

Exploring the Future of Geologic Hydrogen

Defining the Path Ahead

June 2025



Project Team

Dr. Ernest J. Moniz
CEO and President

Dr. Madeline Gottlieb Schomburg
Vice President of Research

Dr. Tatiana Bruce da Silva
Deputy Director of Research

Beth Dowdy
Research Associate

Divine Maduakolam
Research Fellow

Additional Contributors

Joseph S. Hezir
President and CFO

April Salas
Chief Operating Officer

Alex Kizer
Executive Vice President and Executive
Director at H2DI

Michael Knotek
Distinguished Associate

Communications Team

David Ellis
Senior Vice President of Communications &
Policy Outreach

Lizi Bowen
Deputy Director of Communications

Alex Miller
Communications Associate

Publication Support

Danielle Narcisse
M. Harris & Co.

Jane Hirt
M. Harris & Co.



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Table of Contents

I. Why Geologic Hydrogen? Why Now? 1

II. The Opportunity: Vast Potential and Economic Outlook Are Promising..... 3

III. Uncertainty Is Huge But Potential is Even Larger 8

IV. Clear, Streamlined Rules Will Expedite Exploration.....11

V. Market Viability Depends on Co-Locating Demand and Production15

VI. Federal-State Coordination Is a Critical Foundation17

VII. Public Funding Must De-Risk Early-Stage Investment19

VIII. Build Support Through Messaging and Collective Action.....21

IX. Conclusion: A Narrow Window for U.S. Leadership.....22

References24

I. Why Geologic Hydrogen? Why Now?

Geologic hydrogen is a naturally occurring and potentially abundant global energy source. While not yet proven at scale, early discoveries span multiple continents—from Africa to Australia to Europe and North America—and suggest that hydrogen may exist in large quantities underground, formed and replenished through natural geochemical processes.

In addition, using technologies to stimulate the subsurface production of hydrogen, perhaps in tandem with engineered geothermal development, is attracting growing attention. If the promise of geologic hydrogen is realized, its potential to deliver low-carbon, low-cost hydrogen energy at scale could play a transformative role in decarbonization and emerging global energy markets. It could be the missing link in revolutionizing multiple sectors of the economy, including steel, fertilizer, long-haul transport, shipping, and industrial heat.

With relatively modest investment and targeted coordination, it could be determined within the next few years whether geologic hydrogen is a scalable, affordable low-carbon energy resource. This makes geologic hydrogen an unusually low-risk, high-reward proposition. And because this is one of the few areas in energy today where true breakthroughs remain possible, it is precisely the kind of frontier the United States should be exploring through public-private partnerships.

If successful, geologic hydrogen also would extend American leadership in energy innovation, rooted in the strength of our institutions, workforce, and technical expertise. That expertise is formidable. The United States is home to world-class infrastructure and capabilities in drilling, geoscience, and subsurface resource management. It has decades of experience across oil and gas, geothermal, and mining industries, and a rich ecosystem of national laboratories, universities, data archives, and service providers. In addition, recent policies, including the Bipartisan Infrastructure Law (BIL), provide the United States a head start in jumpstarting a new domestic market by crowding in at least \$50 billion of private capital across nearly 500 private companies.^a

Navigating this moment of declining federal investment in research and development (R&D) will be critical. Key agencies face growing pressure to limit new spending and reduce discretionary research budgets, and the ranks of experienced federal research managers have been thinned considerably. That makes it more difficult, but also more urgent, to bring private funders and philanthropies off the sidelines. As one expert noted, “This is not something that any one company is going to be able to do. ... It’s going to take industry plus government plus academia and philanthropy all coming together.”

^a According to EFIF’s internal analysis of the regional H2Hubs program.

Recognizing this opportunity, the EFI Foundation held a full-day private workshop under Chatham House Rule^b to bring together more than 40 technical experts, geologic hydrogen companies, policymakers, and investors to assess the current state of geologic hydrogen and chart a path forward. The discussion illuminated several key points:

- Geologic hydrogen's potential is massive, but confirming it requires a willingness and ability to “fail fast” with enough “shots on goal” to eventually scale, assuming the geological realities are supportive.
- Regulatory clarity on permitting and definitions is foundational for project development.
- Host communities cannot be afterthoughts; they must be brought in from the start.
- The initial high capital risk for exploration means early-stage public support is essential to unlock private investment.
- Federal science and standards must complement state-level decision-making.
- Privately held data provides a competitive advantage, but shared frameworks can reduce duplication and accelerate sector learning.
- Without viable transportation and offtakers, even cheap, naturally occurring hydrogen can be left undeveloped, or stranded.

These insights form the foundation of this report. The workshop's primary objective was to outline a strategic path for federal and state governments, industry leaders, philanthropies, and the research community to test the hypothesis of geologic hydrogen and prepare for its potential. Whether it proves to be a breakthrough or a niche resource, now is the time to find out. The stakes—for climate action, energy security, and long-term industrial competitiveness—are too high to leave this question unanswered.

^b Unattributed quotes throughout the report originate from the workshop discussion.

II. The Opportunity: Vast Potential and Economic Outlook Are Promising

"We've been worrying about the energy problem for 40 years, and it just has not gone well. But now this pops up, and it's like—good God, how did we miss this?"

Hydrogen is not new in the energy landscape. In 2023, the world produced almost 100 megatons, but nearly all of it came from fossil fuels with high carbon emissions.¹ In the U.S. alone, around 10 megatons of hydrogen are produced annually, and nearly all of it is consumed domestically.² Cleaner hydrogen alternatives exist, but in 2023, low-emissions hydrogen made up less than 1% of global production, held back by costs that cannot compete with fossil-based hydrogen.^{3,c} As countries work to decarbonize fossil-based hydrogen industries such as fertilizer production and hard-to-electrify sectors like heavy industry and transport, clean hydrogen is gaining attention. However, to play a meaningful role in the energy transition, low-emission hydrogen needs to become more available and more affordable.

That's where geologic hydrogen comes in.

Resource Potential of Natural Hydrogen

Until recently, it was widely believed that only manmade clean hydrogen could be a viable energy source. Naturally occurring hydrogen was dismissed as too diffuse or reactive to accumulate in useful amounts. However, recent discoveries suggest that under the right geologic conditions, hydrogen can collect in underground reservoirs, opening the door to a previously untapped, low-carbon energy source.

^c The International Energy Agency (IEA) estimates: "Depending on regional gas prices, the levelised cost of hydrogen production from natural gas ranges from USD 0.5 to USD 1.7 per kilogramme (kg). Using [carbon capture, utilization, and storage] technologies to reduce the CO₂ emissions from hydrogen production increases the levelised cost of production to around USD 1 to USD 2 per kg. Using renewable electricity to produce hydrogen costs USD 3 to USD 8 per kg." Source: International Energy Agency, *Global Hydrogen Review 2021: Executive Summary*, 2021, <https://www.iea.org/reports/global-hydrogen-review-2021/executive-summary>.

"There aren't many potential real breakthroughs left for the clean energy transition—and geologic hydrogen would be put in that bucket [of remaining breakthroughs]. It's a game changer, if it all comes to pass."

In fact, estimates state that the Earth's crust may contain anywhere from thousands to billions of megatons of hydrogen, with some experts proposing a median figure of around 5 million megatons.^{4,5} However, these sources may be located at great depths, offshore, in remote or diffuse accumulations, or trapped in geological formations lacking suitable reservoirs or seals.

Even if a small fraction of the potential—say 2%—can be recovered, it could yield around 100,000 megatons of usable hydrogen... that would be enough to supply the world's energy needs more than 18 times over.

Even if a small fraction of the potential—say 2%—can be recovered, it could yield around 100,000 megatons of usable hydrogen. As of 2023, that would be enough to supply the world's energy needs more than 18 times over.⁶ The resource potential is extraordinary, and momentum is building. As one workshop participant stated, "I've been told anecdotally that there's perhaps more than 100 companies now around the world that are actively exploring for geologic hydrogen." Even so, exploration in the United States and internationally is still in its early stages.

Production Pathways

The idea of extracting hydrogen directly from the Earth's subsurface was barely on the radar until a surprising discovery in Mali (Box 1). There, naturally occurring hydrogen was found and successfully used directly from the well to generate electricity, providing one of the world's first demonstrations that geologic hydrogen can be both accessible and useful. This example sparked global interest in the resource and showed that geologic hydrogen could potentially be developed using conventional drilling techniques.

Box 1. The first discovery of natural hydrogen: What happened in Mali?

Mali is home to the first known commercial use of naturally occurring geologic hydrogen. In the village of Bourakébougou, a hydrogen-rich gas was accidentally discovered in the 1980s during a water drilling operation. Initially capped for safety, the site was later studied and confirmed to be venting nearly pure hydrogen, generated naturally by underground geochemical reactions.

By 2012, the hydrogen was harnessed to power a small generator, supplying clean electricity to the local community. The project demonstrated that natural hydrogen could be extracted with conventional drilling methods and used, much like natural gas.

This unexpected success provided the world’s first real proof of concept and continues to serve as a reference point for the emerging geologic hydrogen industry.

Today, several approaches, shown in Table 1, are being explored to access geologic hydrogen. Each offers distinct advantages and challenges.

Table 1. Comparison of geologic hydrogen sources

Source	Description	Advantages	Challenges
Natural hydrogen accumulations	Hydrogen collects naturally in underground reservoirs over time, like natural gas.	Uses conventional drilling and simple extraction once found.	Locating reservoirs is difficult and uncertain.
Hydrogen flux zones	Operators drill into rocks where natural reactions are producing hydrogen, capturing it as it migrates through the subsurface.	Accesses ongoing hydrogen production.	Requires precise timing and location; underdeveloped.
Stimulated hydrogen production	Humans inject water into reactive rocks to trigger hydrogen-producing reactions.	Can produce hydrogen on demand in new areas.	Experimental; costly; regulatory hurdles; no commercial projects yet.

Source: EFI Foundation.

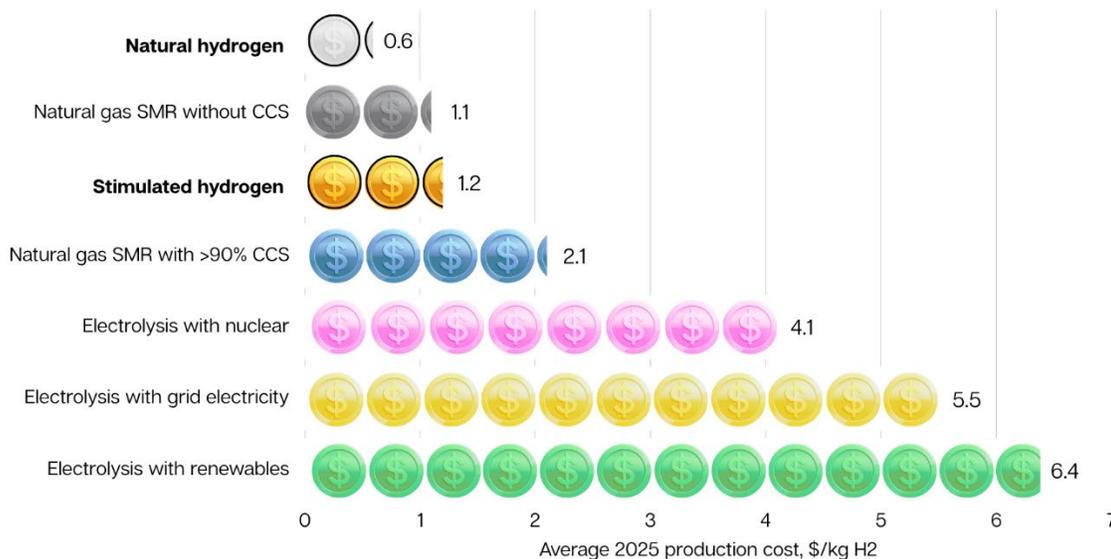
Early Economic Outlook

The early economic outlook for producing geologic hydrogen is promising. As one participant explained, “The current barrier isn’t technical. It’s economic. It’s the ability to find, prove, and price this resource.”

Cost estimates for production currently range from \$0.40 to \$1.50 per kilogram, depending on the method. Natural accumulations are projected to be the most cost-effective, with estimates between \$0.40 and \$0.80 per kilogram. Stimulated production is currently more expensive—ranging from \$0.80 to \$1.50 per kilogram—but may benefit from cost reductions as the technology matures. For context, hydrogen produced from natural gas via steam methane reforming (SMR) without carbon capture typically costs between approximately \$1 and \$2 per kilogram (Figure 1).⁷ This makes some geologic hydrogen scenarios cost-competitive with current industrial supply.

Cost estimates for production currently range from \$0.40 to \$1.50 per kilogram, depending on the method.

Figure 1. Average hydrogen production cost by production pathway



Natural and stimulated hydrogen pathways are highlighted in bold. Different colors represent distinct production pathways. Cost estimates based on varying facility sizes and capital expenditure assumptions; see source for more details. Natural gas costs from the U.S. Energy Information Administration. For SMR with CCS, costs include the use of grid electricity. Electrolysis costs are based on nuclear-powered production in Illinois and behind-the-meter renewable-powered production in California, Texas, and New Jersey. Grid electricity costs use the U.S. average grid price. Adapted from: U.S. Department of Energy. 2024. Pathways to Commercial Liftoff: Clean Hydrogen. December 2024. <https://www.energy.gov/lpo/pathways-commercial-liftoff-reports>

One of the biggest cost drivers today is the up-front capital investment. This includes exploration, drilling, and securing subsurface rights, all of which can present a significant barrier for early-stage projects. However, once these initial costs are covered

and operations reach scale, production costs could drop significantly. Some projections suggest prices could fall below \$0.20 per kilogram over time.⁸ At that level, geologic hydrogen becomes cost-competitive with natural gas on an energy-equivalent basis, particularly when produced near end users to avoid transportation costs.^d

R&D Breakthroughs

“Map, baby, map—before it’s drill, baby, drill.”

Preliminary mapping has identified several U.S. regions with strong potential for geologic hydrogen (Figure 2).^e These include the midcontinent region, covering parts of Kansas, Iowa, Minnesota, and Michigan; the Four Corners region of Arizona, Colorado, New Mexico, and Utah; the central California coast; and areas along the East Coast. While these areas are geologically diverse, they share conditions^f that could support the generation or accumulation of natural hydrogen underground.

This early mapping (Figure 2) marks an important first step toward identifying states and regions that could warrant government attention. Workshop participants commended the effort as a strong foundation for prioritizing early exploration but noted that the map is designed for broad regional assessment and carries significant uncertainty for site-specific project planning. It does not address extraction costs, site feasibility, or other critical information needed by developers. Future efforts could build upon this important baseline by producing higher-resolution maps, integrating reservoir and seal analyses, incorporating access considerations, and systematically reinterpreting legacy subsurface data for hydrogen-specific indicators.

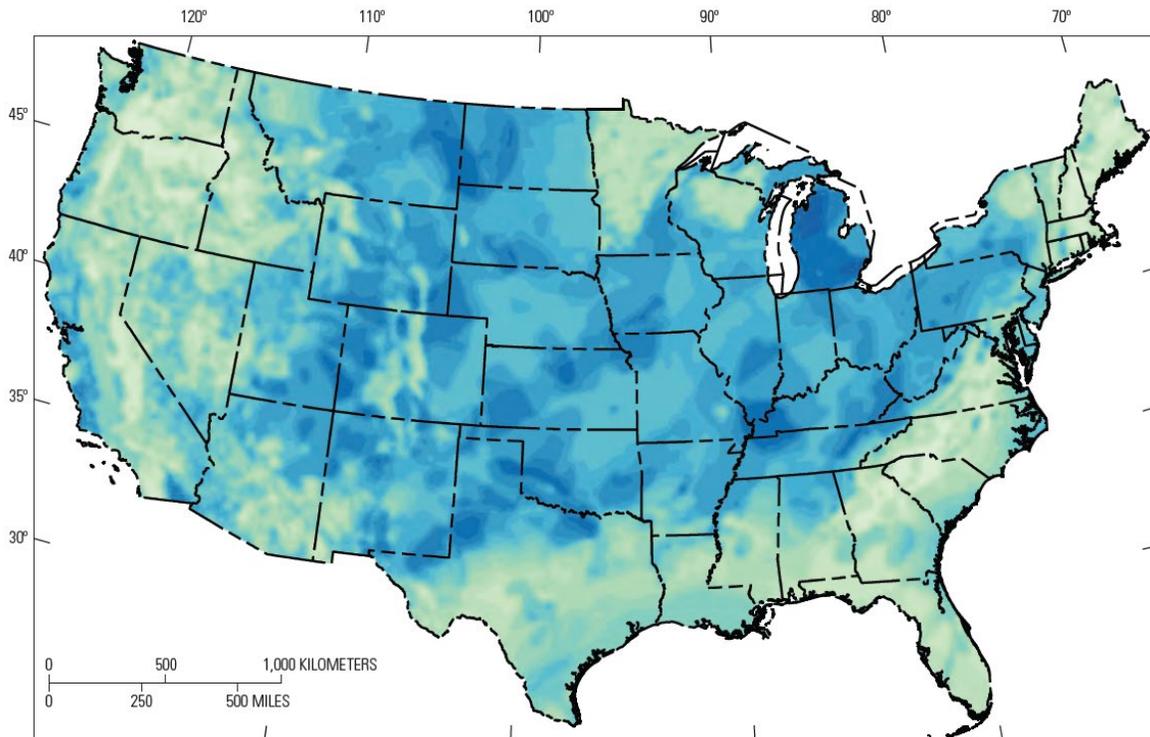
“‘Everyone who drills will find hydrogen.’ The real question is—how much?”

^d Energy-equivalent basis means comparing different fuels based on the amount of usable energy they deliver, typically measured in units such as British thermal units (Btu) or megajoules (MJ), rather than by volume or mass alone.

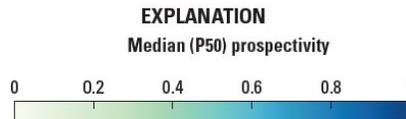
^e See Table 1 for the different sources of geologic hydrogen. In this context, "geologic hydrogen" is also commonly called "natural hydrogen accumulations."

^f These regions often feature iron-rich rocks, ancient and stable geologic formations, faults and fractures that enable hydrogen migration, and sedimentary basins or salt structures that can trap and preserve hydrogen underground.

Figure 2. Multiple U.S. regions may host untapped natural hydrogen resources



Base from U.S. Geological Survey, The National Map, 2021
 Albers Equal-Area Conic, U.S. Geological Survey contiguous United States projection
 North American Datum of 1983



This map highlights regions in the United States that show promising potential for underground natural hydrogen. The darker blue areas represent higher potential, based on early modeling of geologic conditions like rock type, fault structures, and historical tectonic activity. Source: U.S. Geological Survey, “USGS Releases First-Ever Map of Potential Geologic Hydrogen in the U.S.,” news release, January 16, 2025, <https://www.usgs.gov/news/national-news-release/usgs-releases-first-ever-map-potential-geologic-hydrogen-us>.

III. Uncertainty Is Huge But Potential is Even Larger

Despite the scale of the opportunity, uncertainties remain. Key barriers include the limited availability and high cost of essential geologic data, as well as environmental and technical uncertainties. Without focused federal and state action, including R&D that elevates geologic hydrogen as a priority program area, these challenges could cause major delays in progress.

Data Limitations

Some early private-sector exploration is underway in regions with historical oil and gas activity where public or private datasets are available. However, according to participants, these areas do not always overlap with the most promising geology for hydrogen. Other high-potential regions are being neglected, not because of a lack of natural resources, but because the necessary pre-competitive data are unavailable or too expensive for companies to collect independently.

Depending on the state, geologic data can remain confidential for anywhere from 18 months to five years.^{9,10} One participant noted that a vast archive of subsurface geophysical data, especially 2D seismic surveys, exists but remains effectively inaccessible because of high licensing fees. “There’s a humongous treasure trove we can’t get our hands on because it’s tens of millions [of dollars],” the participant explained. “The state needs to get [the] budget to buy it and release it publicly.” This lack of accessible data slows progress and raises costs, making it harder to identify viable resources or plan early-stage development effectively.

“The data is the business.”

Companies have little reason to share data voluntarily, since it is central to their exploration strategy. As one participant put it, “The data is the business.” These protections and the broader reluctance to share data are understandable from a commercial standpoint, but they nevertheless limit opportunities to build a shared knowledge base and reduce duplication across projects. The high commercial stakes make it unlikely that private companies will want to share data in a timely way.

Unresolved Environmental Questions

“It should be absolutely clear what the issues and mitigations are. ... We’re not hiding. There’s nothing to scoop under the carpet. Let’s have that conversation super early on.”

There are open technical and environmental questions that the field will need to address as development progresses. Key uncertainties remain around materials compatibility in wells and pipelines, potential impacts on aquifers and microbial communities, and whether certain development methods could trigger seismic activity.

Additionally, scientists have observed that hydrogen naturally seeps from underground into the atmosphere, but the rates and locations of this natural leakage are still poorly

understood. Current research shows that while some hydrogen is trapped underground like natural gas, a portion may escape through faults or porous rocks over time. In addition, early studies suggest that producing geologic hydrogen could create fugitive emissions (e.g., small leaks during drilling, production, or processing) that could reduce the overall climate benefits if not carefully controlled.^{11,12}

Crafting an R&D Roadmap

A dedicated R&D roadmap—with clear timelines, milestones, and agency roles—could begin to answer some of these outstanding questions. Participants identified the upcoming update to the *U.S. National Hydrogen Strategy and Roadmap* as a key opportunity to formally embed a geologic hydrogen R&D roadmap within the broader federal hydrogen strategy. While the current strategy mentions geologic hydrogen only briefly, the three-year statutory update due next year offers a natural entry point to embed a focused geologic hydrogen R&D agenda within the broader federal approach.

The *U.S. National Hydrogen Strategy and Roadmap* sets a federal vision to scale clean hydrogen for deep decarbonization, targeting 10 megatons of production by 2030 and 50 megatons by 2050. It focuses on three strategies: prioritizing high-impact, hard-to-electrify sectors (like industry and heavy transport); reducing the cost of clean hydrogen to \$1 per kilogram; and building regional hydrogen hubs.¹³ It provides a clear signal to stakeholders about the government's priorities for hydrogen development and indicates where public funding and private investment opportunities are expected to concentrate in the coming years.

As the roadmap is updated, it could also outline strategies to address outstanding challenges. For example, to improve data access, participants suggested that the federal government could offer targeted incentives—such as tax breaks, preferential access to public lands, or conditions tied to federal research funding—to encourage companies to share geologic data. At the same time, a coordinated R&D effort could advance understanding of critical environmental and technical questions, including impacts on groundwater, materials compatibility, and potential fugitive emissions. Together, these efforts would reduce early-stage risks and accelerate the development of a viable geologic hydrogen industry.

Recommendations

- Congress should offer additional incentives—such as bonus tax credits, public land access, or expanded grant eligibility—for companies that voluntarily choose to share data, while keeping data sharing optional and not a requirement for baseline incentive eligibility.
- The federal government should prioritize R&D to address environmental uncertainties, including impacts on groundwater, microbial life, fugitive emissions, and potential seismicity.

- The Department of Energy (DOE) should embed a dedicated geologic hydrogen R&D roadmap in the upcoming update of the *U.S. National Hydrogen Strategy* to formalize agency roles and timelines.

IV. Clear, Streamlined Rules Will Expedite Exploration

Clear regulation is essential to reducing risk and uncertainty and attracting investment in geologic hydrogen. Workshop participants discussed the need to define geologic hydrogen within existing legal systems, streamline permitting processes, and avoid premature or overly burdensome regulation that could stall innovation. As one participant stated, “Regulators’ job is to lay out clear rules of the road—certainty is what enables investment.”

Defining Geologic Hydrogen in Law

Geologic hydrogen exists in a legal and regulatory void, with no clear definition under federal mining or oil and gas laws and inconsistent definitions at the state level. Establishing a clear legal definition for geologic hydrogen could catalyze development by clarifying how and if existing regulations apply. Consistent adoption across states would amplify this impact by reducing regulatory uncertainty and enabling more coordinated project deployment.

“Increasing the ‘shots on goal’ takes substantial capital. Government has a role, but attracting private investment will depend on providing clarity.”

One major source of ambiguity stems from the Mineral Leasing Act of 1920, which governs the leasing of certain subsurface resources on federal lands. Geologic hydrogen is not explicitly covered under the act.¹⁴ Because the act authorizes leasing for specific resources like oil, natural gas, and coal, but does not mention hydrogen, there is regulatory uncertainty around whether federal agencies like the Bureau of Land Management can lease public lands for hydrogen exploration and production. Without clarification from Congress or agency rulemaking, developers face uncertainty over ownership, leasing rights, and operational frameworks for hydrogen on federal lands.

Workshop participants also emphasized the need for a clear federal definition of “stimulation” in geologic hydrogen production, distinguishing it from naturally occurring hydrogen. As one participant noted, “It’d be really important from the federal side to identify or define what exactly stimulation is and what it’s not.” Because stimulated hydrogen is artificially created, it raises questions about ownership and mineral rights. In other words, do owners’ rights accrue to the person whose land is used to create

(stimulate) the hydrogen or the person creating it? Though stimulated hydrogen is likely still years away, proactive planning can expedite early exploration efforts.

“It would be really important for the federal government to clearly define what ‘stimulation’ means... clarifying stimulation could help states understand where regulation, especially around mineral rights, might come into play.”

Some states have begun to address this regulatory uncertainty. These early moves are not uniform, but they demonstrate a range of practical approaches that could inform future federal and interstate coordination. In 2024, for instance, Iowa revised its statutory definition of “gas” to include “all naturally occurring gases.”¹⁵ Similarly, Minnesota updated its regulations to classify gas as “both hydrocarbon and nonhydrocarbon gases.”¹⁶ Other states have yet to define it, leaving open questions about which regulations it would be subject to, particularly from a permitting perspective. As of this writing, the EFI Foundation is not aware of any states that have defined “stimulation” either.

Clarifying Permitting Pathways

Setting clear guidelines for permitting is essential to accelerating geologic hydrogen exploration. Permitting frameworks will likely differ between natural hydrogen accumulations—where near-term activity is focused—and stimulated production methods. Workshop participants emphasized that immediate permitting efforts should prioritize exploratory drilling for natural accumulations, while permitting frameworks for stimulation can be treated as a longer-term concern as the technology matures.

For exploratory drilling targeting natural accumulations, permitting would typically fall under conventional state oil and gas regulations, not the federal Environmental Protection Agency’s (EPA) Underground Injection Control (UIC) program. UIC permitting becomes relevant only if fluids are injected for stimulation, enhanced recovery, or underground storage.

Navigating the UIC System: Class II, Class V, and Lessons from Class VI

Within the UIC system, wells are categorized based on purpose and fluid type. Class II wells are used to inject fluids associated with oil and natural gas production, while Class V covers a broad range of experimental or low-risk injection wells that do not fit into other categories.⁹ Class V is often used initially because hydrogen stimulation is still

⁹ Other well classes are I: used to inject hazardous and nonhazardous wastes into deep, isolated rock formations; III: used to inject fluids to dissolve and extract minerals; IV: shallow wells used to inject

nascent and exploratory, and no dedicated well class exists. As the industry scales, experts argue that Class II can also be used—especially when fluids are injected under pressure to release subsurface hydrogen, similar to enhanced oil recovery.

Participants also warned that permitting delays experienced under the Class VI program for carbon dioxide (CO₂) sequestration should serve as a cautionary lesson for geologic hydrogen: “Let’s avoid Class VI permitting regulations as being overly burdensome.” Class VI permitting has sometimes exceeded five years, stalling project development. As of April 2024, the EPA had issued only eight Class VI permits over a 13-year period.^{h,17}

“From a regulatory standpoint, development isn’t just chasing the shortest permitting timelines—it’s going where the process is most predictable.”

In response to these delays, several states have pursued Class VI primacyⁱ to streamline permitting, with North Dakota, Wyoming, West Virginia, and Louisiana securing primacy by April 2025.¹⁸ This trend toward state-led regulation reflects a broader effort to enable more efficient and responsive project development.

State Primacy

For states that hold primacy over relevant UIC well classes, this authority can allow for more streamlined and responsive permitting processes compared to federal pathways. Several participants emphasized that obtaining or expanding primacy can be a strategic advantage in reducing delays and attracting early-stage projects.

For instance, Nebraska is regulating hydrogen wells under its existing oil and gas framework by treating them as Class II UIC wells. Because Nebraska holds primacy over Class II wells, it can manage hydrogen permitting internally without relying on federal agencies¹⁹—offering a potentially more efficient path forward for early projects.

hazardous or radioactive wastes into or above a geologic formation that contains an underwater source of drinking water; VI: used in CO₂ geologic sequestration.

^h To address some of these regulatory inconsistencies and technical gaps, workshop participants also discussed the possibility of establishing a new well class, or a dedicated subclass within Class V, specifically for geologic hydrogen. While Class V offers flexibility, it lacks technical requirements tailored to hydrogen’s mobility and reactivity. A dedicated well class or subclass could allow regulators to develop standards that better protect groundwater, improve operational safety, provide more consistent permitting requirements across states, and build greater public confidence in early stage drilling. However, the timeline to create a new well class can be quite lengthy. For example, developing the Class VI rule for CO₂ sequestration took approximately five years of formal regulatory action, following several years of research, technical analysis, and public engagement. Establishing a hydrogen-specific well class would likely require a similar timeline.

ⁱ Primacy allows states to take over implementation of the UIC program from the EPA.

Even with state primacy, however, challenges remain. Developers noted that permitting delays can arise both between and within states, as differences in timelines, technical standards, and agency coordination can create confusion, increase costs, and slow project development.

Avoiding Regulatory Bottlenecks

In addition to streamlining permitting structures, workshop participants emphasized the importance of minimizing unnecessary regulatory hurdles during early-stage exploration, particularly under federal environmental review requirements.

Workshop participants also noted, for instance, that early-stage environmental review could be streamlined through categorical exclusions under the National Environmental Policy Act (NEPA) of 1970, building on models used in the geothermal sector. They pointed to examples from the geothermal sector, where low-impact activities such as drilling shallow exploratory wells, conducting geophysical and geochemical surveys, building small-scale infrastructure, and performing baseline environmental monitoring are categorically excluded from full NEPA review, provided they do not trigger extraordinary circumstances.^{20,21}

Participants suggested that agencies could adapt similar exclusions for geologic hydrogen to lower barriers for new entrants, accelerate early data collection, and reduce permitting delays. More detailed Environmental Assessments or Environmental Impact Statements would still be required for higher-risk or larger-scale projects.

Finally, participants cautioned against prematurely layering heavy regulation onto a still-nascent industry. Overregulation at this stage—before the basic viability of the resource is proven—risks stalling innovation, discouraging private investment, and undermining the exploratory momentum now building in the United States.

Recommendations

- States that do not currently have primacy over Class II UIC programs should seek it.
- The EPA should update definitions to ensure that stimulation methods for geologic hydrogen fall under the existing Class II well category.
- State oil and gas regulators should assess whether statewide oil and gas regulations are fit for geologic hydrogen exploration and update them as necessary.
- Congress, federal agencies, and state legislatures should update relevant definitions (e.g., for “gas”) to explicitly include geologic hydrogen.

- The Council on Environmental Quality^j and relevant federal agencies should develop a categorical exclusion for geologic hydrogen under NEPA.

V. Market Viability Depends on Co-Locating Demand and Production

“But if we go off and drill a massive well in Iowa, Kansas, or Colorado—and you can’t take it to market—then... what’s the point commercially?”

Developers already are looking to develop geologic hydrogen in the United States, not only because of its resource base but also because of its broader enabling environment, including established energy markets, infrastructure readiness, institutional capacity, and the opportunity to integrate hydrogen into existing industrial and energy systems.²²

Workshop participants emphasized that enabling a clear pathway to market is critical for the commercial viability of geologic hydrogen. The government could play a key role in supporting infrastructure by acting as a hydrogen offtaker through procurement or supporting offtake programs.

Avoiding Stranded Resources

Ultimately, without a clear path to monetization and infrastructure development, even the most promising hydrogen discoveries risk being left undeveloped, becoming a “stranded gas.” Co-location of hydrogen production with demand centers or existing infrastructure can help mitigate this risk.

Mining emerged as a particularly strong candidate for early co-location, given its substantial on-site energy needs and the geographic overlap between hydrogen-bearing formations and critical mineral or base metal deposits.²³ With energy costs accounting for a significant portion of mining expenses—often ranging from 15% to 40% of operating costs—a clean, on-site hydrogen supply could help power operations such as drilling, ore processing, and heavy vehicle transport.²⁴ Using hydrogen in place of diesel or grid electricity could reduce emissions and operating costs, making it an attractive energy solution for the mining sector. Other co-location opportunities can be identified using the Hydrogen Transition Framework (HyTF).

^j The Council on Environmental Quality oversees NEPA implementation.

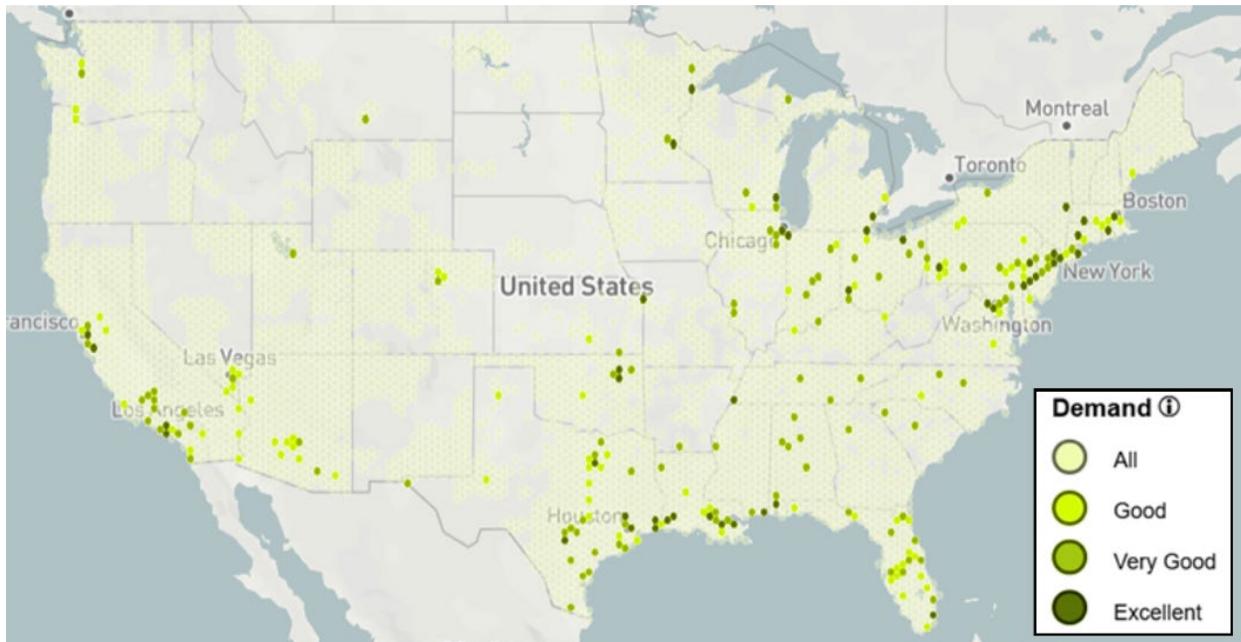
HyTF as a Tool for Identifying Demand Centers for Geologic Hydrogen

HyTF is a geospatial tool developed by the EFI Foundation to help identify where hydrogen demand exists or could grow—making it useful for targeting geologic hydrogen opportunities.

Using data from more than 11,000 sites, HyTF currently maps how local resources, infrastructure, and market factors support hydrogen deployment across the United States. It covers the full value chain, including supply, infrastructure, workforce, and demand, and offers insights for developers, policymakers, and investors. The demand layer in HyTF (Figure 3) tracks both current and future uses—all candidates for geologic hydrogen consumption.

The current version of HyTF can be further updated to guide geologic hydrogen siting, infrastructure planning, and investment by adding subsurface data and exploration results.

Figure 3. Demand layer in the EFI Foundation’s Hydrogen Transition Framework (HyTF)



HyTF ranks areas as Excellent, Very Good, Good, or All based on how many key elements they have to support hydrogen market development. Areas classified as All have some relevant elements but lack the concentration of activity needed to qualify as Good. Source: EFI Foundation.

Recommendations

- Geologic hydrogen companies should prioritize co-locating production with industrial demand centers to reduce transport costs and avoid stranded resources.

- Congress, DOE, and state agencies should leverage their procurement power to act as early offtakers and support programs that help establish reliable hydrogen demand.
- Developers pursuing geologic hydrogen production should use the EFI Foundation’s HyTF to identify and prioritize co-location opportunities near industrial demand centers.

VI. Federal-State Coordination Is a Critical Foundation

“When we look at some of these frontier areas, we need investment in partnership with the federal government to know more about the [state] resources we have.”

Advancing geologic hydrogen will require speed and coordination. This means taking more calculated risks by testing early, learning quickly, and adapting as new information becomes available. At the same time, this kind of innovation must be supported by collaborative research and clear regulatory frameworks.

As one participant put it: “Test often, fail fast, and pivot quickly.” Moving quickly must also mean moving together—with federal and state governments aligned on roles, responsibilities, and the knowledge needed to manage uncertainty and guide responsible development.

Complementary Roles are Emerging

States are progressing at different speeds and using varied strategies. As one participant noted, “Every state is different—and they will not agree on how to regulate hydrogen.” Still, there was broad consensus that maintaining state leadership is critical for effective development, allowing each state to choose regulatory pathways that fit local needs.

Some states are already moving forward. Minnesota, for example, recently released recommendations for permitting geologic hydrogen development, including a requirement that exploratory wells that find gas must be sealed and cannot be converted into production wells by private developers.²⁵ Companies would need to post financial assurance to guarantee cleanup of exploration, and landowners would be protected through rules ensuring fair compensation if their mineral rights are used.²⁶

A Model for Federal-State Partnerships

Developing geologic hydrogen resources will require strong coordination between federal and state governments. Participants emphasized that while states should lead in regulating resource development, federal support is critical for providing the scientific foundation needed to inform state decision-making. Participants identified a complementary federal-state model:

- The federal government would focus on research and data generation, particularly through agencies like the U.S. Geological Survey (USGS) and the national labs.
- States would be primarily responsible for regulating exploration and production, tailoring their approaches to geologic, environmental, and economic conditions.

“We have resource assessment expertise at the state level, but not the kind of deep scientific capacity you find at the national labs.”

Existing models demonstrate how federal and state governments can successfully collaborate on subsurface resource management. One example is the STATEMAP program, part of the USGS National Cooperative Geologic Mapping Program. STATEMAP funds state geological surveys to produce detailed maps that support resource exploration, environmental management, and land-use planning. The program's success is attributed to its collaborative approach, involving partnerships between the USGS, state geological surveys, and academic institutions.^{27,k} A similar federal-state collaboration model could support geologic hydrogen exploration by funding state-led geological assessments that specifically identify and validate the resource.

Recommendations

- Congress should expand the USGS STATEMAP program to fund state-led mapping and assessment of geologic hydrogen resources, as the program's scope cannot be modified without congressional action.
- DOE, the USGS, and other federal agencies should establish structured partnerships with state geological surveys and research institutions to coordinate data generation, regulation, and exploration efforts.

^k Although STATEMAP has not focused specifically on geologic hydrogen, it demonstrates a collaborative model where the federal government provides funding, technical support, and coordination, while states lead data collection and mapping based on local needs. This structure could be adapted to support geologic hydrogen development.

VII. Public Funding Must De-Risk Early-Stage Investment

Participants estimated that approximately \$500 million in funding will be needed to catalyze the next phase of geologic hydrogen development—and that it is unlikely to come from venture capital. Public investment is critical to reducing uncertainty, attracting private capital, and enabling timely progress toward commercialization. Federal support could be structured to encourage multiple “shots on goal” in early exploration, recognizing the high risk of dry holes and the need to avoid premature conclusions about viability.

Use Strategic Incentives to Unlock Capital Flows

Workshop participants identified several targeted policy levers that could unlock private investment and de-risk early-stage geologic hydrogen development.

Exploration tax credits—modeled on those used in the U.S. mineral sector or Norway’s dry-hole incentive—could help offset the high up-front costs and technical uncertainty of exploratory drilling. Until 2022, Norway’s model allowed oil and gas companies to receive cash refunds for a portion of exploration expenses, including in cases where wells were nonproductive, effectively reducing downside risk for early exploration efforts.^{28,29}

Eligibility Under 45V

Participants emphasized the importance of making geologic hydrogen explicitly eligible under the Section 45V clean hydrogen production tax credit, which offers up to \$3 per kilogram of hydrogen produced, depending on life cycle greenhouse gas emissions. Including geologic hydrogen under 45V would ensure it competes on a level playing field with other production pathways, such as electrolysis. However, some participants cautioned that if production volumes from geologic hydrogen are as high as some projections suggest, it could pose significant fiscal challenges under the current tax credit structure.

IDC Deductions: Aligning With Subsurface Realities

Finally, applying intangible drilling cost (IDC) deductions was recommended for geologic hydrogen. IDCs include non-salvageable expenses, such as wages, fuel, supplies, and site preparation, incurred during the drilling and development of oil, gas, or geothermal wells. These are one-time, consumed costs that are essential to preparing a well but have no resale or recovery value once the work is complete. Although these costs are typically treated as capital expenditures, taxpayers have two options for cost recovery. They may deduct IDCs as current business expenses in the year the costs are incurred, or they can amortize the costs over 60 months, starting when the expenses were paid or incurred.

Taxpayers elect to deduct IDCs by claiming the deduction on a tax return. If a well turns out to be nonproductive and the taxpayer has capitalized the IDCs, those costs may be deducted as an ordinary loss in the year the well is completed.³⁰

Congress or the IRS could extend IDC treatment to geologic hydrogen to offer immediate tax relief for early investments, ease the financial burden of exploratory drilling, and reduce risk for first movers. Even if wells are nonproductive, allowing the recovery of non-salvageable costs would help mitigate losses and create a stronger incentive for early participation in the sector.

Collaborative Efforts With the Private Sector

Moving from the lab to the field is critical, and piloting efforts must begin without delay. Several participants recommended funding multi-well pilot projects across two to three distinct geologic settings to validate resource models and test production methods.

“The geologic understanding is still in its infancy. That’s okay. What unlocks it is clear: lots of drilling, geophysics, data, and planned exploration. There’s a gap right now, and piloting needs to start as soon as possible.”

Collaborative R&D models such as DOE-funded geothermal pilots and the Hydraulic Fracture Test Site (HFTS) in the Permian Basin illustrate how public investment can lower financial barriers and generate open-access data in subsurface energy development.^{31,32} These programs pair DOE funding with national lab and industry expertise to conduct field-scale demonstrations that are too risky or costly for private companies to undertake alone.

In the case of geothermal, DOE has supported drilling and data collection in high-potential areas. Similarly, HFTS established collaborative test beds to study hydraulic fracturing performance across multiple wells and geologies, enabling detailed reservoir characterization and advanced monitoring. Modeling early-stage geologic hydrogen efforts on these programs could provide a coordinated framework for validating resource potential, understanding subsurface behavior, and informing regulatory decisions such as appropriate well classifications (e.g., Class V vs. Class VI).

Recommendations

- Congress should include geologic hydrogen in the 45V tax credit but add volume caps to manage fiscal risk.
- Congress should amend the Internal Revenue Code to extend intangible drilling cost (IDC) deductions to geologic hydrogen projects.

- Congress should create a geologic hydrogen exploration tax credit or dry-hole mitigation incentive.
- DOE should fund multi-well geologic hydrogen pilots with requirements for open-access data sharing.

VIII. Build Support Through Messaging and Collective Action

Building a new industry is not just about resource potential or technology readiness. It is also about people. Success depends on an informed workforce, capable regulatory agencies, and public trust.

Support from the broader public hinges on clear, early, and accessible communication. Misunderstanding or lack of transparency about the risks of a project can quickly fuel resistance. Participants emphasized that community engagement must be structured as an ongoing dialogue. Effective messaging should demystify the science, address local concerns directly, and invite communities into the development process.

Workforce Capacity Building

Just as local communities need clear, credible information to build trust, so does the workforce. Workers are not only implementers, they are messengers. A well-informed workforce strengthens public confidence and ensures safe, effective deployment on the ground.

However, the hydrogen industry currently faces a workforce readiness gap. Several participants noted that federal and state permitting programs, which will oversee much of the regulatory review, may experience staffing shortages. Recruiting qualified geologists, hydrologists, engineers, and technical experts into public agencies is already difficult, particularly when public-sector salaries cannot compete with private industry. Without targeted investment in agency capacity, permitting timelines could slow, increasing uncertainty for developers and communities alike. As one participant put it, “If government is going to be an accelerator, we need more human capital.”

Many technical skills from the oil and gas sector—such as drilling, reservoir management, and subsurface operations—are directly transferable to building the broader hydrogen workforce. However, hydrogen introduces new safety standards, materials handling requirements, and monitoring practices that will require additional training and specialization. “We don’t have much of a hydrogen workforce,” one participant observed. “We need to expedite that if we’re going to take advantage.”

“We have a workforce in this country that understands the subsurface, pipelines, and many of the critical skill sets needed for this industry.”

There is reason for optimism. The United States already leads in many of the core disciplines needed to support geologic hydrogen production. As one participant summarized, “At the end of the day, it’s about drilling a hole. There’s no one better at that than the United States.” However, capitalizing on that advantage will require building a workforce that understands traditional subsurface practices and the specific demands of hydrogen handling and storage.

Interstate Learning: Sharing What Works

Many participants emphasized the value of interstate collaboration. While some states have deep institutional knowledge in subsurface energy development and regulation, others are starting from a limited base. Rather than building new systems from scratch, participants suggested, less experienced states should look to those with more robust infrastructures and experience. “Rather than try to reinvent the wheel,” one participant said, “states without a lot of experience should rely on states that have a significant amount of experience.”

This collaboration already appears to be taking root. Several participants observed that there is “a good collaborative spirit for helping and sharing,” especially as more states begin engaging with hydrogen. Establishing formal pathways for peer-to-peer exchange could help institutionalize this cooperation and reduce the learning curve for newcomers.

Recommendations

- States, community colleges, vocational schools, labor unions, and universities should work together to create and implement workforce development programs.
- A newly designated federal entity should establish a working group of state, federal, and private-sector stakeholders to coordinate learning, develop shared messaging, and support the development of best practices to guide responsible exploration and deployment.

IX. Conclusion: A Narrow Window for U.S. Leadership

The promise of geologic hydrogen is real—but it remains unproven. Early discoveries around the world have captured imaginations, but realizing the full potential of this resource will require the United States to act decisively. Without near-term public investment, regulatory clarity, infrastructure planning, and research coordination, the U.S. risks missing a unique opportunity to lead in a field where it holds a strong natural and technical advantage.

If successful, geologic hydrogen could supply low-cost, zero-carbon fuel at scale—helping to decarbonize hard-to-electrify sectors like steel, fertilizer, long-haul transport, and industrial heat. As a distributed resource, it also could reduce the infrastructure

bottlenecks faced by other clean energy technologies, offering regions across the country the chance to participate directly in the energy transition.

The United States is positioned to lead. It has world-class capabilities in drilling, subsurface resource management, geoscience, and data analytics. It has decades of experience in oil and gas, geothermal energy, and mining, and a rich ecosystem of national laboratories, universities, and service providers. These strengths provide the technical foundation needed to validate geologic hydrogen's potential and bring it to market faster and more efficiently than other countries.

Workshop participants emphasized that success requires urgent action on multiple fronts:

- Federal and state governments must establish clear legal definitions and permitting pathways to give developers confidence and attract early investment.
- Strategic public funding must de-risk early-stage exploration and incentivize data sharing to close critical information gaps.
- Infrastructure and market planning must be integrated from the outset to ensure that early production has a clear path to monetization.
- Workforce development must begin immediately to ensure permitting agencies, project developers, and communities have the expertise needed to engage with this resource safely and effectively.
- Community engagement must be early, transparent, and continuous, ensuring that development is both technically and socially sustainable.

The window for leadership is narrow. Other countries are moving quickly to assess their geologic hydrogen potential and build first-mover advantages. If the U.S. delays, it risks falling behind in a market where early leadership could define global standards, technical expertise, and commercial leadership for decades.

Geologic hydrogen presents a rare frontier moment in energy policy—an opportunity to apply America's traditional strengths in subsurface development to a globally significant clean energy resource. With modest investment, strategic coordination, and thoughtful governance, the United States can turn a once-overlooked natural phenomenon into a major pillar of economic competitiveness, energy security, and climate leadership.

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