

**OPPORTUNITIES AND CHALLENGES ASSOCIATED
WITH DEVELOPING GEOLOGIC HYDROGEN IN
THE UNITED STATES**

HEARING
BEFORE THE
COMMITTEE ON
ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE
ONE HUNDRED EIGHTEENTH CONGRESS
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CONTENTS

OPENING STATEMENTS

Manchin III, Hon. Joe, Chairman and a U.S. Senator from West Virginia	Page 1
Barrasso, Hon. John, Ranking Member and a U.S. Senator from Wyoming	5

WITNESSES

Wang, Hon. Dr. Evelyn N., Director, Advanced Research Projects Agency– Energy, U.S. Department of Energy	10
Ellis, Dr. Geoffrey S., Energy Resources Program Lead for Geologic Hydrogen, U.S. Geological Survey, U.S. Department of the Interior	15
Johnson, Pete, CEO and co-founder, Koloma	21

ALPHABETICAL LISTING AND APPENDIX MATERIAL SUBMITTED

Barrasso, Hon. John:	
Opening Statement	5
Economist article entitled “The Rush for Colourless Gold” published on December 23, 2023	7
Ellis, Dr. Geoffrey S.:	
Opening Statement	15
Written Testimony	17
Responses to Questions for the Record	45
Johnson, Pete:	
Opening Statement	21
Written Testimony	23
Responses to Questions for the Record	52
Manchin III, Hon. Joe:	
Opening Statement	1
Chart entitled “Selected Regional Clean Hydrogen Hubs”	3
Wang, Hon. Dr. Evelyn N.:	
Opening Statement	10
Written Testimony	12
Responses to Questions for the Record	40

OPPORTUNITIES AND CHALLENGES ASSOCIATED WITH DEVELOPING GEOLOGIC HYDROGEN IN THE UNITED STATES

WEDNESDAY, FEBRUARY 28, 2024

U.S. SENATE,
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Washington, DC.

The Committee met, pursuant to notice, at 10:00 a.m. in Room SD-366, Dirksen Senate Office Building, Hon. Joe Manchin III, Chairman of the Committee, presiding.

OPENING STATEMENT OF HON. JOE MANCHIN III, U.S. SENATOR FROM WEST VIRGINIA

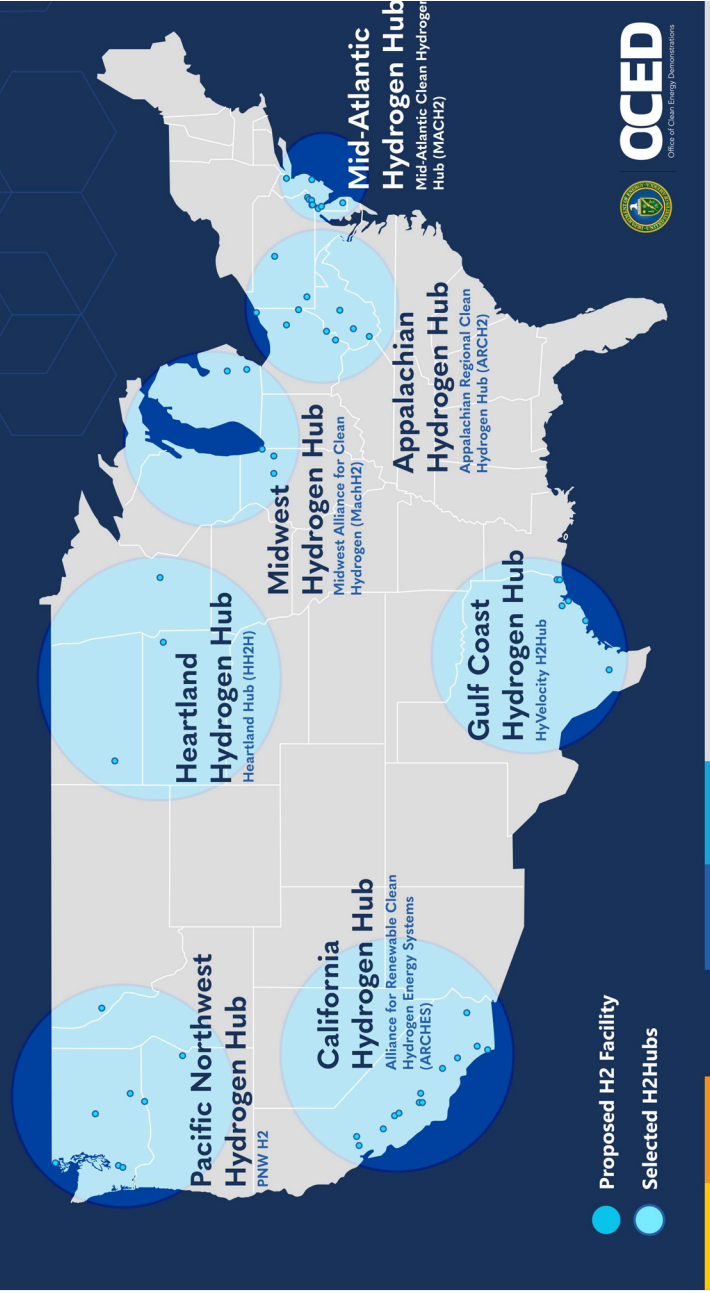
The CHAIRMAN. Today we are here to discuss the opportunities and challenges of developing geologic hydrogen, and that is hydrogen produced below the Earth's surface. We have not talked about geologic hydrogen in this Committee before, but it is gaining momentum and we must ensure the United States continues to lead the world in advanced energy technologies by using all of our abundant resources in the cleanest way possible, including all types of hydrogen to safeguard our country's energy security. I want to thank our witnesses for being here to provide their valuable perspective from the Administration and private sector on the opportunities for geologic hydrogen to become a part of America's energy system.

We have talked a lot about how hydrogen can give us the same horsepower as our baseload fossil fuels for industrial manufacturing, transportation, dispatchable electric power, and more. And industry knows it. In fact, the Department of Energy predicts demand for hydrogen to increase tenfold by 2030 in the United States, and it has the potential to decarbonize up to 25 percent of global energy emissions. The development of the hydrogen industry is also expected to promote new economic opportunities for Americans and create over 100,000 new good-paying jobs, particularly exciting for the areas that have historically carried the load of powering our nation such as West Virginia and Wyoming and New Mexico and Colorado. Now, hydrogen is not a new concept, but it was not nurtured in the same way some other energy technologies have been to get to maturity. Congress acted to rectify that and support exponential growth for the hydrogen industry by providing tools and incentives in the Bipartisan Infrastructure Law and the Inflation Reduction Act to help make all types of hydrogen cost competitive.

Specifically, this Committee provided DOE with \$8 billion to pursue hydrogen hub projects, and I think—do you want to put that up? We are going to keep this up for you all to see where they are located.

[Displayed chart follows:]

SELECTED REGIONAL CLEAN HYDROGEN HUBS



The CHAIRMAN. Those are the seven that have been awarded, the hydrogen hubs, which we are excited about—\$1.5 billion for hydrogen technology research and development and \$750 million for small- and medium-sized businesses to manufacture clean energy technologies like hydrogen in coal communities. We doubled down in the Inflation Reduction Act with the creation of the first-ever Clean Hydrogen Production Tax Credit to incentivize the production of clean hydrogen. Fast forward to today, and seven hydrogen hub projects have been chosen across 16 states representing ground zero of what will be a national clean hydrogen industry. West Virginia is proud to be partnered with the Appalachian Regional Clean Hydrogen Hub, known as ARCH2, as part of the DOE's hydrogen hub program. The impact of ARCH2 is substantial, with the project expected to result in over \$5 billion of new investment, thousands of new high-paying jobs, and public-private partnerships that will create a network for hydrogen manufacturing and production in West Virginia, and each of the other hubs have the same outcome, basically—expedition and expansion—that we are all expecting.

Now, I know many of our Committee members are excited about similar benefits that they are going to expect also. But the laws we passed will only be successful if this Administration implements them as written and abandons its efforts to impose extreme limitations on the hydrogen tax credit that weren't included—were never considered, were never even talked about in the law. They were all made up. And we are not going to stand for it. This is an egregious example of an agency overstepping the authorities Congress has provided for them. Nowhere, as I said before, in the IRA will you find language authorizing Treasury to limit hydrogen credits only to those producers who get energy from additional new power plants, or to require producers to match the hour of power generation with the hour of hydrogen production, or to restrict the location where electricity for hydrogen is sourced from. Can you imagine building and investing the billions of dollars it will take for the electrolyzers that run 24/7 and expecting wind and solar to power them 24 hours a day? It doesn't make any sense at all. And unfortunately, the hydrogen tax credit is just one example in a long line of the Administration trying to implement the law that they wanted, not the one that we passed.

The Administration takes the most liberal view possible for credits that benefit the industries the extreme Left likes—like EVs and solar—and the most restrictive view possible when it comes to incentives for industries that these activists oppose—like hydrogen and critical mineral production credits. In this case, the Administration initially celebrated the announcement of the hub awards, and we all have, and the jobs that are going to be created. However, now they have bent to pressure to obstruct hydrogen development, which will kill every one—every one of these and the progress that was intended and that was being made. Just this week, all seven hydrogen hubs, again, representing major investments in 16 states, wrote to the Administration urging them to change course on proposed rules for the hydrogen tax credits that threaten the success of the hubs. I want you to know, this is the first time, I think, in my long line of public service that I have ever

had California—a hydrogen hub in California agree with the hydrogen hub in Appalachia. It has never happened before. So, to have all of us on the same page tells you how serious this is. I am glad the hubs are making their concerns known. I am going to support them every step of the way, pushing back on the Administration's unlawful proposal. And I think all of us that represent these areas where the hubs are located feel the same.

Let me now pivot back to geologic hydrogen and the spur of new activity we are seeing, both to map and access naturally occurring hydrogen underground, and to develop ways of producing hydrogen underground. Knowing where the hydrogen reserves are is fundamental to advancing geologic hydrogen as an energy source to help meet the nation's future energy needs. The USGS Energy Resources Program maps and conducts scientific research on geological resources and their supply chains, including geologic hydrogen. Specifically, Earth MRI, the USGS mapping program that was authorized in the Bipartisan Infrastructure Law, provides essential data for identifying areas with mineral and geological hydrogen potential. Meanwhile, the Advanced Research Projects Agency–Energy at the Department of Energy, better known by its acronym ARPA-E, recently announced 16 new geologic hydrogen projects awarded to universities, national labs, and companies that will propel innovation and growth in the geologic hydrogen industry. I am pleased to say that Shepherdstown, West Virginia will be hosting ARPA-E's Geologic Hydrogen Kickoff event in May. This event will serve as the launch point for numerous new ARPA-E and other federally funded geological hydrogen projects. As America's energy powerhouse, West Virginia is excited to be supporting these advanced energy technologies.

With all that we have accomplished through recent legislation, I know this Committee remains committed to fostering the growth of hydrogen in the United States due to its potential to reshape our energy landscape, create economic opportunities, and contribute to ensuring our energy security. We look forward to continuing our work with the DOE, the USGS, and the private sector in this area, and I look forward to hearing our witnesses' perspectives today on advancing geologic hydrogen.

With that, I am going to turn to Ranking Member Barrasso for his opening remarks.

**OPENING STATEMENT OF HON. JOHN BARRASSO,
U.S. SENATOR FROM WYOMING**

Senator BARRASSO. Well, thank you so much, Mr. Chairman, and thank you for holding today's hearing.

The Energy Information Administration projects that the world demand for energy is going to increase by 34 percent by the year 2050. To meet this demand, our nation is going to need more of every type of energy, and that includes hydrogen. Hydrogen offers many advantages. It is light and abundant. It is especially energy dense. Hydrogen, also, is very clean. When combusted with oxygen, hydrogen emits only water vapor and warm air. It is widely believed that we will need hydrogen in order to reduce emissions in sectors of the economy that use large amounts of energy. That includes steel, concrete production, transportation, and electricity

generation. For years, our attention on hydrogen production has been focused on using natural gas or cracking water through a process called electrolysis. Today, we are going to look at the potential to tap underground deposits of pure hydrogen, also known as geologic hydrogen.

Geologic hydrogen is formed when water reacts with iron-rich rock at high temperatures underground. Scientists have long known that water and iron-rich rock produce hydrogen. Until recently, they believed that hydrogen would not remain in a pure state for very long. They believed hydrogen would bond with other elements like oxygen to form water or carbon to form hydrocarbons. They believed that hydrogen would be eaten by microbes or escape to the surface and into the atmosphere. Scientists have recently found that in some areas, deposits of pure hydrogen can remain trapped. When this happens, the hydrogen accumulates. And if enough hydrogen accumulates, the hydrogen can be extracted, like oil and gas. The scientific community and private sector are cautiously optimistic that the world contains large reserves of geologic hydrogen. Dr. Ellis, one of our witnesses, has estimated that even if just a small fraction of these reserves is economically recoverable, it would meet the world's projected demand for hydrogen for hundreds of years.

In December, The Economist ran an article about geologic hydrogen. Mr. Chairman, right here—"The Rush for Colourless Gold." The Economist has a diagram of how they do that. It is a very, very thorough, good article.

[The article referred to follows:]

DRILLING FOR HYDROGEN

THE RUSH FOR COLOURLESS GOLD

The boffins, barons and buccaneers searching for a clean fuel that could one day replace oil

I BELIEVE THAT water will one day be employed as fuel, that hydrogen and oxygen, which constitute it, used singly or together, will furnish an inexhaustible source of heat and light." So wrote Jules Verne in 1875. Visionaries and cranks have long searched for cheap ways to manufacture hydrogen, with limited success. Now the world is once more hyperventilating about the simplest element, but with a twist. Some modern visionaries don't want to make it; they want to drill for it. A rush is starting for colourless gold.

Unlike actual gold, hydrogen is spectacularly useful. As a fuel, in theory it could power cars, buses, planes and ships. It could be burned in power plants, generating electricity. And because, unlike fossil fuels, it emits no greenhouse gases, it could help curb climate change (so long as it is cleanly obtained).

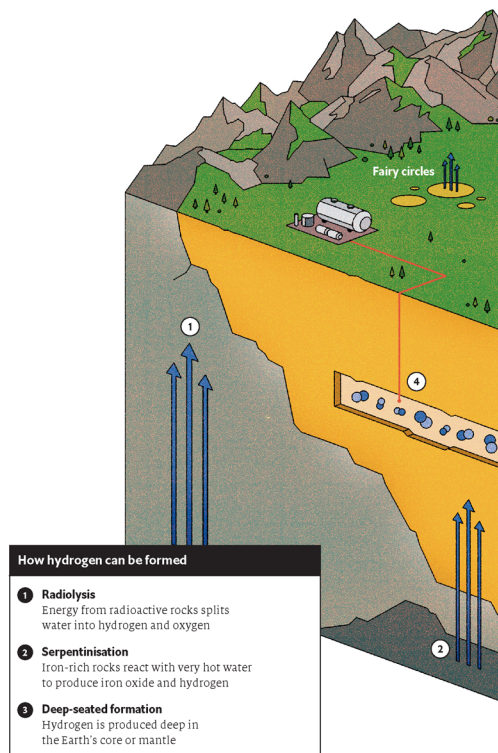
Governments are throwing subsidies at efforts to make hydrogen fuel. America's Inflation Reduction Act offers lavish support for producing it cleanly from fossil fuels (which involves the clunky process of capturing and sequestering the carbon dioxide by-product), as well as from carbon-free nuclear power and renewables (which requires lots of energy to split water into hydrogen and oxygen via electrolysis).

The snag is that making hydrogen in any of these ways is costly, and likely to remain so for years. Hydrogen is the most common element in the universe but, says America's National Renewable Energy Laboratory, "typically does not exist freely" on Earth. It is normally found bound up with oxygen, as water, or carbon, as hydrocarbons. Releasing the hydrogen can require lots of energy, complicated kit and hassle.

So a motley crew of hydrogen hunters are searching for "natural" (or "geological") hydrogen, which they believe is more common than is widely supposed. To those who dismiss them as dreamers, they point out that the notion of plentiful oil in the ground was once dismissed as crackpot, too.

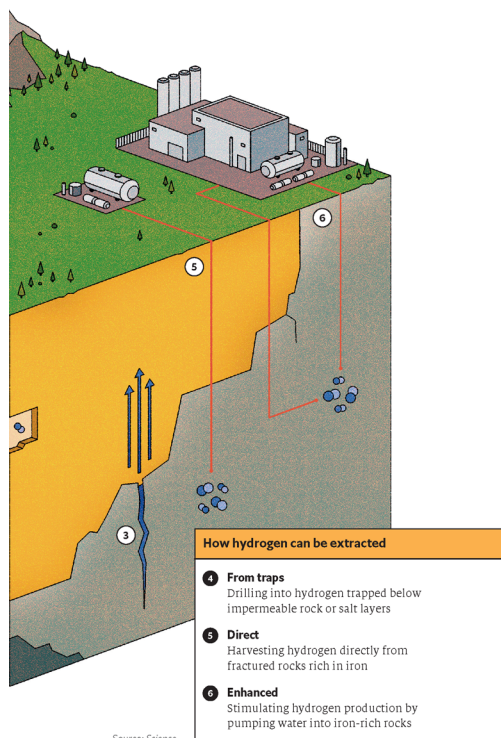
In the middle of the 19th century, the world faced an energy crisis. Whale oil was in short supply. Some thought petroleum might work as a replacement, but many attempts to dig for it had flopped. When Edwin Drake proposed drilling for oil in Pennsylvania, investors mocked the notion: "Oil coming out of the ground...? Nonsense! You're crazy." Then, one day in 1859, Drake hit a gusher, and the oil age began.

Could something similar happen with hydrogen? In a small way, it already has. In 1987 in Bourakebou-



gou, in a remote corner of Mali in West Africa, locals searching for water drilled 100m down and, since the hole was dry, gave up. Then, to their surprise, a mysterious emission from that hole caught fire. The well was quickly capped and forgotten—until a sparky local businessman came along.

"I want to be the king of hydrogen!" bellows Aliou Diallo. The son of a railway worker in Mali, Mr Diallo made his first fortune investing in distressed debt, parlayed those winnings into industrial concessions, and went on to acquire a gold mine. He has dabbled in politics, despite the dangers in a coup-prone country like Mali, running for president in 2018 and coming a respectable third. But now he has given up politics to concentrate on hydrogen.



By happenstance, the hydrogen-emitting hole in Bourakebougou was within an oil and gas concession that had been granted to a firm run by Mr Diallo. The villagers, seeing flames shooting out of the ground, assumed the place was cursed. Mr Diallo, who is not superstitious, decided to investigate. Tests confirmed that the well was producing 98%-pure hydrogen. Mr Diallo brought in equipment from Canada to do more drilling and testing. A coup in 2012 spooked outsiders, but he forged ahead. Now those villagers have reliable light and power day and night—a rarity in rural Mali.

The well tapped into a large reservoir of natural hydrogen that continues to flow to this day. Mr Diallo's firm drilled over two dozen more wells, from shallow ones akin to the first water well to ones 1,800m deep, to

map and master the geology. Hoping to replicate his success elsewhere, he has set up a firm called Hydroma in Canada to scour more stable countries for the gas. (Mali has had two more coups since 2020.) "Hydrogen is the gamechanger for humanity," he says.

He is no longer alone in this view. Hydrogen has been found in France, America, Brazil, Australia, Colombia and Oman (see map). A place in Turkey thought to be the location of the original Olympic flame has burned for millennia thanks to an energy source now known to be rich in hydrogen. The mid-Atlantic ridge and the African rift valley emit the gas. And mysterious surface formations known as "fairy circles", spotted in the Carolinas, Poland and western Australia, also appear to seep it.

Why have these hydrogen sources not previously been noticed? It may seem odd, but big oil firms never looked for hydrogen or deployed sensors to detect it. Geoffrey Ellis of the United States Geological Survey (USGS) adds that, as well as being odourless and colourless, the gas is often gobbled up by microbes below the surface. So prospectors may have to drill with the explicit intention of detecting hydrogen if they are to find what is hidden under their noses.

THE BENEFITS OF BAD SOVIET SCIENCE

In 2020 Viacheslav Zgonnik, a chemist of Ukrainian origin, published a review of academic literature showing that "molecular hydrogen is much more widespread in nature than was previously thought." Earlier Western scholars had focused on papers in English. Dr Zgonnik, who is fluent in Russian, scoured the undigitised, untranslated paper archives of the old Soviet Union for clues. After reviewing over 500 studies, he had a breakthrough.

Much of the relevant field research over the past century took place in the Soviet Union and was largely unknown to Western researchers. Soviet engineers often found hydrogen not because they wanted it but because they had a different (and now debunked) theory of how petroleum originates. They believed it was generated from inorganic matter rather than crunched-up dinosaur bones. On this view, carbon from the earth's mantle would interact with hydrogen deep underground to produce hydrocarbons, so it made sense to look for hydrogen as a telltale sign of petroleum.

There are, by one estimate, more than a dozen ways that hydrogen might occur naturally, but only a handful seem likely to yield commercially extractable deposits (see graphic). The most promising, says Dr Zgonnik, is serpentinisation: iron-rich rocks below the Earth's surface react with very hot water to produce iron oxide and hydrogen gas—in effect, rusting. This reaction has been well studied. Dr Zgonnik's company, Natural Hydrogen Energy, has identified a likely spot in Nebraska and drilled the world's first wildcat well for hydrogen, to a depth of some 3,400m. Though the pandemic and financial constraints have slowed it down ("very few investors are willing to take this kind of risk," he sighs), with new partners the firm plans to drill again soon at the site.

Another theory, deep-seated formation, holds that hydrogen is produced deep in the earth's core or mantle, and seeps up to the surface as it rides along cracks. Yet another, known as radiolysis, proposes that energy from radioactive rocks splits water into hydrogen and oxygen deep underground. However hydrogen is ▶▶

formed, its molecules are so small and slippery that it can easily seep its way to the surface unless it is either caught in a trap (say, under an impermeable salt layer) or consumed by microbes.

Since the publication of Dr Zgonnik's article, interest in hydrogen has been fizzing. The Geological Society of London attracted over 200 experts to a conference on the topic in July. America's Department of Energy, while still pumping billions into schemes to manufacture hydrogen, has come round to the view that "large quantities of geologic hydrogen [probably] exist in the Earth's subsurface." Dr Ellis of the usgs reckons there could be enough to power the global economy for centuries. The usgs will soon publish an assessment of the most promising locations—in other words, a treasure map.

The search for hydrogen is attracting millions of dollars in investment, says s&p Global, a financial-data firm. Australian explorers such as HyTerra and Gold Hydrogen have raised millions more through public offerings. Other efforts are funded by government grants or quiet money from oil and mining giants. Koloma, a secretive startup based in Denver, recently attracted \$9m in funding from the venture-investment arm of Breakthrough Energy, a climate-innovation organisation started by Bill Gates.

Talking to *The Economist* on the sidelines of the UN climate conference, Mr Gates said of natural hydrogen: "It could be gigantic or it could be a bust, but if it's really there... wow!" That is why he is betting on Koloma, which rejects trial and error in favour of a rigorous scientific framework. At Ohio State University Tom Darrah, the firm's chief technology officer, and a team of researchers are working feverishly in an ordinary-looking cinderblock building. Dr Darrah has drawn up his own map of where he thinks natural hydrogen can be found. He says there is "very little overlap" with where oil and gas are found.

Asked what his theory of the case is, the bespectacled academic leaps to the whiteboard and starts scribbling. "We use the SMARTS [Specific, Measurable, Attainable, Realistic and Time-Bound goals] approach," he explains, which is inspired by the subsurface modelling used by the oil industry. By applying "hydrogen smarts", his firm is looking for the best source rocks

With enough hydrogen, you can do anything

that might contain hydrogen, finding traps and seals on top, and using his long experience in research to validate findings quickly in the laboratory.

When the usgs releases its treasure map, it will point wildcatting rivals in the right direction. However, he insists, his firm has an edge thanks to its systemic approach, which includes improved detection tools, reservoir simulation and in-situ stimulation of hydrogen. He says he knows "what scientific questions to ask" to find "real drillable areas".

In his spare time, Dr Darrah hunts deer with a bow and arrow. (He says he gets some of his best ideas in the woods.) At work, he is hunting something bigger. He does not want another Mali; he wants to find the Saudi Arabia of hydrogen, perhaps in America. It might, however, be in Australia.

THE GREEN BARON

"I have a rather unpopular view that science and innovation are likely to come to our rescue on climate, rather as they did over covid," says Baron Howard of Lympne. Michael Howard, as he used to be known, has been an oilman, an opposition leader and Britain's environment minister. Now he is chairman of Earth Source Hydrogen, a startup looking for the elusive gas in Australia. He insists his firm is not wildcatting randomly, but rather applying for licences in promising areas and doing desktop exercises before drilling. It is eyeing areas close to big mining operations, which might want to buy the fuel if he finds any.

Dr Ellis of the usgs calls Australia "one of the hottest areas for exploration". An Australian competitor, Gold Hydrogen, has just set the industry ablaze. Nearly a century ago, diggers struck hydrogen in southern Australia and, unusually, took careful notes. After looking at those notes, which showed extremely high concentrations of the gas, Gold Hydrogen decided to drill at the same location. Neil McDonald, the firm's boss, reports ecstatically that the initial data from drilling in October show that hydrogen levels are still high there, just as they were in 1931. That suggests a long-term source or large reservoir, he reckons. The gas can probably be tapped directly, with no need for fracking or other complicated processes to flush it out.

The most basic question has been answered, says Philip Ball of the Clean Air Task Force, an American environmental group. "We are rapidly converging on agreement that a lot of hydrogen exists," he says, "as we find the stuff everywhere." The question now is whether it can be exploited.

Great uncertainty remains about whether any of the hydrogen dreamers' dreams can be realised. But it is possible that a cheap, low-carbon fuel could be widely available at some point in the future.

Hydrogen has the highest energy density of all chemical fuels and is also very reactive, says Eric Toone, chief technology officer of Breakthrough Energy. This makes it potent. It could be used to make essential but currently dirty things such as liquid fuels, steel and ammonia. With enough hydrogen, Dr Toone reckons it might be possible to make starch without photosynthesis, which would revolutionise agriculture. Only nuclear fusion has a comparable potential, he says, and he thinks hydrogen is a less risky bet. "If you have enough hydrogen and it is cheap enough, you can do literally anything," he summarises. Jules Verne would surely agree. ■

◆ Hydrogen-exploration startups, selected ● Confirmed natural-hydrogen detections, selected



Sources: "The occurrence and geoscience of natural hydrogen", by V. Zgonnik, 2020; "Abiotic hydrogen sources and sinks near the mid-ocean ridge with implications for the subsurface biosphere", by S. Worman et al., 2020; "Subduction and hydrogen release", by L. Moretti et al., 2023; "Hydrogen in Australian natural gas", by C. Bornham et al., 2021; "Natural H₂ exploration", by D. Lévy et al., 2023; "Natural hydrogen: the race to discovery and concept demonstration", by P. Ball & K. Czado, *Geoscientist* 34, 2024

Senator BARRASSO. It quotes the leader of one geologic hydrogen company stating that he holds the “unpopular view that science and innovation are likely to come to our rescue on climate as they did over COVID.” Republicans have advocated for reducing carbon emissions through innovation, and quoting you, “innovation, not regulation.”

The CHAIRMAN. Or elimination.

Senator BARRASSO. And without elimination. Geologic hydrogen is purely an area that we should pursue. Companies exploring for geologic hydrogen use many of the same technologies that are used in the oil and gas industry. In fact, many of the people exploring for hydrogen today spent their careers exploring for oil and gas. These are many of the same people in technologies that have made the United States the world leader in oil and gas production. In my view, geologic hydrogen, unlike wind, solar, and electric batteries, plays to America’s strengths, not those of China. Scientists and companies exploring for geologic hydrogen are looking to make hydrogen production as affordable, reliable, and clean as possible. I am glad to say the University of Wyoming is participating in these efforts. While there is still much to learn, today’s hearing will shed light on the opportunities and challenges ahead.

I want to thank our witnesses for joining us here today and I look forward to hearing the testimony.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Senator Barrasso.

And now, we are going to have our three witnesses. We have the Honorable Dr. Evelyn Wang. She is Director at the Advanced Research Projects Agency–Energy.

We have Dr. Geoffrey Ellis, Energy Resources Program Lead for Geologic Hydrogen at the U.S. Geological Survey.

And then we have Mr. Pete Johnson, co-founder and CEO of Koloma.

And we will start with Dr. Wang. And if you have any of your family members here, we would like for you to introduce them. It would be very nice.

Okay, Doctor, go ahead.

STATEMENT OF HON. EVELYN N. WANG, DIRECTOR, ADVANCED RESEARCH PROJECTS AGENCY-ENERGY, U.S. DEPARTMENT OF ENERGY

Dr. WANG. Thank you, Chairman Manchin, Ranking Member Barrasso, and distinguished members of this Committee. It is my privilege to appear before you today to represent the Department of Energy as Director of Advanced Research Projects Agency–Energy, commonly known as ARPA-E. Our agency is tasked with supporting the research and development of high-risk, high-reward energy technologies that have the potential to fundamentally change the way we generate, use, and store energy. Today, I am pleased to appear before you to discuss this important topic of geologic hydrogen. ARPA-E’s support of this topic aligns with our mission of disrupting learning curves and creating new markets.

Hydrogen is an element that could be used to cleanly produce heat and electricity, and is relevant to reducing harmful emissions from some of the most energy-intensive sectors of the economy,

such as chemical industrial processes like ammonia and steel, and heavy-duty transportation. It can be produced from a variety of domestic resources, such as natural gas, nuclear power, biomass, and renewable power, like solar and wind. Hydrogen has end-uses across almost all sectors, from industrial to commercial, transportation, agriculture and more.

Historically, hydrogen can store and deliver usable energy as a carrier, but as an element, not much is found in the atmosphere due to its reactivity and light weight. Consequently, it is typically produced from compounds that contain it. Geologic hydrogen presents a unique opportunity where advanced technologies can stimulate and extract hydrogen directly from the Earth's subsurface. The realization of these technologies would make hydrogen a primary energy source in addition to a carrier of energy, potentially increasing the domestic supply of hydrogen and lowering costs of this form of energy for millions of Americans. Given recent interest in the discovery of naturally accumulating deposits of subsurface hydrogen, ARPA-E is interested in accessing these deposits and exploring the possibility of developing this source of hydrogen. By advancing transformative technologies that would enable the stimulation and extraction of this hydrogen, we could potentially yield larger quantities of it than are currently produced.

To that end, in September 2023, ARPA-E announced \$20 million in available support for teams to be a part of this historic effort to advance the research and development of this technology. ARPA-E selected 18 projects across 9 states as part of this funding opportunity announcement. While simply extracting the current supply of naturally accumulating hydrogen, in and of itself, can enhance the U.S. energy economy, ARPA-E is committing research support to explore a potentially disruptive step in the process. Through understanding how we can artificially stimulate these deposits, there is a theoretical potential to produce enough clean hydrogen to impact U.S. energy demand. Therefore, the funding announced in September is part of two ARPA-E exploratory topics. The first explores research into the stimulation processes. The second focuses on technologies relevant to the management and extraction of hydrogen from geologic reservoirs. The historic significance of this moment is clear, with this being the first time that the U.S. Government has competitively selected teams to research this technology.

The potential for geologic hydrogen represents a paradigm shift in the way we think about hydrogen as an energy source. If our programs show success, this new source of hydrogen could lower energy costs and increase our nation's energy security and supply chains. In addition, existing technology, infrastructure, and workforce capabilities from industries such as geothermal, oil, gas, and mining may be leveraged for the stimulation and extraction of geologic hydrogen. We understand the inherent risks of this early-stage research, and recognize this risk is essential in ARPA-E's mission to enhance American innovation. Thank you for the opportunity to appear before the Committee today, and I look forward to your questions.

[The prepared statement of Dr. Wang follows:]

TESTIMONY OF
DR. EVELYN WANG, DIRECTOR
ADVANCED RESEARCH PROJECTS AGENCY – ENERGY (ARPA-E)
BEFORE THE
COMMITTEE ON ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE
REGARDING
GEOLOGIC HYDROGEN
February 28, 2024

Introduction

Thank you, Chairman Manchin, Ranking Member Barrasso, and distinguished members of this Committee. It is my privilege to appear before you today to represent the Department of Energy as Director of the Advanced Research Projects Agency – Energy, commonly known as ARPA-E.

Our agency is often referred to as the Department of Energy’s “Moonshot Factory,” tasked with supporting the research and development of high-risk, high-reward energy technologies that have the potential to fundamentally change the way we generate, store, and use energy.

ARPA-E has helped realize technologies across sectors, including industrial decarbonization, geothermal, and energy storage.

Our success in advancing this research stems from the philosophy that we embrace challenges that few others dare to and accept that this risk is essential in our mission to revitalize American innovation.

Today, I am pleased to appear before you to discuss this important topic of geologic hydrogen.

ARPA-E’s support of this topic aligns with our mission of disrupting learning curves and creating new markets.

Opportunity of Geologic Hydrogen

Hydrogen is an element that can be used to cleanly produce heat and electricity, and is relevant to reducing harmful emissions from some of the most energy-intensive sectors of the economy, such as chemical and industrial processes – like ammonia and steel – and heavy-duty transportation.

Clean hydrogen is a flexible energy carrier that can be produced from a diverse mix of domestic clean energy resources, including renewables, nuclear, and fossil resources with safe and responsible carbon capture. Hydrogen has end-uses across almost all sectors – from industrial to commercial, transportation, agriculture, and more.

Geologic hydrogen presents a unique opportunity where advanced technologies can stimulate and extract hydrogen directly from the Earth’s subsurface.

The realization of these technologies would make hydrogen a primary energy source in addition to a carrier of energy, potentially increasing the domestic supply of hydrogen and lowering costs of this form of energy for millions of Americans.

Opportunity to Support Technologies

Given recent interest in the discovery of naturally accumulating deposits of subsurface hydrogen, ARPA-E is interested in accessing these deposits and exploring the possibility of developing this source of hydrogen.

By advancing transformative technologies that would enable the stimulation and extraction of this hydrogen, we could potentially yield larger quantities of it than are currently produced.

Exploratory Topics

To that end, in September 2023, ARPA-E announced \$20 million dollars in available support for teams to be a part of this historic effort to advance the research and development of this technology. ARPA-E selected 18 projects across 9 states as part of this Funding Opportunity Announcement. In addition, the projects selected are the lead organization and work in conjunction with other research teams spread out across the country.

This effort could enable the production of enough hydrogen to decarbonize industries that may have a more difficult path transitioning through renewables or electrification.

While simply extracting the current supply of naturally accumulating hydrogen, in and of itself, can enhance the U.S. energy economy, ARPA-E is committing research support to explore a potentially disruptive step in the process.

Through understanding how we can artificially stimulate these deposits, there is a theoretical potential to produce enough clean hydrogen to impact U.S. energy demand.

Therefore, the funding announced in September is part of two ARPA-E Exploratory Topics.

The first explores research into the aforementioned stimulation processes, specifically identifying the technologies and developing an understanding of controlling these hydrogen-producing geochemical reactions.

The second focuses on technologies relevant to the management and extraction of hydrogen from geologic reservoirs, this includes how we can contain and transport this source of energy from the Earth's subsurface, and mitigate risks associated with these efforts.

This funding will include significant research using advanced modeling and characterization tools so that we can better predict the viability of subsurface resources both on and offshore.

Using samples from sites of interest, teams will utilize analytical laboratory techniques to understand the environment necessary to stimulate and extract hydrogen from the subsurface. The historic significance of this moment is clear with this being the first time that the U.S. government has competitively selected teams to research this technology.

Conclusion

The potential for geologic hydrogen represents a paradigm shift in the way we think about hydrogen as an energy source.

If our programs show success, this new source of hydrogen could lower energy costs and increase our nation's energy security and supply chain.

In other words, it could fundamentally change how we use energy.

In addition, existing technology, infrastructure, and workforce capabilities from industries such as geothermal, oil, gas, and mining may be leveraged for the previously referred-to stimulation and extraction methods.

While we are encouraged by these possible benefits, we believe the first step in realizing this technology is extensive research and development.

We understand the inherent risks of this early-stage research, and recognize this risk is essential in ARPA-E's mission to revitalize American innovation.

ARPA-E has consistently proven its ability as an agency to not only fund these R&D efforts, but to successfully guide the realization of disruptive energy technologies.

Thank you for the opportunity to appear before the Committee today, and I look forward to your questions.

The CHAIRMAN. Thank you, Doctor.

And now we will have Dr. Geoffrey Ellis. He is our Energy Resources Program Lead for Geologic Hydrogen at the U.S. Geological Survey. Thank you, Dr. Ellis.

STATEMENT OF DR. GEOFFREY S. ELLIS, ENERGY RESOURCES PROGRAM LEAD FOR GEOLOGIC HYDROGEN, U.S. GEOLOGICAL SURVEY, U.S. DEPARTMENT OF THE INTERIOR

Dr. ELLIS. Good morning, Chairman Manchin, Ranking Member Barrasso, and members of the Committee. Thank you for inviting me to testify before you today on the opportunities and challenges associated with developing geologic hydrogen resources. My name is Geoff Ellis and I lead the research efforts into understanding the resource potential of geologic hydrogen in the U.S. Geological Survey, or USGS.

The existence of naturally occurring hydrogen is well documented in many geologic environments, with the notable exception of petroleum reservoirs. Out of millions of oil and gas wells that have been drilled around the globe, only a few dozen oil fields have been documented to contain more than trace levels of hydrogen. This led many geoscientists to conclude that economic accumulations of hydrogen in the subsurface are non-existent. However, the accidental discovery of geologic hydrogen gas accumulation in Mali, West Africa about 12 years ago brought about a re-examination of this notion. There are now a growing number of geoscientists who recognize that we simply have not looked for geologic hydrogen in the right places with the right tools.

The geologic setting of the hydrogen accumulation in Mali is not unique, which suggests that geologic hydrogen accumulations could be widespread. In the wake of this discovery, active exploration for geologic hydrogen has begun in Brazil, Colombia, and elsewhere, and research into this potential low-carbon energy resource has taken off, particularly in France and Australia. In the United States, the first well specifically targeting a geologic hydrogen accumulation was drilled in the State of Nebraska in 2019. Several additional hydrogen exploration wells have been drilled in the United States since then and more are planned for later this year. The USGS began investigating geologic hydrogen resource potential in 2021.

The USGS recently developed a model of global hydrogen resource potential based on known properties of hydrogen and well-understood accumulations of other geologic resources, such as petroleum, geothermal energy, and noble gases like helium. According to the model, the estimated in-place global geologic hydrogen resource ranges from thousands to potentially billions of megatons, or million metric tons. However, the model makes no prediction about the spatial distribution of this resource. Given our understanding of other geologic resources, the vast majority of the in-place hydrogen is likely to be in accumulations that are too deep, too far offshore, or too small to ever be economically recovered. However, if even a small fraction of this amount could be recovered, that would constitute a significant resource.

More geoscience research and data collection is needed to better understand where natural accumulations of hydrogen might be

found. Fortunately, we have extensive experience from petroleum, geothermal, and hydrothermal mineral resource exploration that can be applied to understanding geologic hydrogen resources. Building on that experience, the USGS is developing a conceptual geologic model to refine our understanding of the potential for hydrogen accumulation in the subsurface. The USGS model will initially be applied to mapping the relative likelihood of the presence of geologic hydrogen resources across the Lower 48 states of the U.S. In addition to our mapping efforts, we are collaborating with the Colorado School of Mines and a consortium of industry partners to advance the geoscience related to geologic hydrogen and to investigate exploration methods needed to develop this potential resource.

Another significant area of research is the potential to stimulate hydrogen generation in the subsurface, which is distinct from its natural occurrence. We are partnering with the U.S. Department of Energy to identify the geologic conditions under which new technologies may be applied in ways that are effective, safe, and protective of local communities' health and the environment. Advancement of stimulation technologies could substantially add to our current estimate of the global potential for economically recoverable geologic hydrogen.

In summary, our current understanding suggests that the amount of naturally occurring hydrogen in the Earth's interior is likely to be large. However, the potential for this hydrogen to be present in accumulations that could be economically, safely, and responsibly recovered is currently unknown. Research is now underway at the USGS to improve our understanding of this novel resource that can help provide a low-carbon and secure supply of energy to our nation. Thank you for the opportunity to testify today. I look forward to answering any questions that you might have.

[The prepared statement of Dr. Ellis follows:]

**Statement of Dr. Geoffrey S. Ellis
Energy Resources Program Lead for Geologic Hydrogen
U.S. Geological Survey
before the
Senate Committee Energy and Natural Resources
on
February 28, 2024**

Good morning, Chairman Manchin, Ranking Member Barrasso, and Members of the Committee. Thank you for the opportunity to testify before you today on the potential for geologic hydrogen resources. My name is Geoffrey Ellis and I lead the U.S. Geological Survey's (USGS) research on geologic hydrogen resources.

Introduction

The USGS is the science arm of the Department of the Interior and brings impartial, actionable science to an array of stakeholders and partners, including decision-makers such as Congress, resource managers, and the public.

Congress passed the USGS Organic Act in 1879, in part to gain greater understanding of our Nation's energy and mineral resources. That goal remains central to our mission 145 years later. We provide science and data on the occurrence and distribution of national and global energy resources and on the potential environmental and socioeconomic effects associated with resource occurrence and use.

The USGS's research addresses the full life cycle of energy resources, from how and where resources form and accumulate, through resource extraction, to disposal, recycling, reclamation, and the potential to reuse waste as a resource. We study widely-used energy commodities such as petroleum, coal, geothermal energy, and uranium, as well as the use of subsurface pore space for disposal of energy waste, including geothermal and hydraulic fracturing fluids and carbon dioxide. We also study emerging energy resources such as gas hydrates and geologic hydrogen.

Hydrogen as an energy resource

Hydrogen is the most abundant element in the visible universe. In its molecular form (H₂), it contains more energy per unit of weight than any other fuel. Hydrogen is currently an important feedstock for a variety of industrial processes, including petroleum upgrading, steel manufacturing, and fertilizer production. Hydrogen is also viewed as an important emerging medium for storing and transporting energy.

Today, most commercially-available hydrogen is produced from natural gas. This "grey" hydrogen is relatively energy-intensive and releases about 10 tons of carbon dioxide to the atmosphere for every ton of hydrogen gas generated. Until recently, additional hydrogen was projected to come from a combination of hydrogen derived from natural gas, coal, or biomass coupled with carbon capture and sequestration ("blue" hydrogen), and hydrogen generated by electrolysis of water using renewable sources of electricity ("green" hydrogen). Today, my

testimony will focus on a previously overlooked source of hydrogen: naturally occurring geologic hydrogen accumulations in the Earth's subsurface ("white" or "gold" hydrogen).

Why the recent interest in geologic hydrogen?

The existence of naturally occurring hydrogen is well documented in many geologic environments. Nevertheless, out of the millions of oil and gas wells that have been drilled to date, only a few dozen oilfields have been documented to contain more than trace levels of hydrogen. This has led many geoscientists to conclude that economic accumulations of hydrogen in the subsurface are non-existent. However, recent evidence indicates that we have simply not looked for geologic hydrogen resources in the right places with the right tools.

In 1987, a shallow water well drilled in Mali, West Africa, produced an unexpected gas explosion and was quickly abandoned. Nearly 25 years later, an oil and gas company returned to the site and discovered that the gas was more than 97 percent hydrogen. Subsequent exploration identified five geologic reservoirs containing nearly pure hydrogen gas. This hydrogen has been in production for more than 10 years and is used to provide electricity to a local village.

This discovery was first described in the scientific literature in 2018 and stimulated new interest in the resource potential of naturally occurring or 'geologic' hydrogen. Several countries are actively working toward a hydrogen economy through investments in geoscience, technology, infrastructure, and by readying utilities and the manufacturing industry. Researchers in France have investigated geologic hydrogen resource potential for more than a decade. Australian research has expanded in recent years. Active exploration campaigns are ongoing in Brazil, Colombia, and elsewhere.

In the United States, the first well ever drilled specifically to target a geologic hydrogen accumulation was in Nebraska by Natural Hydrogen Energy LLC in 2019. The USGS began investigating geologic hydrogen resources in 2021. Several more hydrogen exploration wells have been drilled in the United States in the last two years and more are planned for 2024.

What do we know about the resource potential?

The geologic setting of the hydrogen accumulation in Mali is not unique, which suggests that geologic-hydrogen accumulations could be widespread. In fact, researchers have begun reviewing historical industry records and unpublished data and have uncovered historical discoveries of natural hydrogen that had gone unnoticed in numerous places around the world.

The USGS has recently developed a model of global hydrogen resource potential.¹ The model is based on known properties of hydrogen and well-understood accumulations of other geologic resources, including petroleum, geothermal energy, and noble gases such as helium. These factors provide some constraints on the possible magnitude of the global geologic hydrogen

¹ Ellis, G.S. and Gelman, S.E., 2022. A preliminary model of global subsurface natural hydrogen resource potential. Geological Society of America Annual Meeting, Denver, Colorado, October 9-12, 2022. Geological Society of America Abstracts with Programs, v. 54, no. 5. <https://doi.org/10.1130/abs/2022AM-380270>

resource in the Earth's crust. Estimated in-place² global geologic hydrogen resources range from thousands to billions of metric tons (Mt), with an approximate mean value in the tens of millions of Mt. The model does not predict the spatial distribution of hydrogen in the subsurface.

Based on historical data on other geologic energy resources, the vast majority of the in-place hydrogen resource is likely to be in accumulations that are too deep, too far offshore, or too small to be economically recovered. However, the remainder could constitute a significant resource.

What more needs to be done?

More geoscience research and data collection is needed to better understand where natural accumulations of hydrogen might be found. Fortunately, we have extensive experience from petroleum, geothermal, and hydrothermal mineral-resource exploration that can be applied to understand geologic hydrogen resources. Building on that experience, the USGS is developing a conceptual geologic model for evaluating the potential for hydrogen accumulation in the subsurface.

The USGS model will initially be applied to mapping the likelihood of finding geologic hydrogen resources in the lower 48 states of the U.S. To better understand the global potential for geologic hydrogen resources, we are partnering with geological surveys of other nations to share data and refine our model. We are working with the Colorado School of Mines and several industry partners to advance the geoscience and exploration methods needed to mature our understanding of geologic hydrogen resource potential.

Another significant advance in our understanding of global geologic hydrogen resource potential would be the incorporation of better data on the potential to stimulate hydrogen generation. We are partnering with the U.S. Department of Energy to identify the geologic conditions under which these technologies may be applied, in ways that are effective, safe, and protective of local communities' health and the environment.³ Advancement of stimulation technologies could significantly add to our current estimate of the global potential for economically recoverable geologic hydrogen.

Summary

In summary, our current understanding suggests that the amount of naturally occurring hydrogen in the Earth's interior is likely to be large. However, the potential for this hydrogen to be present in accumulations that could be economically, safely, and responsibly recovered is unknown. Research is currently underway at the USGS to improve our understanding of the potential for economic accumulations of hydrogen and to develop exploration tools for this potential low-carbon primary energy resource.

² In-place resources are the total volume occurring in accumulations regardless of technological or economical ability to recover them.

³ U.S. Department of Energy Announces \$20 Million to Explore Potential of Geologic Hydrogen, September 7, 2023, <https://arpa-e.energy.gov/news-and-media/press-releases/us-department-energy-announces-20-million-explore-potential-geologic>

Thank you for the opportunity to testify today. I look forward to your questions.

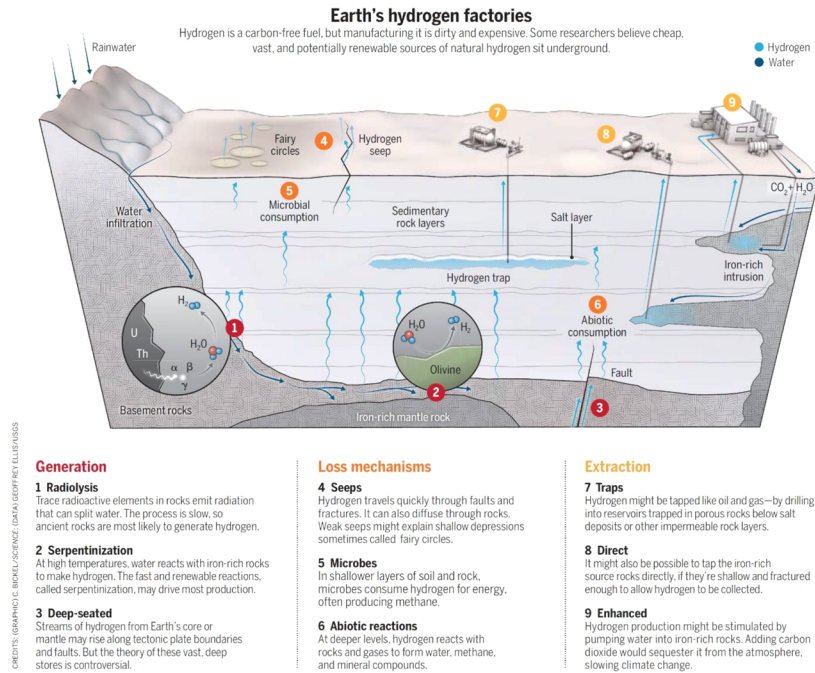


Figure 1. Schematic diagram showing potential mechanisms for generation (1-3) and consumption (4-5) of hydrogen in the subsurface as well as potential approaches for resource recovery (7-9). Three conceptual types of exploitable hydrogen include natural accumulations (7), natural generation (8) and stimulated generation (9). (Source: Hand, E. 2023, Hidden Hydrogen – Does Earth hold vast stores of a renewable carbon-free fuel?: Science 379:6633, p. 631-636, <https://doi.org/10.3133/ofr20211045>.)

The CHAIRMAN. Thank you, Doctor.

Now we have Mr. Pete Johnson. I believe you have some family members here, sir.

Mr. JOHNSON. Yes, I would like to introduce my mother, who was born in DC and came here to witness the event. Stand up, Mom.

The CHAIRMAN. Stand up. Thank you for being here.

Mr. JOHNSON. I bring her to every important meeting I go to.

The CHAIRMAN. Well, it is always good to have your mom with you, especially in these meetings.

**STATEMENT OF PETE JOHNSON,
CEO AND CO-FOUNDER, KOLOMA**

Mr. JOHNSON. Thank you, Chairman Manchin, Ranking Member Barrasso, and other distinguished members of the Committee for the opportunity to speak to you about geologic hydrogen and its potential to benefit the United States.

My name is Pete Johnson. I am the co-founder and CEO of Koloma. I am the father of four active kids and I love nothing more than spending time with my wife and them outside, enjoying the forests, the mountains, and coastlines of this beautiful country. I am passionate about clean energy and I believe I have a moral responsibility to do what I can to benefit the health of both my children and the planet. I am also a pragmatist. I am an engineer by training and I am an entrepreneur. I have designed and built clean energy facilities in the Southwest United States, in Australia, in India along the Pakistan border, and most recently in Nebraska. I have founded and built multiple clean energy companies, including another successful clean hydrogen business, and I have also worked as an investor in a traditional energy fund focused on energy transition opportunities.

I first learned about the concept of geologic hydrogen three years ago while working in the investment industry. I was very skeptical. Everybody is looking for a silver bullet in the clean energy business. This one seemed too good to be true. In the last 12 months, Science magazine, the New York Times, the Wall Street Journal, the Economist, which Senator Barrasso lifted up—they have all featured this and they have highlighted this field and its potential. But three years ago, there was very, very little to go by. I was curious enough back then, and I dug into as much data as I could find. And it became clear to me that the science of hydrogen formation in the subsurface was real. It was indisputable. The reaction between water and iron-rich rock happens, and hydrogen seeps are present on all six continents and have been well studied. Hydrogen is seeping out of the mid-Atlantic sea floor. Hydrogen is coming out in the steam in Iceland and the Geysers Geothermal Field in California.

I have worked in the hydrogen business for a long time and I did the math. If geologic hydrogen accumulations can be found, this would change the hydrogen business dramatically and have a massive advantage in terms of cost and availability. It would open up new avenues for decarbonization that just are not possible now. But the key questions remained: Are there accumulations that are large enough to matter? Are they close enough to markets? Can we

find them with a high enough hit rate to justify the high cost of exploration activities?

During this process, I was introduced to Dr. Tom Darrah, a tenured geology and geochemistry professor at the Ohio State University. Tom had spent the better part of 20 years collecting and analyzing data around geologic hydrogen from six continents, and was widely recognized as the world expert in the field. I saw that the analytical tools and technology that Tom had developed could be further honed to create a strong advantage in finding commercially relevant geologic hydrogen reserves. We brought in other experts in resource exploration who agreed that the technical advantages we had would help de-risk the effort. At that point, Tom and I, along with another co-founder, Paul Harraka, invested our personal capital alongside a seed investor and founded Koloma in 2021 as a data-driven technology-enhanced geologic hydrogen exploration company.

Today, Koloma has 35 employees who are a unique mix of geologists, data scientists, traditional energy resource professionals, and hydrogen experts. Koloma has offices and facilities in Denver, Colorado and at the Ohio State University. We have been actively gathering and analyzing data, conducting lab experiments, leasing mineral rights, and exploring in prospective regions in the United States. We are very excited about the opportunity in what we are seeing.

I would like to share a few key points about geologic hydrogen's potential impact on U.S. efforts toward decarbonization. First, geologic hydrogen is domestic primary energy. All other forms of hydrogen require more energy to produce than the hydrogen itself holds. The geologic hydrogen is a source of energy. Senator Barrasso pointed out that demand increasing is just going up. Adding energy into the system is a critical element of decarbonization. Second, this is incredibly clean energy. In multiple third-party lifecycle analyses and peer-reviewed journal articles, geologic hydrogen has been found to have a very low carbon footprint, akin to renewables-powered electrolyzers. In addition, geologic hydrogen will result in lower land use and lower water consumption than any other form of hydrogen. And last, this is a great way to leverage the enormous talent base and talent advantage the U.S. has built in resource exploration and production. Downstream facilities will leverage that as well.

I would like to conclude by noting that this will not be easy. This will take time, money, and effort to figure out. Nobody has all the answers today, but the early data looks promising, and I believe that geologic hydrogen can play a very large role as we decarbonize the U.S. energy economy. The efforts we put in now to commercialize this will be worth it. Thank you.

[The prepared statement of Mr. Johnson follows:]

Opening Statement of Peter Johnson
Chief Executive Officer, Koloma
Before the Committee on Energy and Natural Resources
U.S. Senate
February 28, 2024

Introduction

Thank you Chairman Manchin, Ranking Member Barrasso, Senator Hickenlooper from Koloma's home state of Colorado, and other distinguished Members of the Committee for the opportunity to speak with you today and for your interest in geologic hydrogen and its potential to benefit the United States. Geologic hydrogen is a relatively new entrant in the hydrogen economy, so we especially appreciate your use of this committee's platform to educate policymakers and the broader public about geologic hydrogen. Your leadership and engagement now are of vital importance to advancing this new industry.

I'm Pete Johnson, co-founder and CEO of Koloma. I'm the father of four active kids and I love nothing more than spending time with my wife and them outside, enjoying the forests, mountains and coastlines of this beautiful country. I'm passionate about clean energy and believe I have a moral responsibility to do what I can to benefit the health of the planet. I'm a pragmatist, an engineer by training, and a clean energy entrepreneur by experience. I've founded and built multiple companies in this space, including another successful clean hydrogen business, and have also worked with a traditional energy firm to develop energy transition investment strategies.

Founding Story

I first learned about the concept of geologic hydrogen three years ago while working in the investment industry. I was skeptical. Everybody is looking for a silver bullet in the clean energy business, and this seemed too good to be true.

In the last twelve months, Science magazine, the New York Times, Wall Street Journal, Forbes¹, and other media have all highlighted this field and its potential; three years ago there was very little to go by. But I was intrigued with the potential and dug into as much data as I could find. It became clear to me that the science of hydrogen formation in the subsurface was real. A natural chemical reaction occurs when water contacts iron-rich rock below the surface of the earth and hydrogen is produced. This reaction is the source for many hydrogen seeps that have been well studied and documented on nearly every continent.

¹ ["Hidden Hydrogen: Does Earth Hold Vast Stores of a Renewable, Carbon-Free Fuel?"](#) by Eric Hand. *Science*. February 16, 2023. ["It Could be a Vast Source of Clean Energy, Buried Deep Underground"](#) by Liz Alderman, *New York Times*, December 4, 2023. ["Underground Hydrogen could Supercharge Green Energy. First, Scientists have to Find It"](#) by Eric Niller. *Wall Street Journal*. June 5, 2023. ["Forget Oil. New Wildcatters are Drilling for Limitless 'Geologic' Hydrogen"](#) By Alan Ohnsman. *Forbes*. June 26, 2023.

I've worked in the hydrogen business for a long time and I did the math. If geologic hydrogen accumulations are discovered, this would change the hydrogen industry dramatically and provide a massive advantage in terms of cost and availability. It would open new avenues for decarbonization that aren't possible now. But key questions remained: are there accumulations that are big enough to matter? Are they close to markets? Can we find them through intentional, economic exploration efforts?

During this process, I was introduced to Dr. Tom Darrah, a tenured geology and geochemistry professor at the Ohio State University. Tom had spent the better part of twenty years collecting and analyzing geologic hydrogen data from six continents and is widely recognized as the world expert in the field. I saw that the analytical tools and technology that Tom had developed could be further honed to create a strong advantage in finding commercially relevant geologic hydrogen reserves in the US and abroad. We brought in other experts in resource exploration who agreed that the technical advantages we had would help de-risk the effort. At that point, Tom and I, along with another co-founder Paul Harraka, invested our personal capital alongside a seed investment and founded Koloma in 2021 as a data-driven, technology enhanced geologic hydrogen exploration company.

Today, Koloma has 35 employees who are a unique mix of geologists, data scientists, traditional energy resource professionals, lab technicians, and hydrogen experts. Koloma has teams in both Denver, Colorado and at our research facility at the Ohio State University. We've been actively gathering and analyzing data, conducting lab experiments, leasing mineral rights, and exploring in prospective regions within the United States. We're very excited about the potential we see to move geologic hydrogen forward as a true commercial low-carbon energy solution.

Geologic Hydrogen

As Members of this committee are well aware, clean hydrogen can play a vital role in addressing climate change by enabling decarbonization in transportation, agriculture, steel production, high-grade industrial heat, and more. Geologic hydrogen is poised to be a significant and important part of this new hydrogen economy.

I'd like to share a few key points about why I believe geologic hydrogen has the potential to dramatically advance the US's effort towards decarbonization:

First, geologic hydrogen is a form of domestic primary energy which will have 24/7/365 availability. All other forms of hydrogen involve the conversion of one form of energy into hydrogen, pulling energy out of the system and forcing us to collect even more. Geologic hydrogen will require far less energy to produce than it contains, adding energy into the system.

Second, geologic hydrogen has a near-zero carbon footprint, as confirmed by multiple third-party life cycle analyses and a peer-reviewed scientific journal article². In addition, geologic hydrogen will result in lower land use and lower water consumption than any other form of hydrogen production. Geologic hydrogen is a critical tool in our toolbox and will help enable the clean energy transition.

² Brandt, A. "Greenhouse Gas Intensity of Natural Hydrogen Produced from Subsurface Geologic Accumulations." *Joule*. 2023, 7, 1818-1831.

Third, a growing geologic hydrogen industry will create new, domestic, high-paying blue and white collar jobs, particularly in rural communities where the resource is discovered. Some of the best technology and most talented technical people in our country come from the traditional energy industry. This is a great opportunity to leverage that massive talent advantage this country has developed. Downstream facilities converting the hydrogen into fertilizer, sustainable aviation fuel, and other necessary products will create additional jobs and bring economic prosperity to producing regions.

Our production methods source hydrogen in a clean, continuous, and cost-effective manner, eliminating the barriers that have historically hindered widespread adoption. We are actively engaged in exploration and are appraising assets that will play a significant role in domestic, and global, decarbonization efforts.

Sustainability

Koloma focuses on the sustainability of our hydrogen from a full life cycle perspective. Beyond geologic hydrogen's implicit attributes of low surface disruption, water need, and energy need, Koloma's strategy to maximize hydrogen climate benefits is three-pronged.

First, as a geologic hydrogen producer, Koloma produces clean hydrogen that is decoupled from natural gas. Hydrogen sourced from our wells contains small, if any, quantities of natural gas that are easily managed and sequestered onsite.

Second, Koloma will monitor fugitive emissions at all our production sites. This is not only important from an economic point of view (fugitive emissions reduce hydrogen production), but also from a safety point of view (fugitive hydrogen emissions pose a safety risk) as well as minimizing any impact on our climate and environment.

Finally, Koloma strategically selects our well sites to be in close proximity to potential hydrogen offtakers. It is clear from the scientific literature that transporting hydrogen long distances increases the potential of hydrogen leaks. By selecting well sites that are close to hydrogen offtakers, we minimize the distance for hydrogen transport and the chances for hydrogen to leak into the atmosphere. This also brings benefits to local economies as our hydrogen production will support the development of the rural hydrogen industry.

Koloma aims to produce cost competitive clean hydrogen and we believe geologic hydrogen has massive potential for decarbonization.

Safety

As a leading geologic hydrogen company, our responsibility and commitment to safety is paramount to everyone at Koloma. The bottom line is that we – both Koloma and our industry partners – must get safety right if we are to succeed as a company and in delivering on our promise of driving economic development, developing cost-effective clean hydrogen climate solutions, and supporting national energy security.

We are utilizing the best safety practices, which have been developed and proven through over a century of subsurface exploration and hydrogen industry development. Koloma is proactively working to apply and update those long standing hydrogen safety best practices to the newer geologic hydrogen industry by requiring specially-developed training specific to each employee or contractor's role, developing updated engineering systems, instituting multiple layers of defense against key risks, maintaining continuously monitored safety channels, and holding our vendors to the same standards.

We believe this is our responsibility to our employees, partners, and communities.

Best in class safety practices and outcomes are a crucial part of our social license to operate and it's our top priority.

Looking ahead – what's next

We are extremely optimistic about the future of the geologic hydrogen economy. We are at a key moment where the technology, the markets and the policy frameworks are coming together in way that can drive massive growth in geologic hydrogen and position the United States as the global leader in this sector.

We are grateful for recent key policies that have been enacted that support the hydrogen economy, most particularly, the Sec. 45V Hydrogen Production Tax Credit, which was included in last year's Inflation Reduction Act. That being said, we also believe the credit must be implemented in the technology neutral manner that was intended in order to support all hydrogen production methods, including geologic hydrogen.

As you know, just before the end of the year, the Treasury Department issued its draft regulations for this credit. "Geologic hydrogen" was mentioned several times in the guidance, reflecting the growing focus and importance of this energy source.

We agree with Congress's focus on ensuring that the credit must be 'technologically neutral,' which is to say that the policy was oriented around the amount of emissions reductions of a hydrogen production pathway, rather than around any specific technology or method. We strongly believe that as new hydrogen technologies continue to evolve and develop, new entrants must be allowed to efficiently utilize the credits as intended by Congress.

As outlined in our recently submitted comments, it is crucial that finalized guidance specifies the following:

- 1) The Provisional Emissions Rate (PER) process balances expediency and thoroughness and does not detract or diminish the urgency to develop a specific 45VH2-GREET pathway for geologic hydrogen. Furthermore, there should be a safe harbor provision for the CI scoring of facilities.
- 2) A Final Investment Decision (FID) should be specified as an appropriate measure of project maturity to commence the DOE's PER process for geologic hydrogen.

- 3) System expansion, the current emissions allocation process for co-products in 45VH2-GREET should be universally applied across hydrogen production technologies.
- 4) The definition of a "qualified clean hydrogen production facility" must clearly apply to a geologic hydrogen production well. Consistent with the law's specification of "emissions through the point of production (well-to-gate)," the lifecycle greenhouse gas emissions should be determined at the Shared Facility level.
- 5) We are grateful for the thoughtful consideration that the departments of Treasury and Energy gave to geologic hydrogen and, as our sector matures, we look forward to continued work with the Departments of Energy and Treasury to advance the domestic clean hydrogen industry. While we are encouraged by aspects of the proposed regulations, we also believe there is still work to do.

Conclusion Chairman Manchin, Ranking Member Barrasso and Senators, thank you for the opportunity to be here today to share my perspective and views of geologic hydrogen. I'd like to conclude by noting that this will not be easy. This will take time, money, and effort to figure out. Nobody has all the answers today. But the early data looks very promising and I believe that geologic hydrogen can and will play a very large role as we work to decarbonize the US energy economy.

As you and your colleagues work to understand and develop policies to support this key sector of the hydrogen economy, I hope you will view me and the Koloma team as partners and as a resource to you. Again, thank you for inviting me here today and I look forward to your questions.

The CHAIRMAN. Thank you, Mr. Johnson.

Now we are going to start with our questions, and I will lead off with—Dr. Wang, this one is going to be for you.

The Greenhouse gases, Regulated Emissions, and Energy use in Technologies model, otherwise called GREET, is a tool used to evaluate the emissions of hydrogen production for the 45V hydrogen production tax credit. Earlier this month, ARPA-E awarded a grant to the Argonne National Laboratory to develop the GREET model to include a method for calculating the emissions of geologic hydrogen. Can you provide more information on when the update to the GREET model will be complete so that geologic hydrogen producers can use it to determine their tax credit values?

Dr. WANG. Thank you, Chairman Manchin, for that question.

Indeed, an important part to be able to make geological hydrogen now applicable to the 45V tax credit is indeed having the life-cycle analysis to understand the amount of emissions from the CO₂ emissions from geologic hydrogen. So we did fund Argonne National Lab as a part of our exploratory topic work to now incorporate geologic hydrogen in doing the life-cycle analysis for it. And so, we expect that to be done by the end of the year. And so, not only can our researchers access it, but make it now open to anyone that wants to access that model, to be able to now apply for the—to be able to make it applicable for the tax credit.

The CHAIRMAN. What was the time period again?

Dr. WANG. The time period is by the end of the year.

The CHAIRMAN. End of the year. Okay.

Mr. Johnson, this will be for you.

Speaking as you have, and you being, I think, the lead company in the country, really, doing what you are doing—Committee members, I think that we all agree that to develop new energy sources like geologic hydrogen, we are concerned about the workers. And a lot of the people, as they transition, as we transition our energy portfolio, hydrogen seems to me to be the most consistent with what we are doing today, by doing it cleaner with hydrogen versus traditional sources that we use now. Do you see that transition being with the skill sets we have? Do we have to retrain, for the heavy lifting that hydrogen can do with trucks, diesels, trains, planes, and everything in between?

Mr. JOHNSON. I think a big benefit that geologic hydrogen brings is that it can really tap into the existing talent base. It's not a perfect fit.

The CHAIRMAN. Sure.

Mr. JOHNSON. This is a different kind of rock. There are different challenges that have to be sorted out, but if you just look at our team of geologists, geochemists, reservoir engineers, drilling engineers, you know, land professionals, this looks and feels a lot like another resource play. We have different science going on, but we can put the workforce to work doing, you know, clean hydrogen. I would say a lot of people in the oil and gas industry who are really interested in moving into energy transition, they see this as an incredible opportunity.

The CHAIRMAN. Let me ask you this—the hydrogen we have right now that you all have been tapped into, you know that we have those reserves of clean hydrogen in the ground now that can be ex-

tracted—can they be put into the market the same as natural gas is as we extract that or oil?

Mr. JOHNSON. Well, I would say, you know, one of the challenges we have, right, that is similar to oil and gas 50 to 100 years ago, is that there is not a massive distribution system for moving hydrogen back and forth. So my view is that the initial commercial production reservoirs of geologic hydrogen will end up being used near the point of production by ammonia plants or other facilities built close by. I think that, you know, you might have to wait a period of time to see a large enough basin developed to start to see pipelines. So, I don't—

The CHAIRMAN. Can the same pipeline system we have now for gas—can hydrogen be used in that same type of transportation?

Mr. JOHNSON. I would say the jury is out on that. All of the pipeline companies are studying this. And there are views that you can go up to 5 or 10 or 20 percent. I think the jury is out on that. I wouldn't—I am not enough of a metallurgist to make more comment than that.

The CHAIRMAN. Thank you.

Dr. Ellis, the USGS has stated they are actively engaging in several endeavors to evaluate the potential of our geologic hydrogen reserves. What states or areas in the U.S. have that potential geologic hydrogen resources have you identified?

Dr. ELLIS. Thank you for that question, Chairman Manchin.

At this time, I can't give you an exact answer to that question. That's something that we are currently in the process of working on. So, the answer will be developing, evolving over time as we get more data coming in. But I can tell you, in our initial efforts, we see areas along the East Coast of the United States, actually all the way from New Jersey down to Georgia as being potential—

The CHAIRMAN. Are we talking like the shale play was? I mean, we have Marcellus and Utica in our area, and you have the Permian and all the different shale plays that are going on. Is that what you seem to be able to identify, or not?

Dr. ELLIS. No, this would be independent from the shales.

The CHAIRMAN. Got you.

Dr. ELLIS. This is related to offshore iron-rich rocks that could be a source for hydrogen, and then it would be migrating toward the coastline.

And another prospective area is the Mid-Continent Rift, where we have ultramafic rocks—these iron-rich rocks that extend all the way from northeastern Kansas up through Nebraska, Iowa and into Minnesota, and up into Ontario, and then down into Michigan are also an area that we think is highly prospective. This is based on our understanding of where the source rocks are most likely to be, but it's complicated.

The CHAIRMAN. Sure.

Dr. ELLIS. We need to have the reservoirs—

The CHAIRMAN. What is your timetable?

Dr. ELLIS. Excuse me?

The CHAIRMAN. What is your timetable to identify them? Because we're not going to go out and start drilling until you tell us where to go.

Dr. ELLIS. No, well, two things on that. The timetable is that we are aiming to get our initial map of prospectivity for the U.S. by the end of this year. But the second key point here is that once we have this map, it's not going to tell you where to drill your wells. This is going to tell us where the best places are to start doing more detailed exploration.

The CHAIRMAN. Thank you very much.

Senator BARRASSO.

Senator BARRASSO. Thanks so very much, Mr. Chairman.

Mr. Johnson, so a well-known investor backing your company recently stated the following about geologic hydrogen: "It could be gigantic or it could be a bust, but if it is really there, wow." So, would you tell us why you think geologic hydrogen has real promise and won't be a bust?

Mr. JOHNSON. I think the science of geologic hydrogen formation in the subsurface is very clear. There are hydrogen seeps all over the planet that have been documented. The question that needs to be answered, and to echo Dr. Ellis here, is what we don't know is, are there accumulations that are large enough to be commercial, right? If you have got a really small puff of hydrogen from one well out in a farmer's field, that is hard to commercialize, right? So, you know, the bust scenario is not that there is no hydrogen under the ground. That science is established. The bust scenario is, hey, there is nothing big enough, or the only thing that's big is in the middle of Greenland. I mean, that's the scenario that we are talking about where this ends up not being something that, you know, we believe it could be.

Senator BARRASSO. So, Dr. Ellis, following up—I understand you are still in the process of modeling the world's reserves of the geologic hydrogen and your work isn't finished. Can you give us a general sense of the size of the world's reserves of geologic hydrogen? And in your estimate, how much of these reserves might be economically recoverable?

Dr. ELLIS. Yes, thank you for that question, Senator.

It is very difficult at this time to answer that with much precision. As I mentioned in my opening remarks, we have done this global model and it could be anywhere from thousands of megatons, which really would not be very important, to potentially billions of megatons. And so, I think that at this point the best we can do is to say, as Mr. Johnson has said, is that it is very likely that there are large quantities in the subsurface, and what we need to understand is the potential for these accumulations that could be economically developed. But the key point, I think, is that even just a small fraction of what we think is in the subsurface could constitute a significant resource. And so, I think that we absolutely should be doing the work, the research, to better understand the potential for the accumulations that could answer that question.

Senator BARRASSO. Mr. Johnson, I want to expand a little bit on one of the things you touched on in your introductory remarks. What would you say are the principal advantages of geologic hydrogen over other types of hydrogen production? You mentioned that in your remarks, and when it comes to land and water use, how does geologic hydrogen compare with hydrogen production using, say, wind and solar energy?

Mr. JOHNSON. So I go back to just pointing out that this is a primary source of energy, and that is an additive energy source to the system. When you look at, you know, fossil hydrogen from natural gas or fossil hydrogen with carbon capture or electrolysis, all those take more energy than the hydrogen molecule actually carries at the end of the day. Geologic hydrogen is essentially decoupled from renewables or from natural gas. So you do not have this challenge of this turning off when the wind stops blowing or the sun stops shining. And that's really critical because hydrogen, as its own product, is actually fairly limited. The value of hydrogen is that it can be converted into ammonia or can be converted into sustainable aviation fuel. That means you have to have an expensive facility on the back end taking this hydrogen and running. You have to run that facility 24/7 to make that pay. So you know, as Senator Manchin said, you can't run an ammonia plant on intermittent sunshine hydrogen. So the value of geologic hydrogen is the sense that this will be baseload hydrogen, 24/7/365.

The last point I would make here is, the best gas storage assets we have in this country are depleted gas reservoirs. So if you imagine drilling and producing geologic hydrogen out of a reservoir and eventually producing what that reservoir had to offer, that reservoir will now contain pore space that could be used as geologic storage for other forms of hydrogen converting that to baseload. So this really ties into the broader system.

Senator BARRASSO. So what do you see as the biggest threats to the commercial production of geologic hydrogen in the months and the years ahead?

Mr. JOHNSON. You know, I think one key threat that is important to talk about is ensuring that we have technology-agnostic approaches towards incentives. Geologic hydrogen, we see, in the long term, as being something that will be highly economic on its own. But as is everything, this will take a lot of time and effort to get there, and to incentivize private capital to take those risks, it is really critical that geologic hydrogen is not on an uneven playing field. So, if every other form of hydrogen received tax credits and this did not, it would be very challenging to see the amount of private investment required to get this going. That's one. I mean, on just the true commercial side, it is a matter of finding large enough resources at high enough purity close enough to markets. We are already quite confident that if we find it, off-takers and people who want to utilize that hydrogen to produce energy transition materials will be there.

Senator BARRASSO. The Chairman and I were just talking about, so, the 45V tax credits, I mean, the issue is the government may put its hand on the scale here, because you just said you could get by excluding any kind of tax credits, you don't need any of that. But if the government gets involved and says they want to subsidize one versus another and chooses winners or losers, it would seem to be devastating.

Mr. JOHNSON. That would be very challenging. That would slow things down quite a bit. And I would say, look, long-term, I believe that this could stand on its own as an energy source with nothing. In the short term, I will tell you right now, the first reservoir somebody finds will not be the best. It will take a while to find the Per-

mian of hydrogen, right? And so, the first time somebody finds it, they might not be achieving the ideal optimal cost targets that we will be achieving in 10 years.

Senator BARRASSO. Thank you.

Thank you, Mr. Chairman.

The CHAIRMAN. Senator Heinrich.

Senator HEINRICH. Mr. Johnson, can you kind of drill down into the weeds on what production, in your view, will actually look like? How analogous is it to geothermal production or oil and gas production? And talk a little bit about, you know, you have been talking a lot about reservoirs, but talk about stimulation of hydrogen that is bound up in other compounds versus already precipitated hydrogen that is in a reservoir of its own, and how we should look at those two things and how they are related.

Mr. JOHNSON. Yes, thanks for the question. So, Koloma right now is focused on finding reservoirs that are naturally filled with hydrogen. And to talk about what production would look like on that, it would be a series of wells that look very similar to the wells that we drill for water, geothermal power, oil, and gas, up to wellheads. That hydrogen would then be gathered into a central purification facility, much like natural gas is. The hydrogen would be further purified and then sold to an ammonia plant or a, you know, SAF plant or something like that. So, pretty similar to what we see in today's energy industry.

Regarding, you know, a stimulated hydrogen concept, you know, that is something that Koloma is involved in on the R&D side of. We are pretty far away from conceptualizing what that system would look like, and I would actually defer you back to the DOE, who has spent more time working on that.

Senator HEINRICH. Dr. Wang, do you want to address that?

Dr. WANG. Sure, thank you, Senator Heinrich, for that question.

So, the focus of the ARPA-E effort that we are supporting, in fact, is very much on the stimulation/extraction side. So that is distinct from what my colleagues have been discussing related to the natural hydrogen deposits that could exist. And we think this could be a ripe opportunity for us because if we could actually stimulate it, so actually introduce high-pressure steam into the subsurface with these rocks, these iron-rich rocks.

Senator HEINRICH. Okay. So, we are talking about similar iron ore to what we mined commercially historically in the upper Midwest, for example.

Dr. WANG. That's what we believe right now, and of course, there is exploration to be done in terms of the research to understand what kinds of rocks will actually produce at the rates that we want, the high rates of production of hydrogen from that chemical reaction that occurs with these types of iron-rich rock formations. So, that's really key, but we have to understand that, and that could be an avenue for us to pursue moving forward in addition to the natural hydrogen that potentially is all around the world.

Senator HEINRICH. Dr. Johnson, back to you. We all know that hydrogen itself is not a greenhouse gas, but if you leak hydrogen, it changes the abundance of methane, of water vapor, of ozone, other very potent greenhouse gases in the atmosphere. We are just now getting a handle on methane leakage after 100 years of just

letting it leak out of our pipes. How should we be thinking about this now so that we get it right so that hydrogen leakage does not become an issue the way that fugitive methane has?

Mr. JOHNSON. Yes, it is a very good question. I appreciate it.

So, there have been studies come out and there is a prevailing view that there is a greenhouse gas impact of hydrogen. The degree to which it does that per ton is still debated, and there are lots of different papers, but we agree, hydrogen leakage is not good for the environment. The good thing is, the industrial gas companies have operated hydrogen storage, underground hydrogen storage facilities, hydrogen wells, hydrogen wellheads, and hydrogen purification for a number of decades. And they have actually tracked hydrogen leakage through that time. And so, the data on this is actually pretty solid. Typically, you see between 0.1 to 1 percent hydrogen leakage from the system, storage all the way through to distribution, with a well-operated system around 0.25 percent. That is very low.

Hydrogen is so valuable, and hydrogen leaks are important to match that you really incentivize to monitor and address leakage, but again, we are early on this, right? So Koloma, as we get into our business, we will commit to being, you know, top of the field in looking at this. There are ways to monitor hydrogen leakage that are currently being developed and we will stay on top of those. We think it's a critical issue. We will stay on top of it. But it is also really critical that we think about hydrogen leakage holistically when we think about hydrogen leakage from every form of hydrogen production and don't get so focused on hydrogen leakage from this one element.

Senator HEINRICH. Yes, no, I agree with you wholeheartedly. I mean, this is something that we can get right from the start, which we didn't do with oil and gas.

Mr. JOHNSON. Right.

Senator HEINRICH. And you know, there is an economic incentive in states like mine to capture methane because it is a product and it has got value. However, we have large numbers—you know, the majors have been very good at that, but as you go down to smaller and smaller producers, we still have huge problems with fugitive methane. So, if we can get this right out of the gate, we can avoid a lot of that.

Mr. JOHNSON. Yes, we completely agree.

Senator HEINRICH. Chairman.

The CHAIRMAN. Senator Hawley.

Senator HAWLEY. Thank you, Mr. Chairman. Thanks to the witnesses for being here.

Dr. Wang, if I could just start with you. I want to talk a little bit about the regional impact—potential regional impact—of some of what we have been discussing. Last year, the governor of my state, along with the governors of Nebraska and Iowa, signed a memorandum of understanding to work on a clean hydrogen hub. They are very interested in what this could do—potentially what this technology could do for the region. I wonder if you could just speak to the impact that this technology could have on the economies of Midwest states like Missouri, what we might see going forward. I mean, what do you assess as the possibilities there?

Dr. WANG. Thank you, Senator Hawley, for that question. And certainly, right now we are at the very early stages of research and understanding how to stimulate and potentially extract hydrogen from the subsurface. And so, certainly, if there are rocks that are iron-rich in nature that we can stimulate, there could be many opportunities in your region and elsewhere to be able to use geologic hydrogen as a clean source of energy in the future.

Senator HAWLEY. Very good. Let me just ask you about the potential effect here on farmers. Mr. Johnson has mentioned a couple times, I think, that one of the by-products of hydrogen is, hydrogen can be used to make ammonia. That is a key component, obviously, in the production of nitrogen fertilizers. That is of great interest to my state. We are a farming state. Of course, Russia's invasion of Ukraine severely disrupted the supply of fertilizer all across the globe, much to the detriment of farmers in Missouri and across the country. So, I am wondering if you can speak to the importance of hydrogen and these kinds of technologies to farmers, in particular—what sort of benefits might they see from this technology were it to come online more fully?

Dr. WANG. Absolutely. So, we know that hydrogen is a great feedstock and it is used to create ammonia for fertilizer. If we could really stimulate and extract this hydrogen and produce very large quantities at very low cost, I think this could have significant implications to help and support the farmers.

Senator HAWLEY. Yes, very good.

Mr. Johnson, let me just ask you, speaking of farms and rural areas, you have said, I think in your written statement, that growing geologic hydrogen will create new domestic high-paying blue- and white-collar jobs, particularly in rural communities where the resource is discovered. I am interested in the blue-collar rural community part of that. Can you extrapolate there? Can you tell us more of what you think the potential might be?

Mr. JOHNSON. Well, from a probability standpoint, this country is huge, and most of it is rural. So, when we find new hydrogen resources, they will generally be in rural communities. You know, cities have built up around energy resources, not the other way around. Our view is that the most likely commercial avenue for geologic hydrogen will be infrastructure that is built close to point of production. So, if you find a reservoir of hydrogen in a rural community, you'll probably follow that up with an ammonia production facility or a sustainable aviation fuel production facility.

And so, drilling wells is a temporary effort, where you are drilling wells and you are going to hire local labor to do that. Those long-term operating plants create high-paying jobs that last forever, right? And everybody finances these plants based on 20 or 30 or lifetimes, but we all know they operate for 60 years and 70 years as the backbone of local economies. And so, geologic hydrogen can really establish that kind of backbone in rural areas, and specifically about farming, right? We import 2.4 million tons of ammonia per year in the United States. You know, Missouri was impacted by the spike in ammonia prices, which had nothing to do with the cost of ammonia in the U.S., it was the cost people were paying for ammonia in Europe getting it from Russia, right? The U.S. is the largest net importer of ammonia today.

Food security and energy security are both national security. So this can impact our ammonia and our farming and our food system in considerable ways.

Senator HAWLEY. And what would be, when you talk about blue collar jobs, help me understand what the potential is there. What kind of jobs are we thinking might be associated with this technology? I mean, what kind of jobs might it create for blue collar workers, in particular?

Mr. JOHNSON. Plant operators, facility operators, you know, outside operators, technicians, mechanics, all the people who work, you know, if you look at the workforce that operates chemical plants, refineries, ammonia facilities, liquefiers, the majority of those jobs are blue collar, you know, skilled craft jobs.

Senator HAWLEY. Very good.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Senator.

We are going to go around real quick, if you have another question, Senator Hawley—if you have another one.

Well, I have one. I think Senator Heinrich has one. If you have one, okay?

Mine, very quickly, Dr. Ellis, this is for you. You mentioned that geologic hydrogen could be located offshore. Is that correct? Offshore? Does that mean that we are going to need to look at potential changes to the federal leasing programs to accommodate geologic hydrogen?

Dr. ELLIS. Thank you for that question, Chairman Manchin.

As far as those sorts of regulatory issues, that is really not the purview of the USGS, so I think that that would have to be directed to other agencies as far as—

The CHAIRMAN. Maybe I will go to the private sector. Mr. Johnson, what do you think? We wrote the bill and we're just a little bit concerned here.

Mr. JOHNSON. Yes.

The CHAIRMAN. We think we will have to make some adjustments, but—

Mr. JOHNSON. Well, look, I would say Koloma is purely focused today on onshore resources—

The CHAIRMAN. Yes.

Mr. JOHNSON. Just because those are far less expensive to explore for today. But yes, I expect that we would have to update the way federal leasing programs are done in offshore if we see this as a new resource.

The CHAIRMAN. Senator Heinrich.

Senator HEINRICH. It's probably a question we need to post to BOEM and Interior, I would think.

The CHAIRMAN. Yes.

Senator HEINRICH. Dr. Ellis, I want to ask, and this isn't specific to geologic hydrogen, but given where we are with the hydrogen industry writ large right now, is USGS thinking through potential partnerships with national labs? I am thinking of Sandia, for example, that advises on the strategic petroleum reserve and does other subsurface repository science. Are you thinking through some of the partnerships that can help us characterize the potential for the

sorts of reservoirs, post production, that Mr. Johnson was alluding to?

Dr. ELLIS. Yes, thank you for that question, Senator Heinrich.

Yes, so we do have active collaborations with a number of the national labs. Not Sandia in particular at this time, but we are looking at—in addition to looking at geologic hydrogen as a resource—we also have another group looking at underground hydrogen storage. And so, we are in close communication with them and they are also working with the labs. And we do recognize, as Mr. Johnson has said, that these, you know, depleted hydrogen reservoirs would then, obviously, be great candidates for underground hydrogen storage. So—

Senator HEINRICH. Who is involved in that partnership right now? Who are some of your partners on that work?

Dr. ELLIS. So, on the geologic hydrogen side, we are working with Lawrence Berkeley Lab and Lawrence Livermore Lab and then Argonne Lab at this point. And I—

Senator HEINRICH. And on the repository science?

Dr. ELLIS. On the repository science I have to get back to you in our written response.

Senator HEINRICH. I look forward to that. Thank you.

The CHAIRMAN. Senator Hawley.

Senator HAWLEY. Mr. Johnson, since the Chairman gave me another opportunity to ask a question.

The CHAIRMAN. Maybe that was a mistake.

[Laughter.]

Senator HAWLEY. Let me just ask you just a quick question about the ARPA-E grant that your company has received. I think the announcement said it was \$900,000. Does that sound right to you? That is correct?

Mr. JOHNSON. That's right.

Senator HAWLEY. So, can I just—can you give us a sense of how you are going to use the money, and here is why I am asking—it looks like you are an awfully well-capitalized company. According to your SEC filings, you just completed a \$245.7 million financing round. You are getting money from Amazon. You are getting money from Bill Gates. Forbes reports that Gates and others have given you \$100 million. That's great—I mean, I am happy for you. But I am just wondering, you are getting now money on top of that from the government—\$900,000 of taxpayer money. So, can you just—I am sure you have a good plan to use it well. I am just wondering what it is.

Mr. JOHNSON. Yes, I mean, clearly that is a different amount of money than what we have been raising in the private sector. The investment into Koloma is based on Koloma using its data advantage and technology advantage to find existing natural hydrogen reservoirs. And that's our focus. And so, when the investors, when our shareholders look at it, they are investing because we are going for that near-term opportunity. Stimulation for hydrogen—this works. We are doing it today in our lab. The big question is, can you produce enough gas quickly enough out of a well for the economics to work? The science of it is real. It will probably take five to seven years for us to really know if that works. Our shareholders don't want to fund that. The direction they gave us is focus

purely on near-term hydrogen exploration. You know, if you want to do this, you have to go find partners, academic partners.

So we are participating in a larger academic group. That \$900,000 goes to work that we are doing alongside universities and supporting them with data and work, but it's not—that \$900,000 will not be used exclusively by us. That's to fund a partnership and a consortium.

Senator HAWLEY. So okay, so it sounds like then you are partnering with universities—so some of this will redound to the public, I mean, if the universities get some of this information, the technology, the benefit of this, then that is going to be more broadly available. Does that—

Mr. JOHNSON. Yes, absolutely. Our in-kind contribution on this is a lot of the data that we have already assembled that can help move this further along. I mean, we are a small part of a much broader program.

Senator HAWLEY. Got it. Okay. Fair enough.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you.

Well, let me thank all of you for being here and sharing your knowledge with us, which we appreciate, it helps us immensely.

When we did the Bipartisan Infrastructure bill, we thought that hydrogen was a real player because we knew it was proven technology and we just knew it never had the investments made to mature it. And so, when we chose that as one of the ones that we would have tax credits and incentives for, it was because we thought the private sector could bring it to market once the public sector identified where we could and how we could minimize the risk you are taking. And I think in any good partnership, and I think the government is your partner, not your provider, we take some of that risk factor because we want you to succeed.

What you are telling me here, Mr. Johnson—and what all of you have confirmed—is that we have a cache of reserves that now we have proven, correct? And we just haven't tapped them yet? Is that what we are saying, Mr. Johnson?

Mr. JOHNSON. I don't think we have proven the volume of reserves yet. We know it's there.

The CHAIRMAN. We know it is there.

Mr. JOHNSON. We do not know how much. That's still a question that needs to be answered. And so, when you say proven reserves, that is a very charged term in the resource space, so I have to be careful there.

The CHAIRMAN. Because at one time we were importing natural gas to our country because we needed the energy.

Mr. JOHNSON. Yes.

The CHAIRMAN. And then we found out that we had trapped gas in our shale and were able to unleash that, which gave us a tremendous boom as far as our economy and our self-reliance. I just think that the ability, and what you have told me, we gave credits, as you know, in different categories about the emissions of hydrogen, and gas is the easiest of all the ways that we can produce hydrogen, as I see it, except if it's already produced. That's the difference. So, it is exciting what you are saying here.

So we look forward to exploring this even more, and we have until the end of tomorrow for any of the members to provide any questions they might have.

And with that, let me say thank you, again, to all of you for being here, and the Committee is adjourned.

[Whereupon, at 11:01 a.m., the hearing was adjourned.]

APPENDIX MATERIAL SUBMITTED

U.S. Senate Committee on Energy and Natural Resources
February 28, 2024 Hearing: *Opportunities and Challenges*
Associated with Developing Geologic Hydrogen in The United States
Questions for the Record Submitted to the Honorable Evelyn N. Wang

QUESTIONS FROM RANKING MEMBER JOHN BARRASSO

- Q1. One of your fellow witnesses, Dr. Ellis, was recently asked in the press about research funding for geologic hydrogen. He responded, “It’s surprising to me there’s been very little funding for this type of research really, anywhere in the world, relative to the amount of money that’s invested into research for blue and green hydrogen.” Your Department will soon spend billions of taxpayer dollars on hydrogen production. Nearly all of these dollars will go toward projects that have little or nothing to do with geologic hydrogen. In light of the recent developments in geologic hydrogen, should the Department reconsider its spending plans?
- A1. We are hopeful that the research we support on extraction and stimulation methods will be successful, and welcome support and interest from Congress in this important area. If this research proves successful, then this hydrogen source could serve as an excellent complement to the Department’s work fostering the development of a broader hydrogen economy. Much of the Department’s current work related to processing, delivery, storage, and end-use of clean hydrogen, including innovative uses in the industrial sector, would enable commercialization of successful geologic hydrogen technologies. Together, this Department-wide effort will be crucial to DOE’s strategy for achieving our nation’s climate goal of a 100% carbon pollution-free electricity sector by 2035 and net-zero carbon emissions by 2050.
- Q2. Your office has granted \$20 million in awards to 16 universities, labs, and businesses. These awards will support research on stimulating geologic hydrogen production.
- Q2a. What does a successful outcome for this initiative look like?
- A2a. Success would be the validation of technologies that can stimulate the generation of hydrogen within the subsurface by enhancing/accelerating natural mineralogical processes, and the validation of technologies relevant to the extraction of geologic hydrogen. These technologies include improvements in subsurface transport methods and engineered containment, and reservoir monitoring and/or modeling during production and extraction (*e.g.*, strain, leakage, and/or other risks).

U.S. Senate Committee on Energy and Natural Resources
February 28, 2024 Hearing: *Opportunities and Challenges*
Associated with Developing Geologic Hydrogen in The United States
Questions for the Record Submitted to the Honorable Evelyn N. Wang

- Q2b. What factors will determine if your office develops a program that is exclusively focused on geologic hydrogen?
- A2b. Any new programs, apart from the February announcement of 18 selected geologic hydrogen projects across 9 states, would be determined by additional identified opportunities to support research and development of energy technologies that help ARPA-E meet its statutory mission.

U.S. Senate Committee on Energy and Natural Resources
February 28, 2024 Hearing: *Opportunities and Challenges*
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Questions for the Record Submitted to the Honorable Evelyn N. Wang

QUESTIONS FROM SENATOR JOHN W. HICKENLOOPER

- Q. According to the latest results from USGS's hydrogen model, natural geologic hydrogen in the U.S. is most likely to be found in the Atlantic coastal plain and along the Midcontinent Rift - not in the Rockies. But Colorado's geology makes it ideal for another burgeoning energy source: enhanced geothermal systems. Can you speak about the ways in which enhanced geothermal systems and stimulated geologic hydrogen production are similar? How might the science, technology, and expertise required to harness these two energy sources complement each other?

- A1. Although some early indicators have pointed to certain geographic areas that may contain geologic hydrogen, further geologic research may expand the source geology beyond what is currently indicated.

Enhanced geothermal technologies seem to be most effective in areas where the underground rock is hot but there is not enough natural permeability (the ability for water to move) or fluid/water present to extract the thermal (heat) energy. In those cases, an enhanced geothermal system would create a human-made reservoir to tap that heat for energy by injecting water underground under carefully controlled conditions, which cause pre-existing fractures to re-open, creating permeability.

Although further research is needed, stimulated hydrogen resources are likely to be found in areas where iron-rich rock can be exposed to water. Similar to enhanced geothermal, water could be injected into these subsurface iron-rich rock formations under controlled conditions, to cause pre-existing fractures to expose rock that is not currently exposed to water to generate hydrogen.

- Q2. Since ARPA-E sponsors short-term projects rather than longer term research and development, do you see any potential for other existing DOE programs or offices to focus on geologic hydrogen too?
- A2. It is too early to determine which other offices within DOE would consider programs in geologic hydrogen. ARPA-E's projects in geologic hydrogen will run for two years and are considered early-stage. The Agency will need to learn more about the resource and the proposed technologies before any decisions are made about how to expand the

U.S. Senate Committee on Energy and Natural Resources
February 28, 2024 Hearing: *Opportunities and Challenges*
Associated with Developing Geologic Hydrogen in The United States
Questions for the Record Submitted to the Honorable Evelyn N. Wang

research in the future. However, ARPA-E will continue to coordinate and share learning with other DOE offices via the Department's Hydrogen Crosscut as developments occur.

U.S. Senate Committee on Energy and Natural Resources
February 28, 2024 Hearing: *Opportunities and Challenges*
Associated with Developing Geologic Hydrogen in The United States
Questions for the Record Submitted to the Honorable Evelyn N. Wang

QUESTION FROM SENATOR JOHN HOEVEN

- Q1. The Department of Energy has invested in 18 projects to advance research and development of geologic hydrogen. What are the near-term goals for these projects?
- A1. Success would be the validation of technologies that can stimulate the generation of hydrogen within the subsurface by enhancing/accelerating natural mineralogical processes and the validation of technologies relevant to the extraction of geologic hydrogen. These technologies include improvements in subsurface transport methods and engineered containment, and reservoir monitoring and/or modeling during production and extraction (e.g., strain, leakage, and/or other risks).



United States Department of the Interior

OFFICE OF THE SECRETARY
Washington, DC 20240

APR 5 2024

The Honorable Joe Manchin
Chairman
Committee on Energy and Natural Resources
United States Senate
Washington, DC 20510

Dear Chairman Manchin:

Enclosed are responses prepared by the U.S. Geological Survey to questions for the record submitted following the February 28, 2024, oversight hearing, "*Opportunities and Challenges Associated with Developing Geologic Hydrogen in the United States.*"

Thank you for the opportunity to provide this information to the Committee.

Sincerely,

Pamela L. Barkin
Acting Legislative Counsel
Office of Congressional and
Legislative Affairs

Enclosure

cc: The Honorable John Barrasso
Ranking Member

Questions for the Record
Senate Committee on Energy and Natural Resources
Oversight hearing titled "*Opportunities and Challenges Associated with Developing
Geologic Hydrogen in the United States.*"
February 28, 2024

Question from Ranking Member John Barrasso:

Question 1. Over the last decade, the world has experienced several helium supply shortages. I understand that researchers have found helium in geologic hydrogen deposits. What might commercial geologic hydrogen production mean for commercial helium production?

Response: Exploration for geologic hydrogen is likely to lead to more discoveries of helium resources. Helium is often found in association with hydrogen because both can be generated by radioactive decay of radiogenic minerals. Some of the strategies employed in helium exploration can be applied to geologic hydrogen exploration as well.

Questions for the Record
 Senate Committee on Energy and Natural Resources
 Oversight hearing titled “*Opportunities and Challenges Associated with Developing
 Geologic Hydrogen in the United States.*”
 February 28, 2024

Questions from Senator John W. Hickenlooper:

Question 1. As a geologist, I’m interested in the science USGS uses to understand Earth’s geologic hydrogen resources, and how those results can inform the private sector. Based on your modeling of geologic hydrogen, can you talk about the geology that factors into how and where reservoirs of hydrogen can form?

Response: Longstanding USGS investments in assessing oil and gas resources, helium resources, and geothermal-energy resources provide useful experience and analogues that are helping accelerate our understanding of geologic hydrogen resources. For example, we are modifying our petroleum system framework to develop a hydrogen system model for understanding the potential for geologic hydrogen accumulations. In addition to the geologic system framework, our science also evaluates the types of rocks that may be sources of this resource and the geologic factors that may come together to form resource accumulations in a particular basin. The source rocks for hydrogen are completely different from those of petroleum and include iron-rich rocks, radiogenic rocks, and deep crustal faults. The migration of hydrogen could be distinct from hydrocarbon migration due to differences in their solubilities in water. Traditional geologic seals for hydrocarbon reservoirs may not be as effective at containing hydrogen given the small size of the hydrogen molecule, which could lead to some leakage of hydrogen from geologic reservoirs over time. However, geologic hydrogen can be generated much more quickly than petroleum, so leakage might not substantially decrease the total hydrogen resource in a particular reservoir.

Question 2. USGS also has several mapping projects focused on better understanding the location of critical minerals and other resources. Can USGS leverage its existing projects to help locate geologic hydrogen? What other data and partnerships might help reach that goal?

Response: The USGS is leveraging its existing projects and data to locate geologic hydrogen. We are using datasets from several USGS studies of other resources to inform the geologic hydrogen prospectivity mapping. Data from the Critical Minerals Mapping Initiative (CMMI) trilateral partnership between the USGS, the Geological Survey of Canada, and Geoscience Australia is one example. We are also using USGS interpretive products and proprietary databases of industry information from our national oil and gas assessments. We are identifying opportunities to leverage ongoing Earth Mapping Resources Initiative (Earth MRI) studies, including tools developed by the DARPA-funded Critical Minerals Assessments with AI Support (CriticalMAAS) project. In February 2024, the USGS and the Colorado School of Mines announced a new joint industry consortium to advance the emerging geoscience on geologic hydrogen. We continue to explore opportunities for additional domestic geoscience partnerships on hydrogen. And under the Climate, Critical Minerals and Clean Energy Transformation Compact, we are increasing U.S.-Australia coordination for geoscience on hydrogen.

Questions for the Record
 Senate Committee on Energy and Natural Resources
 Oversight hearing titled “*Opportunities and Challenges Associated with Developing
 Geologic Hydrogen in the United States.*”
 February 28, 2024

Questions from Senator Lisa Murkowski:

Question 1. Dr. Ellis, in your written testimony you state: “The USGS model will initially be applied to mapping the likelihood of finding geologic hydrogen resources in the lower 48 states of the U.S.” Why are Alaska and Hawaii being excluded from the initial mapping efforts by the USGS?

Response: Prospectivity mapping for geologic hydrogen resources has never been attempted before. Given the challenges of developing a new methodology for estimating the relative resource potential of a novel resource, we elected to start model development with the smaller, contiguous area of the lower 48 states, which is simpler than mapping the larger and more geologically complex discontinuous area of the entire nation. This approach will allow us to develop the methodology more quickly and release the initial results sooner. In tandem with that model development, we are coordinating with the Alaska Division of Geological and Geophysical Surveys and the Arctic Research Commission to develop plans and priorities for potential launch of an Alaska hydrogen mapping effort that would leverage the methodology.

Question 2. In response to Chairman Manchin’s question regarding the timetable of mapping, you responded: “We are aiming to get our initial map of prospective hydrogen for the U.S. by the end of this year. The second key point, once we have this map, it won’t tell you where to drill the wells. This will tell us for the best places to start doing more detailed exploration.” When you say “initial map of prospective hydrogen for the U.S.” do you mean the entire United States (all 50 of them) or just the lower 48 states?

Response: The initial geologic hydrogen prospectivity map will only cover the lower 48 states.

Question 2a. If the initial map only focuses on the lower 48 states and will be used by USGS to “tell us for the best places to start doing more detailed exploration,” does that mean that Hawaii and Alaska will be excluded from subsequent phases of USGS’s mapping efforts for geologic hydrogen?

Response: No. Alaska and Hawaii are the top priorities for addition to the national geologic hydrogen prospectivity map once the initial lower 48 states map is released. USGS is engaging with stakeholders to discuss plans for geologic hydrogen prospectivity mapping of Alaska.

Question 3. What is the Survey’s timetable for mapping Alaska and Hawaii to the same quality and degree as the lower 48 states?

Response: The initial geologic hydrogen prospectivity map of the lower 48 states is expected to be released by the end of the year. Data compilation for mapping Alaska and Hawaii may begin

Questions for the Record
 Senate Committee on Energy and Natural Resources
 Oversight hearing titled "*Opportunities and Challenges Associated with Developing
 Geologic Hydrogen in the United States.*"
 February 28, 2024

prior to the release of the lower 48 states map. Because the methodology will be in place, mapping the prospectivity for geologic hydrogen resources in Alaska should proceed more quickly than the lower 48 map. The addition of Alaska to the national map is expected in a matter of months after the release of the lower 48 states map. Extending prospectivity modeling to Hawaii will likely require modifications to our hydrogen system model to account for the unique geology of that State.

Question 4. Dr. Ellis, your testimony states that the survey will partner with other nations to share data and refine the model. Are there going to be any efforts to ensure the model works in Alaska or Hawaii before the survey partners with other nations?

Response: This area of science is so new that every additional piece of data will enhance our understanding of hydrogen resources. Our partnerships with other nations' geological surveys are intended to leverage data that they have collected in analogous environments. These data will improve our geologic hydrogen model and accelerate our progress in domestic prospectivity mapping. Given the rapidly evolving state of our understanding of the potential for geologic hydrogen resources, our maps of hydrogen prospectivity will be dynamic. As new data are obtained and our understanding improves, we will update the prospectivity maps to reflect these advances. While our priority is to add Alaska and Hawaii to the national map, partnering with other nations to study and map their resource potential will provide invaluable information that can directly improve the accuracy of our national map and the maps of Alaska and Hawaii.

Question 5. On page 75 of the FY24 Senate Energy and Water Appropriations Report (relevant section posted below,) the Committee pushed back against DOE's habit of publishing reports and resource mapping efforts that were intended to be national in scope, but in actuality, were limited to 48 out of 50 states. This habit consistently leaves two states without any knowledge of the resources that may be within their boundaries; drives industry investors interested in exploring these resources to states that received resource mapping by the federal government; and by your own testimony, will also lead to additional federal investments to refine resource mapping and data within those states.

National Studies

The Committee is concerned that the Department of Energy is not including Hawaii and Alaska in national needs studies or resource mapping and assessments. The Committee notes this results in an increasing data gap between Alaska and Hawaii and the rest of the United States. If the Department publishes a study that is national in scope but fails to include all 50 States, the Department is directed to provide an explanation of: (1) why certain States were not included; (2) what steps the Department is taking to ensure that all States are included in subsequent versions of the study; and (3) what resources or authorities the Department requires if the Department was unable to include all 50 States in the study.

Questions for the Record
Senate Committee on Energy and Natural Resources
Oversight hearing titled "*Opportunities and Challenges Associated with Developing
Geologic Hydrogen in the United States.*"
February 28, 2024

Is similar language necessary for USGS, or does the Survey have everything they need to include Alaska and Hawaii in their national resource map for geologic hydrogen that is anticipated to be completed by the end of the year?

Response: The USGS has a national focus including Alaska and Hawaii to its work on energy and mineral resources and is well positioned to include all 50 states in our studies of geologic hydrogen. As noted above, Alaska and Hawaii are not included in the initial mapping effort to facilitate method development and validation and to accelerate the process of releasing results to the public. Inclusion of Alaska and Hawaii are the top priorities for the USGS geologic hydrogen prospectivity mapping efforts once the method is in place.

Questions for the Record
Senate Committee on Energy and Natural Resources
Oversight hearing titled "*Opportunities and Challenges Associated with Developing
Geologic Hydrogen in the United States.*"
February 28, 2024

Questions from Senator John Hoeven:

Question 1. What factors does USGS consider when determining whether identified geologic hydrogen reserves are economically recoverable?

Response: Unlike petroleum resources, geologic hydrogen is novel and there is much uncertainty surrounding the potential for accumulations to form. As such, we are not able to estimate economically recoverable reserves at this time.

Question 2. Which regions in the U.S. have the greatest potential for geologic hydrogen, and are those regions close to demand sources?

Response: We are still working on developing our resource prospectivity maps. The initial geologic hydrogen prospectivity map of the lower 48 states is expected to be released by the end of the year.

U.S. Senate Committee on Energy and Natural Resources
February 28, 2024 Hearing: *Opportunities and Challenges*
Associated with Developing Geologic Hydrogen in The United States
Questions for the Record Submitted to Mr. Pete Johnson

Questions from Ranking Member John Barrasso

Question 1: In a recent news article, some environmentalists have voiced concerns about the purity of geologic hydrogen. They say that companies, like yours, might drill wells that produce 20 percent hydrogen, and 80 percent natural gas. How would you respond to these comments?

Koloma wouldn't produce from a well that was 80% natural gas and 20% hydrogen. The economics of geologic hydrogen production – for Koloma and all geologic hydrogen companies - require finding wells with the highest hydrogen composition possible – preferably 80% or more *hydrogen*. Further, geologic hydrogen producers are incentivized to produce hydrogen at the lowest possible carbon intensity; the presence of hydrocarbons like methane would negatively impact both our carbon intensity and our economics.

Notably, while both hydrogen and natural gas occur in the subsurface and can be extracted as a primary energy source, they are created from significantly different chemical processes. The subsurface features and conditions which produce geologic hydrogen (iron-rich rock + water) are completely different from those which produce natural gas (biological matter exposed to high temperature and pressure for millions of years). As a result, geologic hydrogen is typically explored for and found in areas that haven't traditionally produced oil and gas.

Question 2: Koloma has drilled exploratory wells in several places throughout the country.

(a) When do you anticipate producing commercial volumes of geologic hydrogen?

- (a) The science behind “does geologic hydrogen exist?” is settled – it is clearly present. The key outstanding question is how much hydrogen exists and how much of that is commercially recoverable. We are confident that we can, and will, find significant hydrogen reservoirs that we can bring to market in the near future

With the rate that industry is moving, including several widely publicized hydrogen finds within the last year in Australia, Western Europe, and Africa, a producing geologic hydrogen well in the United States could be realized as soon as the next year or two. Having a supportive and durable policy framework in place will accelerate the industry. However, it will take time to scale geologic hydrogen production and find a highly producing, large basin. That is likely still years away.

Moving from initial production to commercial scale production depends on several factors. First, commercially viable hydrogen reservoirs must be proven up. Second, the Inflation Reduction Act must be implemented in the way Congress intended – as a technologically neutral tax credit. The 45V process – including the Provisional Emissions Rate (PER) application process and adding a geologic hydrogen pathway to the 45VH2-GREET Model – must be efficient, usable, scientifically valid, and

**U.S. Senate Committee on Energy and Natural Resources
February 28, 2024 Hearing: *Opportunities and Challenges
Associated with Developing Geologic Hydrogen in The United States*
Questions for the Record Submitted to Mr. Pete Johnson**

operate expeditiously. Otherwise, geologic hydrogen and other innovative technologies will be disincentivized and unfairly disadvantaged in the marketplace. Third, as the industry grows, so too must the infrastructure to support it. Geologic hydrogen is unique in that it naturally provides both production and storage, but transportation infrastructure is also critical.

(b) What types of customers are most likely to be the first to purchase geologic hydrogen?

- (a) We anticipate initial uses of geologic hydrogen will focus on existing uses of hydrogen like ammonia production, a necessary feedstock for nitrogen-based fertilizer.

Ammonia production will have several key benefits. First, our wells will be located primarily in rural areas that are in close proximity to agricultural lands. This provides an immediate and proximate market for fertilizer. Second, the United States is a major importer of fertilizer – and bringing another form of low-carbon hydrogen production can help reduce farmers’ exposure to volatile shifts in fertilizer pricing. Finally, with current difficulties in transporting significant quantities of hydrogen long distances, we are likely to see economic development for the utilization of hydrogen quickly around points of hydrogen production.

- (b) Sustainable Aviation Fuel is a significant area of decarbonization opportunity, and Koloma is proud to be partnered with both United’s Sustainable Flight Fund and Amazon’s Climate Pledge fund. We aim to leverage geologic hydrogen to provide SAF for these and other consumers of aviation fuel.

Questions from Senator John W. Hickenlooper

Question 1: Going forward, I anticipate a growing need for a workforce skilled in the science, engineering, and technology required to safely and responsibly extract and use resources like geologic hydrogen and critical minerals. This is why I cosponsored the Chair and Ranking Members Mining Schools Act. Can you speak to what federal investments are needed to ensure these workforce needs are met? What role should public-private partnerships play in these efforts?

- (a) We are proud to work with The Ohio State University and understand the importance of building a strong pipeline of well-trained and qualified workforce.

One of the key benefits of geologic hydrogen is we can quickly tap into the existing oil and gas workforce. We anticipate minimal retraining needed for existing workers. Geologic hydrogen exploration and production will need talented engineers, geologists, geochemists, geophysicists, landmen and landwomen, and safety experts. as well as a

**U.S. Senate Committee on Energy and Natural Resources
February 28, 2024 Hearing: *Opportunities and Challenges*
Associated with Developing Geologic Hydrogen in The United States
Questions for the Record Submitted to Mr. Pete Johnson**

number of blue collar workers that include rig operators, welders, pipe fitters, [INSERT MORE WORKERS HERE]. Building businesses in this emerging industry requires entrepreneurs, financial planners, business administrators, offtake experts, and partnership managers, as well.

- (a) We are strongly supportive of workforce development programs that will maintain and grow the workforce of tomorrow.

Questions from Senator John Hoeven

Question 1: What regulatory challenges exist that could hinder development of geologic hydrogen, and is this an area Congress could help address?

- (a) We are grateful for the recently announced DOE funding to ARPA-E to add a geologic hydrogen pathway to the 45VH2-GREET model.

The biggest regulatory hurdle we face is finalization of guidance for the 45V Hydrogen Production Tax Credits. These credits were crafted to be technologically neutral. Final guidance must honor the intent of Congress and follow the letter of the law to create a level playing field where hydrogen producers are evaluated based on their carbon intensity score. This guidance must also include a Provisional Emissions Rate [PER] process that is efficient and provides companies with answers in a reasonable period of time.