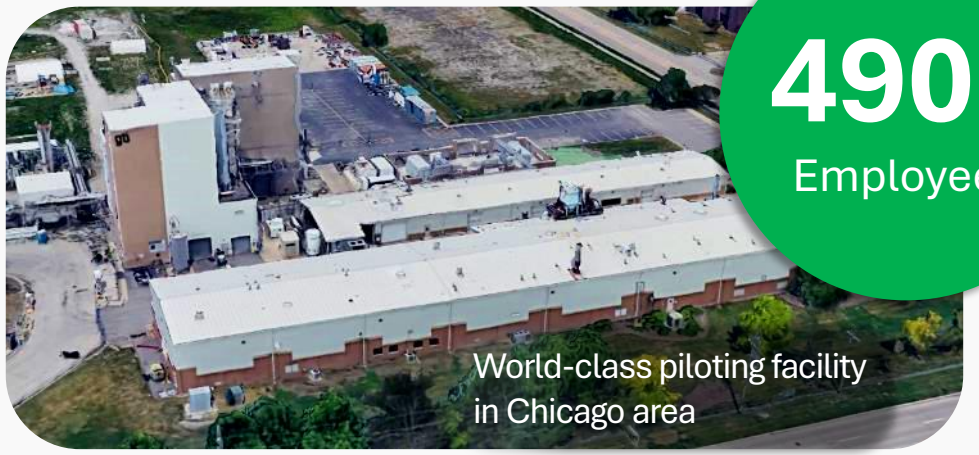

490+
Employees

TOP WORK PLACES 2021
Chicago Tribune

We develop, scale, and deploy energy transition solutions

With a trusted team of scientists, engineers, and partners

Leveraging our deep expertise in gases, liquids, infrastructure and efficiency

Embracing systems thinking, innovation, and collaboration

Delivering impactful innovations—from concept to market

With technologies needed for low-carbon, low-cost energy systems

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SUSTAIN H_2

SUSTAIN H2

SUbsurface Storage Technological Advancements & INnovation for Hydrogen

Accelerating the Deployment of Underground Hydrogen Storage

Contact: SUSTAIN-H2@gti.energy

The need for expanded hydrogen storage

Large-scale low-cost storage solutions will be critical to implementing a hydrogen economy

Long-duration Energy Storage

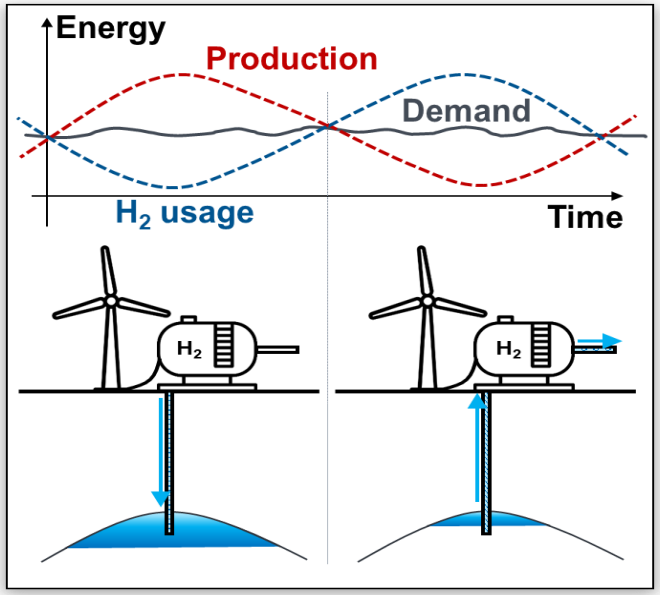
- Comparable to developing storage opportunities for natural gas storage, thus expediting the potential for hydrogen's widespread adoption

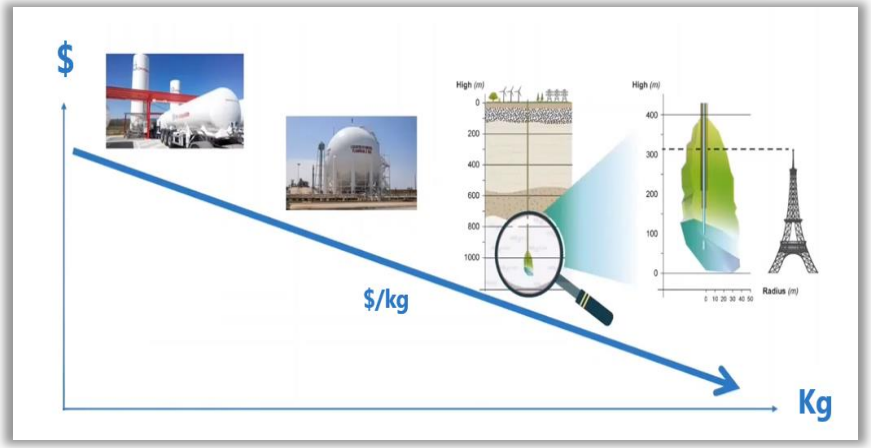
Renewable Energy Integration

- Opportunity to store surplus energy during periods of excess generation.

Resource Optimization

- Minimizing infrastructure development costs and environmental impact.





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Storage: Infrastructure Resiliency Component

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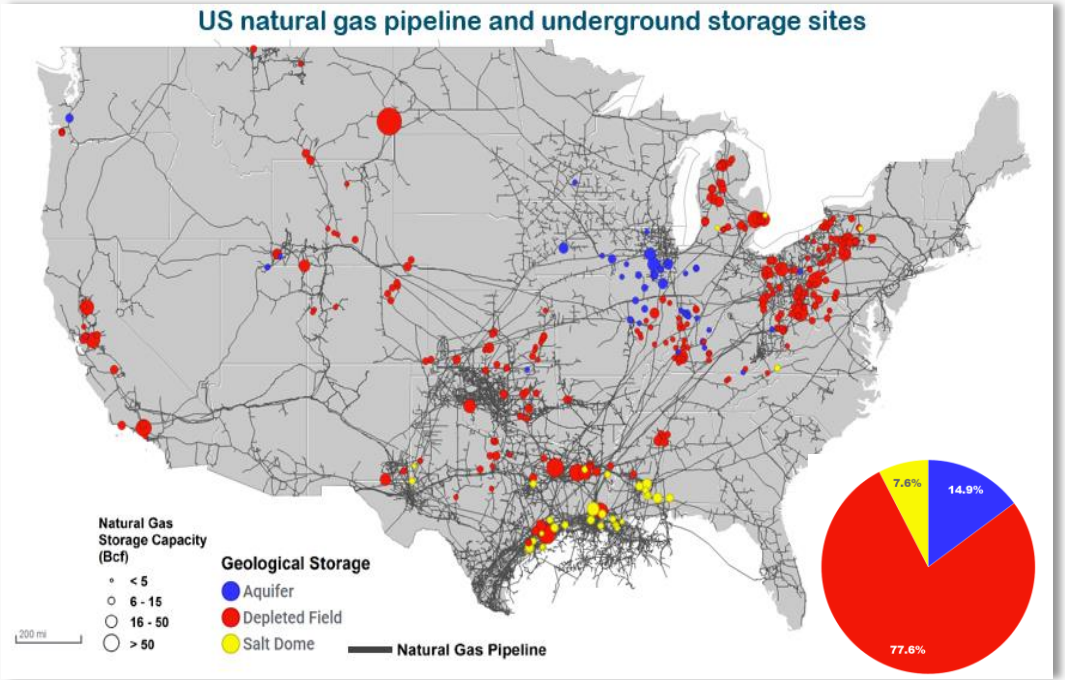
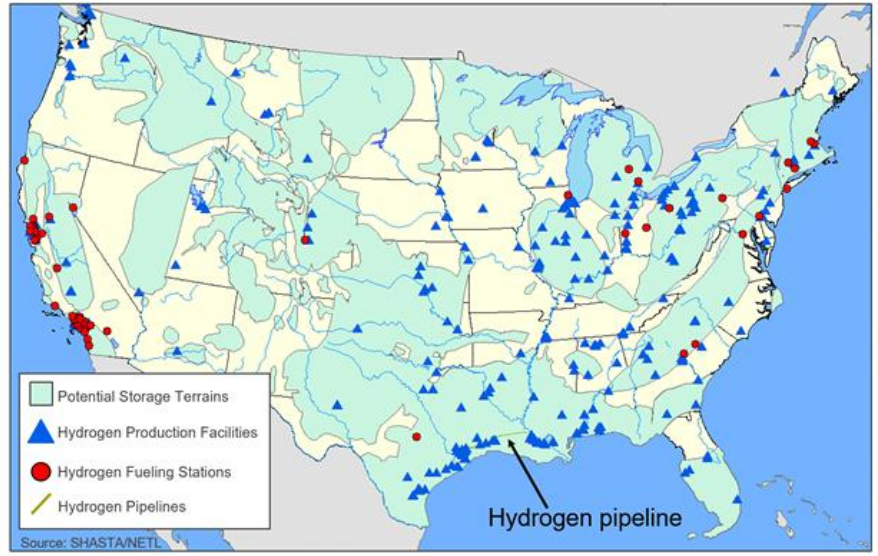
Natural Gas Experience





Locations of potential hydrogen storage systems in the United States and distance to existing hydrogen production and distribution infrastructure. Source: https://edx.netl.doe.gov/shasta/

Today: 4.8 Tcf of underground storage capacity across 412 active facilities

- **20% of winter consumption**
- **Provides economic and price flexibility**

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Timeline to Actions

U.S. National Clean Hydrogen Strategy and Roadmap (2023)

Actions to support safe, efficient, and reliable clean hydrogen delivery and storage infrastructure

	2022-2025	2026-2029	2030-2035
Delivery and Storage Infrastructure	• Develop and update rigorous analytical models and tools to assess delivery and storage pathways, determine gaps, and prioritize strategies. • Develop technologies to tightly monitor and mitigate hydrogen leaks and boil-off. • Assess compatibility of pipeline and component materials with hydrogen and hydrogen blends with natural gas. • Advance novel approaches for low cost, high efficiency hydrogen liquefaction and boil-off mitigation. • Conduct discovery and development of hydrogen carrier materials for use in bulk storage and distribution. • Identify geologic formations that can be used for bulk hydrogen storage, and associated development and operating requirements. • Develop and optimize designs for hydrogen infrastructure in key applications, such as industry and energy storage. • Develop technologies for high throughput dispensing of hydrogen for heavy-duty vehicles. • Develop and harmonize fueling protocols for heavy-duty and off-road vehicles for which hydrogen is the optimal solution. • Accelerate RDD&D to reduce the cost of high pressure and liquid hydrogen storage tanks, including carbon fiber composite vessels. • Establish data monitoring and collection framework to assess upstream and on-site emissions.	• Validate and refine analyses, models, and tools to prioritize delivery and storage pathways for various applications. • Demonstrate efficient and reliable hydrogen pipeline compressor operation. • Quantify loss rates from gaseous and liquid hydrogen infrastructure to inform mitigation requirements in large-scale deployments. • Develop designs for commercial-scale novel, high efficiency systems for hydrogen liquefaction. • Advance promising concepts for hydrogen carriers and design reliable, low-cost regenerator systems. • Initiate regional bulk hydrogen storage demonstrations, including underground approaches, and ensure local and regional benefits. • Demonstrate novel, efficient, and low-cost approaches to bulk hydrogen delivery. • Deploy scalable hydrogen fueling stations to support early fleet markets, such as heavy-duty trucks and buses. • Ensure monitoring systems and data collection are in place for potential hydrogen and other emissions/releases. • Design sustainable and equitable regional clean hydrogen networks in key locations to maximize benefits, ensuring energy and environmental justice and equity.	• Design networks of hydrogen infrastructure optimized for regional supply and demand, in collaboration with local communities and stakeholders to maximize benefits and ensure energy, environmental, and equity goals are addressed. • Demonstrate advanced liquefaction with double the efficiency of current concepts. • Develop long term storage plan/strategic hydrogen reserve to ensure resilience of supply. • Deploy Regional Clean Hydrogen Hubs with advanced low-cost clean hydrogen storage and infrastructure. • Collect data, including emissions data, from demonstrations of bulk hydrogen distribution (e.g., through pipelines or carriers) in real-world environments to inform RDD&D that reduces cost and improves reliability. • Continue collecting data to inform scale up of optimal delivery and storage pathways and RDD • Ensure any safety or other practices related to hydrog infrastructure are shared a diverse stakeholders to en continuous improvement. • Leverage global collaborat hydrogen infrastructure to long term investment plan hydrogen exports opportu

2022 2025 2029

and distribution.
Identify geologic formations that can be used for bulk hydrogen storage, and associated development and operating requirements.
Develop and optimize designs for

systems.
- Initiate regional bulk hydrogen storage demonstrations, including underground approaches, and ensure local and regional benefits.
- Demonstrate novel, efficient, and low-cost approaches to bulk hydrogen delivery.

https://www.hydrogen.energy.gov/clean-hydrogen-strategy-roadmap.html

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Addressing the Challenge

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- Fundamental R&D
- Data and Studies

- Market Assessment & Economics
- Recommended practices
- Capabilities establishment
- **Field demonstrations**

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SUSTAIN H2 Objectives

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Accelerate the deployment of safe & cost-effective long-term underground hydrogen storage beyond salt caverns through a combination of scientific expertise, market insights, field experience, & industry collaboration.

Vision

- **Engage diverse stakeholders** to coordinate cross-collaborative R&D
- **Address key technical challenges** to resolve critical uncertainties
- **Facilitate data collection, sharing, and analysis** to guide site selection
- **Complete national and regional techno-economic assessments**
- **Accelerate field deployment** by engaging all stakeholders and reducing remaining uncertainties

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Scaling Up Underground Hydrogen Storage

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

2021

Fundamental H2 Storage R&D Initiated

2023

Characterize high-potential subsurface H2 storage reservoirs

Scale up of Fundamental Technologies for Prototype Demonstration

2027

Initial Regional H2 Storage Demonstration

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2023

Program Inception

Q1 2024

Stakeholder Engagement

2024- 2025

- Geo-Engineering
- Technology & Operation
- Market & Economics
- System Integration
- Policy & Social Impacts
- Community Engagement

2025+

Field Development Planning

Field Pilots

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Technical Scope

Coordinating, De-risking, Accelerating

Geo-Engineering	Technology & Operations	Market Assessment & Economics	System Integration	Policy & Social Impacts
Technical De-risking	Operational De-risking	Economic De-risking Business Concept	Infrastructure De-risking Hydrogen Value Chain	Legal and Regulatory Frameworks

- ✓ Conduct coordinated R&D to tackle key questions, narrowing the existing knowledge gap.
- ✓ Technologies needed and operational information for implementation of a field pilot
- ✓ Pathways for retrofitting underground natural gas storage facilities
- ✓ Site screening workflow/guideline by structuring collected data and information

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Current Partners and Supporters

GTI ENERGY
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PHMSA

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

Pacific Northwest NATIONAL LABORATORY

OTD Operations Technology Development

DUKE ENERGY®

Ameren

ONEOK

PG&E®

Black Hills Corporation Ready

ENBRIDGE®

National Fuel®

Nicor Gas

ILLINOIS
Illinois State Geological Survey
PRAIRIE RESEARCH INSTITUTE

UA SCIENCE
ARIZONA GEOLOGICAL SURVEY

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SUSTAIN H2 Value Proposition

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- De-risking research
- Reducing cost
- Identifying opportunities
- Developing partnerships

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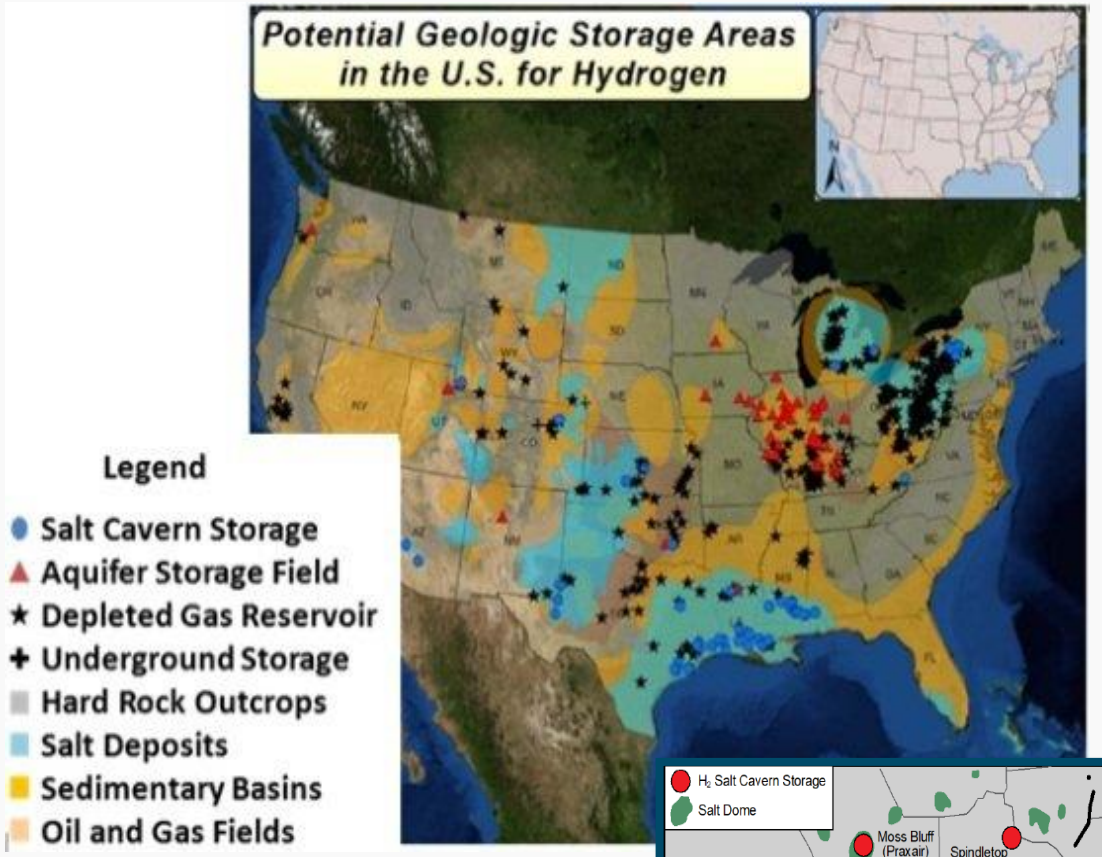
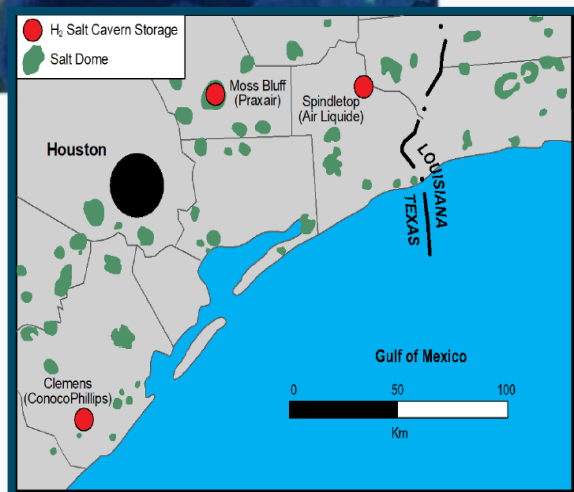
Supplementary Information

- Storage in salt caverns is restricted to the Gulf Coast and with potential thinner salt deposits in the west-central plains.
- Storage in aquifers, depleted reservoirs, and repurposed natural gas storage fields significantly increase the available volumes.
- Experience in underground storage of hydrogen is limited to salt caverns as of now. Storage of hydrogen in depleted fields and aquifer had not been demonstrated.





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