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Hearing on "Unleashing American Power: The Development of Next-Generation Energy Infrastructure."

## Introduction

Chairman Williams, Ranking member Bowman, and members of the committee, thank you for this opportunity to discuss these topics, which are of great importance to our nation, our citizens, and the world.

My name is Richard Boardman, and for the last 33 years I have conducted clean energy research at Idaho National Laboratory. Before that, I conducted graduate student research and development for the National Science Foundation Center of Excellence for Advanced Combustion Research Engineering Research[1] and for the petroleum and steel manufacturing industries.

Currently, I am a fellow in INL's Energy and Environmental Science and Technology Directorate, with leadership responsibilities to the EERE Hydrogen Fuel Cell Technology Office and Office of Nuclear Energy Light Water Reactor Sustainability program. I was recently chosen as the National Technical Director for the Office of Nuclear Energy Integrated Energy Systems program. In these capacities, hydrogen production, storage and use are important research topics. I am also a key member of the U.S. Department of Energy's Hydrogen-at-Scale Initiative (H2@Scale) that has the goal of enabling affordable, reliable, clean, and secure energy across many energy and market sectors.[2]

INL is an applied energy laboratory working to change the world's energy future and secure our nation's critical infrastructure through efforts of national importance in nuclear reactor science and technology, national homeland security, and energy and environmental science and technology development.

INL is the nation's nuclear energy research and development center, and in the next few years we will demonstrate advanced nuclear technologies on our Site, the 53rd, 54th and 55th reactors in our more than seven-decade history.

INL is the lead laboratory not just for advanced nuclear technology development, but also for its application across all energy sectors, including electricity, industrial manufacturing and transportation.

[1] acerc.byu.edu; Founded in 1986 for the National Science Foundation with support from industry and government.
[2] https://www.energy.gov/eere/fuelcells/articles/h2scale

## The hydrogen economy

Beginning in the 1960s, researchers began discussing the potential for a hydrogen economy, where clean hydrogen would account for a substantial portion of the world's energy resources as a fuel, energy carrier, and chemical precursor.

Nuclear energy was never established as a source of heat for industrial applications. Until now, much of the heat produced by nuclear reactors was lost. That is rapidly changing as nuclear energy is now recognized by large, energy-intensive industries as a source of clean, high-capacity and highly concentrated heat that in addition to electricity production can also provide process heat and steam and produce hydrogen using thermal and thermal-electrical processes.[3]

The potential remains for clean hydrogen to play an important role in our economy and help ensure U.S. national security at home and abroad.

In my testimony, I emphasize a long-held belief that national security depends on self-reliance in the most basic energy services and commodities that build a nation and keep it running. These include 1) a reliable and resilient electricity grid, 2) fuels for transportation systems, 3) iron and steel for critical infrastructure, 4) fertilizer to sustain food production, and 5) crucial communications networks.

The draft bills are relevant to each of these pillars of national security. Hydrogen is tied to each of these, including its use for conventional petroleum fuels, biofuels and synthetic fuels produced with a broad spectrum of carbon sources, steel, fertilizers, and even to manufacture electronic microchips. Furthermore, hydrogen and chemicals derived from hydrogen can be stored and used to generate power or fuel the nation's hardest-to-abate industrial processes.

A second point I'll emphasize is nuclear energy being part of the mix in decarbonizing all sectors of our energy economy through hydrogen production and integrated energy systems with other forms of energy. Nuclear energy is capable of reliably delivering affordable clean energy to produce hydrogen in central or distributed locations.

National security is only achieved when three conditions exist simultaneously: 1) energy security, 2) economic stability and 3) environmental sustainability. Hydrogen-at-scale provides an energy currency that helps attain these conditions.

Nearly a quarter of the world's emissions come from industry, primarily processes that require high-temperature heat.

Hydrogen can play an important role in reducing the emissions across all sectors. Quantitative figures for this impact are given in the National Hydrogen Strategy and Roadmap. Hydrogen has an obvious value as a clean fuel for power production. But it also is an energy storage medium and a precursor for a number of valuable chemicals, including synthetic fuels and fertilizer.

The production of steel, chemicals and concrete relies heavily on heat from fossil fuels. In addition, the world is producing about 100 million barrels of crude every day to fuel the transportation and industrial sectors, and other energy needs. This results in another quarter of world carbon dioxide emissions.

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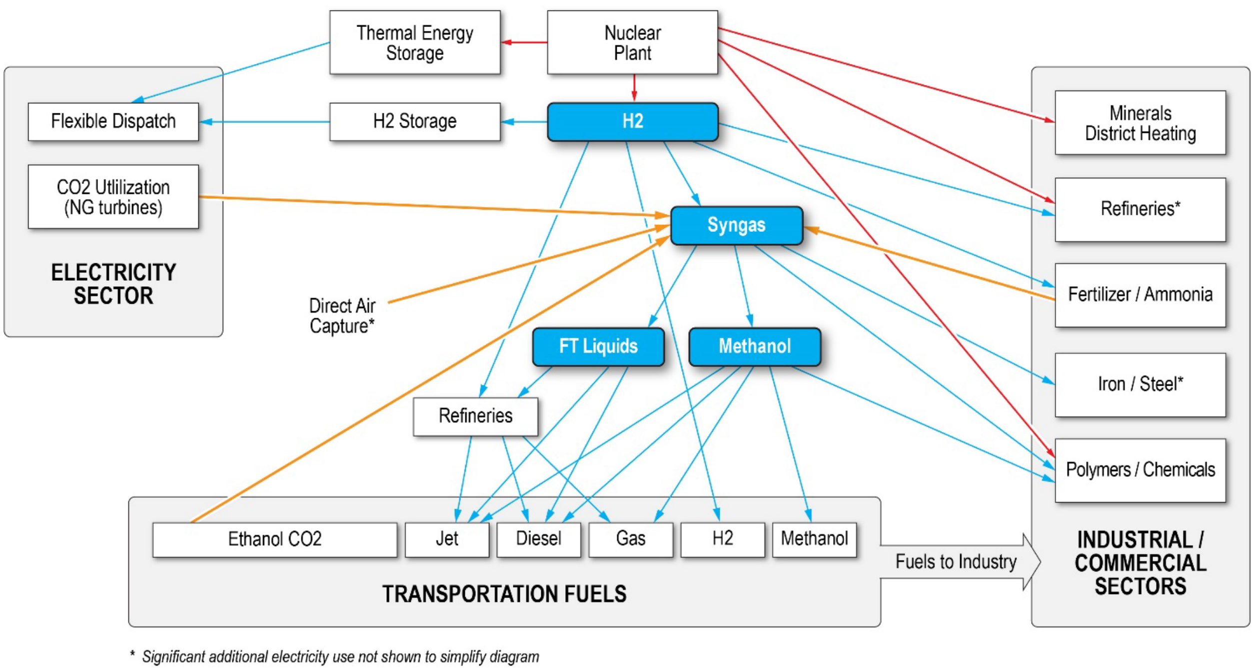
[3] 2022. Boardman, R.D., S.M. Bragg-Sitton, U. Otgonbaatar. Developing a low-cost renewable supply of hydrogen with high-temperature electrochemistry. MRS Bulletin, Vol. 47, March 2022, mrs.org/bulletin; doi:10.1557/s43577-022-00278-6

It is alarming that the United States is partially dependent on foreign supply on our most critical energy services and commodities: fuels, steel and even fertilizers.

At one time, the U.S. produced roughly half of the world's steel and was a major exporter. Now, due to foreign competition that is not compelled to manage solid waste and air emissions, the United States produces less than 10% of the world's steel. Because of this, we import steel from several nations, including some that do not have our best interests at heart, including China.

It is also clearly feasible to electrify a large majority of the transportation fleet to reduce carbon emissions with electrical and fuel-vehicles. However, the cost of an aggressive conversion of all vehicles to electrical vehicles alone will require a massive buildup of new clean power generation systems.

A vision exists for using nuclear energy to support the production of clean substitute fuels by combining nuclear hydrogen and a broad spectrum of recycled carbon sources. In this scheme hydrogen, heat and electricity from nuclear sources are used with the carbon sources to produce a clean drop in combustible fuels.[4]




Clean hydrogen, and all the associated technologies that come with its development, will create jobs and a market of technology for the U.S. and beyond.

## Integrated systems

To meet the needs of industry, transportation and electricity generation, INL researchers are working with other DOE national labs and industry to develop integrated energy systems. These systems directly couple diverse energy generation sources, such as nuclear, renewables and fossil with carbon capture, to support the grid along with industrial and transportation processes.

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[4] Jason Marcikoski, DOE Nuclear Energy All Hands Meeting, March 2023.

These systems can provide both thermal and electrical power to decarbonize industries that are difficult to electrify. They will ensure more efficient energy use and provide increased revenues for plant owners by providing multiple product streams. And they offer great potential for cleaner, lower-cost, and more efficient transportation and industrial applications. Integrated systems will enhance power grid reliability and resilience. They will help stabilize the grid through increasingly flexible operation.

When coupled with nuclear energy, these systems are flexible enough to fill in for renewables when demand is high or conditions unfavorable for wind or solar generation. When grid demand is low, these systems can divert heat and electricity to other energy users, such as a hydrogen production facility.

For hydrogen systems to be established and then expanded, four aspects must be in place.

***First, we must have low-cost hydrogen-production technology.***

Today, about 95% of the hydrogen used in the U.S. is produced from natural gas, using a process that emits carbon dioxide. It is possible to capture and sequester this $CO_2$, and DOE research under the Fossil Energy and Carbon Management Program is assisting industry in implementing this add-on feature to plants that produce hydrogen from natural gas.

Electrolysis uses electricity to split water into hydrogen and oxygen. If the source of electricity is clean, the hydrogen produced is clean.

Recently, electrolysis technologies are beginning to approach the cost of hydrogen produced from natural gas.

Electrolysis could be especially efficient when coupled with high-temperature steam from a nuclear power plant, a process that produces zero carbon emissions. Also, this is pure hydrogen, which is immediately ready for ammonia production, glass making, and other niche markets.

The cost of production can be reduced by supporting electrolysis development, testing and demonstration. Investments in these areas will help American companies reduce costs, quickly ramp up to high-volume manufacturing, and bring down costs.

The testimony one year ago by Keith Wipke, a colleague at the National Renewable National Laboratory, a sister lab to INL, presented important capabilities supporting the development and performance testing of advanced low-temperature electrolysis technologies and the emerging needs and opportunities for hydrogen production tied to renewable energy.[5]

With funding provided by DOE's Hydrogen and Fuel Cell Technology Office (HFTO), INL has stood up a capability to support industry with materials development and performance testing of high-temperature electrolysis.[6] INL's premier lab facilities provide the foundation for research excellence.

[5] Prepared Statement of Keith Wipke, Laboratory Program Manager for Fuel Cell and Hydrogen Technologies, National Renewable Energy Laboratory, U.S. House of Representatives Committee on Science, Space, & Technology Subcommittee on Energy Hearing on "H2Success: Research and Development to Advance a Clean Hydrogen Future", February 17, 2022.

[6] INL- Hydrogen: Our energy future begins at INL, Citation Needed.

***Second, clean energy must be affordable.***

Electrolysis requires electricity. High-temperate electrolysis uses heat and electricity to attain even higher efficiency when a heat source is available. High-temperature electrolysis is especially well-suited for nuclear energy sources.

Renewables, such as solar and wind, can provide low-cost electrons when conditions allow. Nuclear energy can provide clean, concentrated, reliable, high-capacity electricity and heat. The nation's existing fleet of nuclear reactors provide low-cost heat and power. INL leads DOE's Light Water Reactor Sustainability program, which supports plant modernization and extending the operating life of nuclear power plants.[7] This makes the existing fleet an excellent source of power and heat for large hydrogen plants. Building large-scale hydrogen plants and using nuclear energy as a source for electricity and heat will reduce project costs and make low-cost hydrogen possible.

***Third, we must have a market for the hydrogen produced.***

Industry is enthusiastic about the potential for low-cost hydrogen. This includes producing ammonia for fertilizer, reducing iron ore to make clean steel, and using hydrogen with a broad spectrum of renewable carbon sources, including $CO_2$ extracted from the atmosphere, to produce clean chemicals and drop-in fuels.

The steel and fuels markets are enormous and can take more than 100 million metric tons of hydrogen, a 10% increase in what is currently produced.

Increasing production of clean hydrogen will reduce our dependence on foreign supplies of materials and commodities. It will make the U.S. an exporter of clean energy products and services.

A great example of what is possible is the General Electric Turbines division.

GE Aeroderivative gas turbines are being developed, tested and manufactured in the U.S. The installed base for these turbines is more than 1,000 units in the U.S. and more than 5,000 units worldwide. GE is looking to demonstrate 100% hydrogen burning gas turbines for land turbines. This technology could be utilized in flight engines on airplanes within two decades.

Another example of hydrogen's potential is the Cleveland Cliff Direct-Reduced Iron Steel Plant. The company is evaluating the use of hydrogen as a replacement for natural gas. The plant was designed to be ready when hydrogen becomes commercially available in significant quantities. This company is prepared to immediately replace up to 30% of the plant's natural gas consumption with hydrogen, reducing greenhouse gas emissions by approximately 450,000 metric tons per year.

The Advanced Clean Energy Storage project in Utah will develop the world's largest industrial green hydrogen production and storage facility. This facility, powered by renewables, will help meet the growing demand for clean hydrogen.

Oil and gas companies in the U.S. see the potential and are evaluating their opportunities to use clean hydrogen to decarbonize production and refineries.

Also, Dr. H.Y. Sohn, a University of Utah professor, recently published a book, "Flash Ironmaking," that details how a consortium that includes the university, DOE, and the American Iron & Steel

[7] https://lwrs.inl.gov/SitePages/Home.aspx

Institute, joined forces to develop a new technology that will significantly reduce energy consumption, greenhouse gas emissions and process complexities.

Flash iron making is an example of a high-tech innovation that warrants government/private industry collaborative development. A 10 MWe scale pilot demonstration facility is needed to accelerate commercial development.

***Fourth, U.S. policies and regulations must help initiate market expansion that will be supported by investments*.**

Economies around the world are increasingly putting a price on the emissions from their products and activities. Whether through policy and tax actions, business response to consumer demands, or strategic decisions made by capital markets, the cost of carbon emissions tied to products and services will change the global competitive landscape.

Those that develop and deploy technologies that lower the emissions of their products and services will succeed. This will shift the balance of economic competitiveness globally, and it is imperative that the United States lead in this new frontier of economic competition.

To capture this advantage, industries seek to embed nuclear heat and power sources in industrial and manufacturing operations. Microreactors, paired with industrial processes, can offer the United States an incredible competitive edge.

Joining these "plug and play" nuclear microreactors with industrial processes is called "incremental provisioning of industry." This entails adding energy modules to match industrial modules and offers an investable way to accelerate industrial decarbonization. It also opens the potential for entirely new business models for deployment, where companies can specialize in leasing zero-emission heat and power to industry.

There is a national economic security imperative for the U.S. to lead in this space and the path to global leadership runs directly through our energy leader and transition communities such as in the state of Wyoming. These regional nuclear first movers are seeking economic growth and diversification based on energy. They also are advanced nuclear energy "first-movers."

This first-mover advantage, combined with their investments in low-emission economic developments and forward-leaning policies relative to nuclear energy applications, could make them global leaders for low-emission products. It could also result in a leadership position for those making modular manufacturing and industrial process systems.

Entrepreneurs in Wyoming are pursuing just that – a regional to global strategy to cement leadership in this new frontier of economic opportunity and competition. Innovative partnerships – between state governments, private sector manufacturers and industry, reactor vendors, investors, and national laboratories are an incredibly important tool in creating these novel, forward-leaning approaches for low-emission economic transformation.

And there is a direct national security implication to this development beyond global economic competitiveness. The military is developing transportable microreactors to meet its evolving mission needs. It is important that commercial and military applications for these new approaches develop in synergy to strengthen supply chains and lower costs.

This dual economic security will be critical for securing our climate, homeland and economic future.

**Current DOE-supported research and development**

DOE hydrogen production and hydrogen use technologies involve cross-cutting program efforts that draw in the Department of Energy's Office of Nuclear Energy, Fossil Energy and Carbon Management, Energy Efficiency and Renewable Energy, Office of Science, and Advanced Research Projects Agency.

A federal Hydrogen and Fuels Cells Interagency Working Group has been created.[8] Representatives from the participating agencies meet regularly to share research results, technical expertise and lessons learned about program implementation, technology development and deployment. They also coordinate interagency programs and activities related to safe, economical and environmentally sound hydrogen and fuel cell technologies.

**Building on our successes**

With DOE support, INL researchers are testing commercial high-temperature electrolysis systems to prove their performance under real-world conditions. Tests with commercial systems ranging up to 100-kWe are underway.

In a few months, INL researchers plan to install a 250-kWe system outside the Energy Systems Laboratory on the Idaho Falls campus. This system could soon provide hydrogen for a new fuel-cell-powered motorcoach, one of 85 motor coaches that safely transport more than 1,600 INL employees to and from their jobs in facilities on our 890-square-mile Site.

Eventually, as the centerpiece of the Clean Energy Technology Proving Ground, INL envisions a 5+ MW system on our Site.

[8] https://www.hydrogen.energy.gov/hfciwg

This system is also connected to INL's real-time grid simulation and associated grid power conditioners.

These capabilities are being established with support from HFTO and industry, especially companies such as Nexceris, OxEON Energy, Cummins, FuelCell Energy, and Bloom Energy. As a result of this collaboration between government and the private sector, important integrated energy systems testing is taking place, buses will soon be running on hydrogen fuel cells, and U.S. technology has an opportunity to capture the marketplace.

A great example of important work is the hydrogen development and demonstration projects jointly supported by the Office of Nuclear Energy and the Hydrogen and Fuel Cell Technology Office.

Exelon Generation is building a hydrogen demonstration project at its Nine Mile Point Nuclear Station in New York. Just recently, this facility became the first in the U.S. to generate clean hydrogen using nuclear power.

A tri-utility consortium is on schedule to demonstrate clean hydrogen production using water electrolysis at the Energy Harbor Davis-Besse Nuclear Power Station in Ohio in 2024. This work will be followed by demonstration of steam electrolysis at an Xcel Energy plant in Minnesota.

These demonstration projects are important contributors to DOE's Earthshot Initiative, which aims to significantly reduce the cost of clean hydrogen over the next decade, decarbonize the industrial sector, and realize a net-zero economy by 2050.

**Grid security and resiliency:**

INL's mission is centered on changing the world's energy future. We also have a mission focused on securing our nation's critical infrastructure and ensuring its cyber and physical resiliency.

The Department of Energy has been a key enabler of the laboratory's efforts to secure the electric power grid. In the last decade, DOE has invested nearly $40 million at INL establishing one of the nation's most comprehensive electric power grid test beds on INL's Critical Infrastructure Test Range Complex.

INL's demonstration grid includes up to 32 miles of reconfigurable distribution line, 16 miles of transmission line, full fiber-optic communications, and transformers capable of supporting demonstrations at 15, 25 and 35 kilovolts.

Dotting the grid are four, 2,500-square-foot research pads designed to house large pieces of equipment for conducting power load testing, smart grid assessments, energy storage experiments, and cybersecurity evaluations of industrial control systems technology. The entire system is operated from an on-site command center featuring up-to-date control systems and real-time power management equipment that allow sections of the test grid to be isolated for specific high-risk demonstrations.

A new 40,000-square-foot test pad and equipment storage building was recently added to the test bed. And an additional 110 miles of energized transmission line that is spread across INL's 890-square mile desert Site can also be utilized for specific experiments.

Optimized to represent the wide range of distribution system configurations found across the country, the grid test bed enables greater flexibility in assessing new ideas and technologies to protect the nation's critical electric infrastructure.

This test grid and INL's technical expertise in cyber-informed engineering and critical function assurance are a vital part of the Administration's National Cybersecurity Strategy.

**Draft legislation**

The draft legislation on hydrogen would help accelerate our transition to a robust hydrogen economy, stimulate U.S. manufacturing, combat the effects of climate change, and strengthen national security. Additionally, the draft bills on grid security and pipelines will help establish national energy security and hydrogen as an energy currency.

These important pieces of legislation would further develop important tools, establish standards for data taxonomies and communications protocol, and provide incentives to carry out crucial regional demonstration projects, with government and industry working to ensure the security and resiliency of our nation's power grids.

In conjunction with investments already made, the hydrogen draft bill will accelerate technology and infrastructure development and would quickly put the U.S. on track to establish the supply chain and industrial use of hydrogen.

It would augment efforts to reduce the risk of investing in new technologies and early adoption by the marketplace. These efforts include production and investment tax credits passed in the Inflation Reduction Act. These credits are game changers for operators of the current nuclear reactor fleet and investors in advanced nuclear technologies.

**Conclusion**

I believe American ingenuity and invention coupled with an orchestrated government and industry technology demonstration and commercial acceleration of hydrogen production, delivery and use by industry, will help build a stronger, stable economy and national energy security while achieving mutual interests in conquering climate change with the global commons.

Through vigorous R&D, robust industry involvement, and bipartisan support at all levels of government, we can attain complete national security as we revitalize American communities, reinvigorate domestic manufacturing, and reinvent industrial and transportation processes. A robust hydrogen economy will help by providing an energy currency for clean energy production sources that include advanced small scale nuclear reactors and many or our existing large nuclear reactors.

Finally, I believe Frontier efforts being led by Wyoming and Alaska can help the essential supply chain for incrementally provisional application of reliable, high-capacity advanced nuclear reactors that can provide industrial heat for process thermal and electrical duties and hydrogen production, obviating large hydrogen storage and delivery systems. This can help clean hydrogen be competitive with large, at-scale systems, particularly those tied to variable generation sources. It will spawn a vibrant U.S. manufacturing and supply chain.

Thank you again for the opportunity to testify before the committee. I look forward to answering any questions you may have.