CONGRESSIONAL PROGRAM
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Policy Opportunities for U.S. Energy Innovation and Security

May 25 - June 1, 2024
Sydney and Canberra, Australia

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AGENDA

SATURDAY, MAY 25:
U.S. participants depart the U.S.

SUNDAY, MAY 26:
U.S. participants travel to Sydney, Australia.

MONDAY, MAY 27:
U.S. participants arrive in Sydney, Australia.

1 – 2:30 PM: Working Lunch
This session will elucidate the rationale behind the Congressional Program's decision to select Australia as the conference venue. It will also offer a comprehensive overview of the conference topic, outline the forthcoming program, and engage members of Congress in a discussion on U.S. energy challenges.

2:30 – 5 PM: Individual Discussions
All invited scholars will be available to convene individually with members of Congress to meet each other before the conference panels and discuss policy opportunities for U.S. energy innovation and security.

5 – 6 PM: Fireside Chat:
U.S.-Australia Relations: The Quad, AUKUS, and Energy Security

This panel will delve into the multifaceted partnership between the United States and Australia, focusing on key areas of collaboration such as the Quadrilateral Security Dialogue (Quad), the Australia-United Kingdom-United States Security Partnership (AUKUS), and energy security initiatives. The Quad, comprising the U.S., Australia, India, and Japan, serves as a strategic forum for addressing regional challenges and promoting a free and open Indo-Pacific. AUKUS, a trilateral security pact between the U.S., Australia, and the U.K., aims to bolster defense capabilities and technological cooperation, particularly in the realm of maritime security. Additionally, the discussion will explore bilateral efforts between the U.S. and Australia to enhance energy security through diversified energy sources and clean energy technologies.

Speakers:
Michael Green, *Professor, Chief Executive Officer, the United States Studies Centre*
Malcolm Turnbull, *29th Prime Minister of Australia*

6:15 – 8:15 PM: Working Dinner
Seating is arranged to expose participants to a diverse range of views and provide the opportunity for a meaningful exchange of ideas. Scholars and lawmakers are rotated daily. Discussions will focus on emerging trends in U.S. clean energy innovation.

TUESDAY, MAY 28:

6:30 – 8:30 AM: Breakfast Available

9 - 9:15 AM: Introduction and Framework of the Conference
This conference is organized into roundtable conversations, working lunches, site visits, pre-dinner remarks, and working dinners. This segment will highlight how the conference will be conducted, how those with questions will be recognized, and how responses will be timed to allow for as much engagement as possible.

Speaker:
Charlie Dent, *Vice President, Aspen Institute;*
Executive Director, Aspen Institute Congressional Program

9:15 – 11 AM: Roundtable Discussion:
The Future of Natural Gas in the U.S. Energy System and Beyond

The fracking boom of nearly twenty years ago pushed the U.S. into becoming the largest producer of natural gas in the world, all while helping to lower energy system emissions through the conversion of coal assets to gas power. And gas has turned out to be an optimal complement to the deployment of intermittent renewable energy like wind and solar, helping to ensure system reliability all while integrating into the grid clean generation assets. Some questions to consider:

- What is the future of natural gas in the context of an ongoing transition to a net-zero U.S. electricity system?
- What role will natural gas play in U.S. energy security in the short, medium, and long terms?
- How should policymakers think about natural gas in the context of broader U.S. energy policy imperatives?
- What are the implications of liquified natural gas for energy security and climate change?

Speakers:
Rich Powell, *Chief Executive Officer, Clean Energy Buyers Association*
Melanie Kenderdine, *Secretary-designate, New Mexico Energy, Minerals and Natural Resources Department*

11 - 11:15 AM: Break

11:15 AM - 1 PM: Roundtable Discussion
Nuclear Energy in the United States

Recent advances in fission technologies, combined with renewed business and policymaker interest in nuclear energy more generally, seems to have positioned nuclear energy at the cusp of a renaissance. Some questions to consider:

- What role could nuclear energy play in reinforcing the reliability and security of the U.S. electricity system?
- How should policymakers understand the ways in which nuclear technologies have evolved and continue to evolve?
- In what ways could nuclear energy address climate change imperatives?
- What are the potential opportunities for U.S. leadership on nuclear energy internationally?

Speaker:
John Kotek, *Senior Vice President, Policy Development and Public Affairs, Nuclear Energy Institute*

1 – 2:30 PM: Working Lunch
Discussion continues between members of Congress and scholars, including Rich Powell, Melanie Kenderdine, and John Kotek, on the future of natural gas and supply chain security in the U.S.

2:30 – 5 PM: Individual Discussions
Scholars will be available to meet individually with members of Congress for in-depth discussion of ideas raised in the morning sessions, including Rich Powell, Melanie Kenderdine, and John Kotek.

6:15 – 8 PM: Working Dinner
Seating is arranged to expose participants to a diverse range of views and provide the opportunity for a meaningful exchange of ideas. Scholars and lawmakers are rotated daily. Discussions will focus on nuclear energy in the U.S. and materials supply chain security.

WEDNESDAY, MAY 29:

6:30 – 8:30 AM: Breakfast Available

9 – 10:30 AM: Roundtable Discussion:
Launching New Opportunities: U.S. Clean Hydrogen Leadership and What it Means for Global Shipping

Ninety percent of globally traded goods are shipped by sea, and maritime trade volumes are expected to triple by 2050. The global maritime shipping sector is undergoing an energy metamorphosis and is expected to decarbonize by 2050, positioning it to become a significant off-taker of green hydrogen-based fuels. This fuel transition will take place on a global scale and creates significant economic opportunities for countries that lead in the development of cutting-edge clean energy maritime technologies and fuels. Building on recent federal investments, the United States has a growing capacity to produce the hydrogen-based maritime fuels and technologies that the global maritime sector needs to meet its ambitious decarbonization goals. This session will consider how the United States can leverage American innovation and resources to help secure a leadership position in these fuels markets while also benefiting the global shipping sector and American businesses and communities.

Speakers:
Meg Gentle, *Executive Director, HIF Global*
Stephen Metruck, *Executive Director, Port of Seattle; Former Rear Admiral, United States Coast Guard*

10:30 AM – 6 PM: Educational Site Visit
The Port of Newcastle
The Port of Newcastle is a pivotal hub of maritime activity and trade in Australia. This visit will offer members of Congress a firsthand experience into the operations and significance of one of the largest and busiest ports in the Southern Hemisphere. Members will explore port operations, including cargo handling, vessel navigation, and port infrastructure. They will gain insights into the port's crucial role in facilitating global commerce, supporting regional development, and fostering economic growth.

7 – 9 PM: Working Dinner
Seating is arranged to expose participants to a diverse range of views and provide the opportunity for a meaningful exchange of ideas. Scholars and lawmakers are rotated daily. Discussions will focus on U.S. clean hydrogen leadership and U.S.-Australian climate cooperation.

THURSDAY, MAY 30 (Overnight in Canberra):

7 – 8:45 AM: Breakfast Available

9 AM – Noon: Travel from Sydney to Canberra

Noon – 1:15 PM: Working Lunch
Discussion continues between members of Congress and scholars, Meg Gentle and Stephen Metruck on U.S. clean hydrogen leadership.

1:20 – 3 PM: Members of Congress Observe a Session of the Australian Parliament
Members of Congress observing a session of the Australian Parliament provides a unique opportunity for cross-cultural exchange and legislative insight. As they witness the democratic processes and debates in action, they gain firsthand understanding of Australia's political system and its parliamentary traditions. This experience fosters collaboration and mutual understanding between nations, enriching diplomatic relations and facilitating the exchange of ideas on governance and policy-making.

3 – 4 PM: Meeting with Senior Australian Government Officials
These meetings will involve high-level decision-makers, including ministers and senior advisors, engaging in strategic discussions, policy coordination, and collaboration on matters of energy security and cooperation. The aim is to exchange ideas, address

challenges, and explore opportunities for cooperation to advance U.S. and Australian interests, particularly in the energy sector.

4:30 – 5:15 PM: Educational Site Visit to the Australian War Memorial
This educational visit will allow members of Congress to gain insight into the sacrifices and valor of Australian servicemen and women from World War I to the present. The memorial serves as a place of reflection and remembrance, ensuring that the human stories behind the conflicts are never forgotten while inspiring future generations to strive for peace and security.

7:30 – 9 PM: Working Dinner and Reception with Australian Senior Government Officials and U.S. Diplomats
This evening will be dedicated to discussing matters of mutual interest and collaboration between the United States and Australia. It will involve conversations on diplomatic relations, strategic partnerships, and shared objectives over a meal.

FRIDAY, MAY 31:

6:30 – 7:55 AM: Breakfast

8 – 9:30 AM: Roundtable Discussion
Managing Load Growth – and Decarbonization

Energy demand ("load") in the U.S. electricity system is poised to grow by an order of magnitude over the next few decades, and consequently ensuring system reliability while meeting this growing demand (from electrification of new sectors, on-shoring of manufacturing, the growth of artificial intelligence services, and more) will be a major challenge. All the while, decarbonization remains a critical parallel priority. The main question to consider: What are tools, policies, and technologies that can meet this challenge?

Speakers:
Anna Foglesong, *Clean Grid Initiative*
Jim Connaughton, *Nautilus Data Technologies; former Chair of the White House Council on Environmental Quality*

9:30 – 9:45 AM: Break

9:45 AM – 11 AM: Roundtable Discussion
Materials Supply Chain Security

As geopolitical competition accelerates, the national and energy security of the United States and its allies will increasingly necessitate attention to supply chain vulnerabilities regarding certain materials and technologies which are essential to the reliability of the energy system and decarbonization efforts. Some questions to consider:

- Looking at critical minerals mining and processing, photovoltaic precursors, hydrogen electrolyzers, and other essential supply chain flows, in what ways might the United States best work with allies to ensure the security of essential resources and technologies?

- How might emergent international relationships like the Quadrilateral Security Dialogue (or, "the Quad") play a role? What essential risks might be top priorities for policymaker attention?

Speakers:
Jonathan Pershing, *Program Director, Environment, Hewlett Foundation; Former U.S. State Department Special Envoy for Climate*
Robin Millican, *Senior Director, U.S. Policy and Advocacy, Breakthrough Energy*

11 AM – Noon: Working Lunch
Discussion continues between Members of Congress and scholars, including Anna Foglesong, Jim Connaughton, Jonathan Pershing, and Robin Millican about materials supply chain security and load growth.

Noon – 4 PM: Travel from Canberra to Sydney

6:15 – 8:15 PM: Working Dinner
Seating is arranged to expose participants to a diverse range of views and provide the opportunity for a meaningful exchange of ideas. Scholars and lawmakers are rotated daily. Discussions will focus on Members' policy reflections and ideas generated throughout the conference.

SATURDAY, JUNE 1:

6:30 – 8:30: Breakfast Available

9 – 11 AM: Policy Reflections for Members of Congress
This time is set aside for Members of Congress to reflect on what they learned during the conference and discuss their views on implications for U.S. policy.

11 AM – 1 PM: Working Lunch
Discussion continues between Members of Congress and scholars, including John Kotek, Anna Foglesong, Jim Connaughton, Stephen Metruck, Rich Powell, Robin Millican, and Melanie Kenderdine on Members' main takeaways and policy ideas generated throughout the conference.

2 – 7 PM: Participants depart the hotel for the airport to return to the U.S.

CONFERENCE PARTICIPANTS

MEMBERS OF CONGRESS AND THEIR SPOUSES:

Rep. Jim Baird and Danise Baird

Rep. Brendan Boyle

Rep. Julia Brownley

Rep. Yadira Caraveo

Rep. Sheila Cherfilus-McCormick and Corlie McCormick

Rep. Dan Crenshaw and Tara Crenshaw

Rep. Ron Estes

Rep. John Garamendi and Patti Garamendi

Rep. Andy Harris and Nicole Harris

Rep. Robin Kelly

Rep. Zoe Lofgren

Rep. Raul Ruiz

Rep. Jan Schakowsky and Bob Creamer

Rep. Kim Schrier and David Gowing

Rep. Pete Sessions and Karen Sessions

Rep. Randy Weber and Brenda Weber

SCHOLARS AND EXPERTS:

Kathryn Benz	*Senior Policy Manager, Ocean & Climate, Energy and Environment Program, Aspen Institute*
Jim Connaughton	*Chairperson, Nautilus Data Technologies; Former Chair of the White House Council on Environmental Quality*
Anna Foglesong	*Managing Director, Clean Grid Initiative*
Meg Gentle	*Executive Director of the Board, HIF Global*
Anand Gopal	*Executive Director, Policy Research, Energy Innovation*
Michael Green	*Professor, Chief Executive Officer, the United States Studies Centre*
Melanie Kenderdine	*Secretary-designate, New Mexico Energy, Minerals and Natural Resources Department*
John Kotek	*Senior Vice President, Policy Development and Public Affairs, Nuclear Energy Institute*
Stephen Metruck	*Executive Director, Port of Seattle; Former Rear Admiral, United States Coast Guard*
Malcolm Turnbull	*29th Prime Minister of Australia*

RAPPORTEUR:

Timothy Mason	*Director, Energy & Climate, Energy and Environment Program, Aspen Institute*

FOUNDATION REPRESENTATIVES:

Robin Millican	*Senior Director, U.S. Policy and Advocacy, Breakthrough Energy*
Jonathan Pershing	*Director, Environment Program, Hewlett Foundation; former Special Envoy for Climate Change, U.S. Department of State*
Rich Powell	*Chief Executive Officer, The Clean Energy Buyers Association (CEBA)*
Daniel Schory	*Chief of Staff, Infrastructure, Arnold Ventures*

ASPEN INSTITUTE CONGRESSIONAL PROGRAM:

Charlie Dent	*Executive Director, Congressional Program and Vice President, Aspen Institute*
Tyler Denton	*Deputy Director*
Carrie Rowell	*Conference Director*
Jennifer Harthan	*Senior Manager of Congressional Engagement*

RAPPORTEURS' SUMMARY

Timothy Mason
Director, Energy & Climate, Energy and Environment Program, Aspen Institute

U.S.-Australia Relations: The Quad, AUKUS, and Energy Security

The conference kicked off with a candid dialogue featuring Dr. Mike Green and former Australian Prime Minister Malcolm Turnbull regarding the longstanding and close relationship between the United States and Australia. Dr. Green, Prime Minister Turnbull, and the members spoke of the multifaceted security challenges and opportunities facing the two countries and their allies.

The Future of Natural Gas in the U.S. Energy System and Beyond

Natural gas is currently the most significant fuel in the United States, contributing to 43% of the nation's primary energy production. The U.S. has emerged as the leading global producer of natural gas, with reserves estimated to last at least 100 years at current consumption rates. This fuel is the primary source of energy for electricity generation and heating in many parts of the country.

Members and experts discussed in a nuanced way the role that natural gas plays in the U.S. energy system. On the one hand, natural gas is a fossil fuel, and many agree regarding the importance of minimizing or eliminating fossil fuels in the domestic and global energy systems to stop climate change. On the other hand, natural gas is essential to energy affordability and reliability in the U.S. and in many other places at least in the short and medium terms. And there may be chances to replace coal with natural gas in some instances, especially abroad, to achieve immediate emissions reductions. Yet, some worry about "lock in" to gas technologies or about the effects of methane leakage.

Natural gas, primarily composed of methane (CH_4), is the simplest hydrocarbon. Methane is abundant and is a byproduct of both natural gas fields and oil production, particularly from shale formations unlocked by the 2006 shale gas revolution. Major production areas include the Marcellus Shale in Pennsylvania, now a key gas production region.

Natural gas is produced both as a pure commodity and as a byproduct of oil production. The infrastructure for extracting, processing, and transporting natural gas includes extensive networks of pipelines and storage facilities. Key players in the industry, such as Conoco, Exxon, Chevron, and Cheniere, contribute significantly to the U.S.'s production capabilities.

Methane is a potent greenhouse gas (GHG), with a global warming potential (GWP) significantly higher than carbon dioxide (CO_2) over a 20-year period. Methane leaks during extraction, processing, and transport are a major concern. The industry has made substantial progress in reducing methane leakage, but there is still much more to do, especially amongst smaller, independent producers.

Combustion of natural gas produces CO_2 and water vapor, with the switch from coal to natural gas being a major factor in reducing the U.S.'s overall CO_2 emissions. The key threshold for methane leakage is 2.75%: below this, natural gas is cleaner than coal; above it, the benefits diminish or disappear entirely.

The industry has implemented numerous measures to control methane emissions. Market-based incentives and technological innovations continue to drive improvements. For instance, the National Petroleum Council's study highlighted significant progress and potential for further emissions reductions through enhanced monitoring and technological deployment.

Additionally, new carbon capture and sequestration technologies, such as those being demonstrated by NETPower, promise to integrate carbon capture in natural gas power plants effectively.

The session underscored that methane emissions are a significant short-term issue, while CO_2 emissions will be a long-term challenge. The GHG intensity of natural gas has decreased by nearly half since 2005, with projections indicating a 66% reduction in methane emissions by 2030 through continued policy support, technological advancements, and industry collaboration.

However, without new policies and technologies, CO_2 (and possibly also methane) emissions from the natural gas value chain are expected to rise. To counter this, robust federal support for CCS demonstrations and advanced monitoring technologies is essential.

Natural gas remains important for the current and future U.S. power sector. While it plays a vital role today, its long-term viability depends on proving it can be a zero-GHG fuel. The industry is focused on efforts to reduce emissions and leverage technology to ensure natural gas remains a key component of a low-carbon future.

Nuclear Energy in the United States

Nuclear energy plays a critical role in the United States' energy landscape, providing approximately 20% of the nation's electricity. It is recognized for its ability to generate large amounts of reliable, low-carbon power, which is essential in the context of climate change and the transition to a zero-carbon energy grid.

Members and experts discussed that nuclear energy has been a somewhat polarizing technology, with some feeling in the past that nuclear energy is either “good” or “bad.” Often, opponents of nuclear energy were worried about nuclear safety, and the disposal of nuclear waste. Now that climate change is emerging as a key focus for policymakers, some are taking a second look at nuclear energy, valuing it for its zero-carbon electricity production, and also taking into account new nuclear generating technologies which were not available decades ago.

The primary fuel for nuclear reactors is uranium, which must be mined and then enriched to increase its concentration. The United States possesses uranium enrichment facilities, including a significant one in New Mexico, although it is foreign-owned. Enrichment is vital because it transforms raw uranium into a form suitable for use in reactors.

Future reactors are expected to use high-assay, low-enriched uranium (HALEU) instead of the traditional highly enriched uranium (HEU), offering enhanced safety and efficiency. A new facility in Ohio has recently started producing fuel for advanced reactors, which is a critical development for the sector.

Uranium fuel remains in a reactor core for 5-6 years, generating heat through nuclear fission. This heat produces steam, which drives turbines to generate electricity. Post-use, the spent fuel is both thermally and radioactively hot and is initially stored in pools before being transferred to dry storage containers, which the Nuclear Regulatory Commission (NRC) deems safe for up to 100 years.

The long-term solution for spent fuel is deep geological disposal. Although the Yucca Mountain repository was designed for this purpose, it has faced significant political and regulatory hurdles. The best practice involves deep geological depositories, but the U.S. needs to overcome legislative barriers related to the Nuclear Waste Policy Act.

The resurgence of interest in nuclear energy is primarily driven by the urgent need to address climate change. Many utilities have pledged to achieve zero-carbon goals, and nuclear energy is seen as a pivotal component in achieving these targets due to its ability to provide consistent, low-carbon power.

Although nuclear plants are more expensive to build compared to solar or wind facilities, they offer system efficiency by reducing the need for overbuilding storage and other assets. This makes nuclear energy a cost-effective option when considering the overall system cost.

China currently leads in new nuclear construction, with the most significant program of new builds globally, surpassing France in nuclear energy generation. The U.S., however, faces challenges in regaining its leadership in this sector due to the hiatus in nuclear construction over the past 30 years. Consistent construction practices, as seen in South Korea, are essential for cost-effective nuclear development.

Innovations in Small Modular Reactors (SMRs) are gaining momentum, with companies like GE Hitachi and NuScale advancing their designs. These reactors offer flexibility and can be deployed in diverse settings, including replacing coal plants in various communities, in lieu of or in parallel to investments in existing plants.

There is significant interest in advanced reactors, including liquid-cooled, gas-cooled, and molten salt reactors. These technologies offer enhanced safety and efficiency and are suitable for various applications, including industrial processes and hydrogen production.

To overcome the "first of a kind" cost barriers, nuclear energy requires robust federal and state support. Legislative efforts such as the ADVANCE Act and the Atomic Energy Advancement Act are some examples of ongoing ideas to address these concerns.

The U.S. needs to enhance its competitiveness in the global nuclear market to counter the dominance of Russian and Chinese technologies. Support from institutions like the Export-Import Bank and the Development Finance Corporation, alongside international financing mechanisms, may be helpful in promoting U.S. nuclear exports.

Ensuring a reliable and competitive supply of nuclear fuel is essential. Investments in new enrichment and fabrication facilities should be prioritized to reduce reliance on foreign sources.

Maintaining the operation of existing reactors through uprates and subsequent license renewals is increasingly recognized as crucial. These measures ensure that the current nuclear fleet continues to contribute to the energy mix.

Implementing regulatory reforms to streamline NRC processes and support new reactor technologies is an emergent policy interest. Legislative measures might focus on reducing bureaucratic barriers and encouraging innovation.

Strengthening U.S. capabilities in the international nuclear market through supportive policies and financial mechanisms will ensure the U.S. can compete effectively with Russia and China.
Nuclear energy remains a vital component of the U.S. energy portfolio. Its ability to provide reliable, low-carbon power makes it indispensable for achieving climate goals. Continued innovation, regulatory reform, and strategic investments are essential to maintain and expand the role of nuclear energy in the United States and globally. The collaborative efforts of industry stakeholders and policymakers will be crucial in navigating the challenges and realizing the full potential of nuclear technology.

Launching New Opportunities: U.S. Clean Hydrogen Leadership and What It Means for Global Shipping

The global transition away from fossil fuels is reshaping the maritime industry. Last year, the International Maritime Organization (IMO) set a goal to phase out greenhouse gas (GHG) emissions from ships by or around 2050. Achieving zero emissions requires the development of zero-emission maritime fuels, and fuels derived from green hydrogen are poised to play a key role. This transition presents significant economic opportunities for countries that lead in the development of clean energy maritime technologies and fuels.

Members and experts discussed how global maritime shipping is the lynchpin of the economy, and yet is often not a subject of policymaker attention unless and until something goes wrong (such as a ship being stuck in the Suez canal wreaking havoc on the global trade system). The usual fuel that powers ships is called bunker fuel, which is particularly dirty to burn (among other negative effects, it releases soot ("black carbon"). Members and experts therefore talked about potential technological and economic solutions to help clean up this sector.

Global shipping is a cornerstone of economic growth and trade, with over 80% of global trade by volume moving by sea. Ships consume around 105 billion gallons of fuel annually, and this number is expected to grow. As the maritime sector transitions to cleaner fuels, the competition for these fuels will intensify, especially for early adopters.

Green hydrogen, produced using renewable energy, is a promising solution for reducing maritime emissions. The United States, with its growing capacity to produce hydrogen-based fuels, is well-positioned to become a leader in this space. By leveraging American innovation and resources, the U.S. can secure a leadership position in clean energy maritime fuels, benefiting both the global shipping sector and American businesses.

The shift to alternative fuels has significant national security implications. With potential supply chain disruptions and new global production hubs emerging, the U.S. fleet and maritime sector must adapt. The military's substantial energy demand presents an opportunity for the government to drive the development and deployment of domestic alternative energy sources. Investing in clean energy fuels may provide fuel flexibility in a global multi-fuel future.

Substantial investment is necessary to capitalize on the hydrogen opportunity. New fuels must compete with conventional energy sources, which have benefited from decades of investment and infrastructure development. Policy may help close the cost gap and provide incentives to accelerate the energy transition in the United States. The Inflation Reduction Act and other policies continue to provide substantial incentives for clean energy investments, particularly in the public sector, such as ports.

Ports are critical in enabling global travel, trade, and commerce. They serve as conveners, bringing together the entire maritime value chain around a common purpose. Ports also play a significant role in national security, resilience, and recovery from disasters. The transition to zero-emission fuels will require ports to expand fuel storage and bunkering services for multiple fuels. Ports like Seattle are exploring their roles in this energy transition while maintaining ongoing economic, social, and environmental responsibilities.

The clean energy transition for shipping is already underway, and with continued investment, the United States can lead in the production and bunkering of clean hydrogen and maritime fuels. This leadership can strengthen national security, promote economic development, and fulfill environmental responsibilities.

Managing Load Growth – and Decarbonization

Energy demand, or "load," in the U.S. electricity system is expected to grow significantly in the coming decades. This growth is driven by several factors, including the electrification of new sectors, re-shoring of manufacturing, and the rise of artificial intelligence services. Ensuring system reliability while meeting this increasing demand is a major challenge, especially as decarbonization remains a critical parallel priority. The main question to consider is: What tools, policies, and technologies can meet this challenge?

Members and experts discussed the paradox between the need to build many assets fast, especially transmission lines, in order to ensure electricity system reliability and address climate change versus the great difficulty, or even impossibility, of being able to actually build those very assets due to permitting and other barriers that often stand in the way. Members and experts reflected on the complex interplay of laws and requirements that lead to inertia in building, and imagined together what could form the foundation for new ways to both build assets quickly while also ensuring that people and the environment remain protected.

Load growth is a positive indicator of economic growth and prosperity. It powers U.S. jobs, supports innovation, and contributes to national security. Significant portions of this growth are attributable to the U.S. leadership in computing and the re-shoring of industrial and manufacturing activities, which create jobs and revitalizes communities. Additionally, the fight against climate change, through efforts like producing clean hydrogen and capturing carbon, also contributes to this load growth.

Historically, the U.S. saw high annual load growth in the mid-20th century, with the 1950s averaging 8.8% and the 1960s at 7.4%. This growth slowed in subsequent decades due to factors like economic changes and efficiency improvements. Recently, load growth has doubled to around 1.2%, and this figure might be an underestimate.

Significant statistics include:

- -The number of manufacturing facilities in the U.S. has grown by over 11% since Q1 2019.
- Construction spending in manufacturing has nearly tripled since June 2020.
- Industrial sector electricity usage is projected to grow by 36 GWs by 2030.

To meet the increasing load demand, several strategies could be considered, particularly given the current bottlenecks in the grid's interconnection capacity:

1. Limit Growth: Not a desirable option as it would lead to brownouts or blackouts, negatively impacting economic growth and reliability.
2. More Local Generation: Delaying retirements or building new local capacity, likely gas, is part of the solution but comes with higher costs, less reliability, and increased pollution.
3. Expand Transmission: The preferred option involves upgrading the existing grid and building new transmission to unlock access to more generation over a wider geography. This approach lowers costs, increases reliability and resilience, and supports climate solutions without committing to a specific energy mix.

Expanding transmission capacity faces three primary challenges, known as the 3Ps: planning, paying, and permitting.

- Planning: Requires forward-looking regional and interregional strategies. FERC's Order 1920, focusing on regional planning and cost allocation, is a positive step but needs further support for interregional planning.
- Paying: Incorporating a federal investment tax credit (ITC) for transmission would help lower overall costs.
- Permitting: There is a clear need for Congress to streamline the permitting process without compromising environmental protections. A system akin to the Eisenhower interstate highway system could expedite this process.

Some Additional Considerations for Load Growth

- Load Differentiation: Different types of loads (curtailable vs. non-curtailable) need different planning approaches.
- Uncertainty: Future technologies and their efficiency, such as AI and direct air capture, could significantly impact load growth projections. Therefore, expanding grid capacity should be prioritized to avoid limiting U.S. growth.
- International Cooperation: Learning from countries like Australia, which face similar challenges, can provide valuable insights.

The overarching policy objective should be to ensure that supply can keep pace with demand, requiring a shift from a scarcity mindset to one of abundance and agility. Key policy imperatives include:

1. National Security: Ensuring a resilient and abundant energy supply.
2. Energy Security: Maintaining reliable and affordable energy.
3. Economic Security: Creating jobs and preventing economic leakage.
4. Environmental Security: Addressing air pollution, habitat conservation, and climate change.

Load growth presents an opportunity for economic growth and innovation in the United States. By implementing the right policies and investing in infrastructure, the U.S. can meet increasing energy demands in a reliable, affordable, and environmentally responsible manner. With a coordinated, bipartisan approach, the U.S. can ensure its energy system is equipped to handle future challenges while fostering national and economic security.

Materials Supply Chain Security

As geopolitical competition accelerates, the national and energy security of the United States and its allies will increasingly necessitate attention to supply chain vulnerabilities regarding certain materials and technologies. These materials are essential to the reliability of the energy system and decarbonization efforts. Understanding and mitigating supply chain risks is crucial as energy remains a fundamental pillar of economic stability and growth.

Members and experts discussed how the complex and interconnected global supply chain both serves Americans while also exposing them to certain risks. Members and experts focused in the conversation on how best to address or minimize supply chain risks particularly with regard to certain geopolitical risks that are often at top of mind for policymakers.

What Do We Mean by Supply Chain Risk? Supply chain risks can manifest in several forms:

1. Geopolitical Risk: Political instability or conflicts, such as the invasion of Ukraine, can disrupt supply chains. These disruptions are particularly concerning for critical industries like semiconductors.

2. Logistical Issues: Unforeseen events, such as the COVID-19 pandemic or the Suez Canal blockage, can create systemic chaos due to the lean, just-in-time nature of global logistics systems.

3. Regulatory and Social Challenges: Long permitting times and societal acceptance issues can significantly delay projects. For instance, it takes about 10 years to build a new transmission line, a major barrier when immediate solutions are needed.

While supply chain risks are often associated with clean energy, fossil fuels also pose significant risks. The global nature of oil and gas markets subjects them to price volatility and geopolitical influences, such as OPEC's production decisions. Overreliance on any single energy source is economically and geopolitically risky. Instead, leveraging a diverse array of energy sources can provide flexibility and resilience, positioning the U.S. as a global energy leader.

Four major areas of concern in clean energy supply chains stand out:

1. Critical Minerals for Batteries: Lithium, nickel, manganese, cobalt, and graphite are essential for lithium-ion batteries used in electric vehicles (EVs) and grid storage. These materials are often sourced from countries with geopolitical risks, like China and the Democratic Republic of Congo (DRC).
2. Other Critical Materials: Copper and aluminum are crucial for wiring and electrical components. The demand for copper is particularly high and experiencing shortages.
3. Rare Earth Elements: Essential for permanent magnets used in EV motors, wind turbines, and military applications. Key elements include neodymium, praseodymium, dysprosium, and terbium.
4. Equipment: Inverters and hydrogen electrolyzers are produced by a limited number of manufacturers, making rapid demand increases a challenge.

Supply chain security for the U.S. involves several strategies:

1. Diversification and Domestic Production: The Inflation Reduction Act (IRA) incentivizes using U.S.-sourced materials and advanced manufacturing, aiming to reduce reliance on non-FTA countries for critical minerals.
2. Defense Investments: Billions are being allocated to bolster the defense industrial base, including critical minerals and essential inputs.
3. Risk Management: It is vital to distinguish between economic risks (market share and jobs) and national security risks (availability of critical products). Strategies should be tailored accordingly.

Some strategies for enhancing supply chain security could include, substitution, innovation, recycling, increasing domestic supply, and international partnerships.

The U.S. might pursue a broad clean energy commercial diplomacy strategy that integrates trade, supply chain assistance, development finance, and technology licensing. This strategy should offer better deals than competitors like China and support international standards for environmental protection, community engagement, and innovation.

Addressing supply chain security is critical for maintaining U.S. economic and national security. By diversifying sources, investing in innovation, and strengthening international partnerships, the U.S. can build a resilient and sustainable supply chain for critical materials essential for the clean energy transition.

POLICY ACTION MEMORANDUM FOR MEMBERS OF CONGRESS[1]

- Methane leakage in the natural gas system remains a major concern, even as gas serves critical energy needs. Enhanced measurement and monitoring for regulatory compliance and "certified gas," could help mitigate these concerns. Some policy ideas that might help address methane concerns might include incentives to drive deeper emissions reductions for CO2 and methane, technology sharing and development, especially for low-capitalized operators and support for new and existing CCS projects to mitigate CO2 emissions effectively.

- Nuclear energy plays a critical role in the United States' energy landscape, providing approximately 20% of the nation's electricity. To overcome the "first of a kind" cost barriers, nuclear energy requires robust federal and state support. Legislative efforts such as the ADVANCE Act and the Atomic Energy Advancement Act are some examples of ongoing ideas to address these concerns.

- Maritime shipping is responsible for roughly 3% of global greenhouse gas emissions. Green hydrogen, produced using renewable energy, is a promising solution for reducing maritime emissions. To seize the hydrogen opportunity, ideas for Congress include:
    - Initiating a challenge similar to the Sustainable Aviation Fuel Grand Challenge to drive the development of maritime fuels.
    - Including ocean-going vessels in fuel incentive programs and reducing barriers to the maritime use of lower-emission fuels.
    - Creating federal grants for demonstrating hydrogen use at ports through a "Hydrogen for Ports Act" to create federal grants for demonstrating hydrogen use at ports.
    - Supporting international market-based measures at the IMO and maintaining a strong U.S. policy presence.
    - Investing in training the next generation of tech-savvy workers to build solutions for increased digitalization and efficiency in the maritime sector.
    - Expanding funding for existing grant and loan programs to include energy projects in and around ports.
    - Investing in research and development of low and zero-emissions maritime fuels, supporting renewable energy infrastructure improvements, investing in

[1] *Note: This policy action memorandum is compiled for Congressional participants and depicts policy ideas that emerged during the conference sessions in Australia. The Aspen Institute is a neutral convener. We merely cataloged the ideas that came forth.*

domestic shipbuilding capabilities, and encouraging federal procurement of clean energy technologies.

- Energy demand, or "load," in the U.S. electricity system is expected to grow significantly in the coming decades. Many experts agree that the United States will need to urgently build much more transmission lines in order to help move electricity around the country from generating points to load centers like major metropolitan areas. Some of the key ideas that emerged for addressing load growth include:
    - Focusing on reducing emissions rather than debating fuel types.
    - Simplifying and streamlining permitting processes, incorporating a performance-based approach.
    - Establishing a federal investment tax credit for transmission.
    - Implementing fees on high-emission countries like China to level the playing field.
    - Developing ways to cross-approve rights of way, such as building transmission along existing highways, railroads, or pipelines.
    - Deriving inspiration from the framework of the Base Realignment and Closure Commission for decision making on permitting of transmission projects.

Certain materials and minerals are essential to the reliability of the energy system and decarbonization efforts. Some strategies for enhancing supply chain security could include:

- Substitution: Investing in research and development to create alternative materials that can replace scarce or geopolitically risky ones. For example, using iron ferrite magnets in applications where high-performance magnets are not essential. This could reduce dependence on neodymium and dysprosium, which are primarily sourced from China.

- Innovation:
    a. Advancing Battery Chemistries: Promote the development of new lithium-ion battery chemistries that minimize or eliminate the use of cobalt and other hard-to-source materials. Innovations in battery technology can reduce the need for critical minerals that are difficult to procure domestically.
    b. Hydrogen Technologies: Support advancements in hydrogen electrolyzers and other equipment that require fewer rare materials or can be produced with more abundant resources.

- Recycling:

a. Improving Recycling Rates: Enhance the recycling infrastructure to recover critical minerals from end-of-life products. Currently, only about 10% of lithium batteries are recycled, but technologies exist that can recover up to 95% of lithium and other materials. Companies like Redwood Materials are leading efforts in this area, though the process needs to become more energy-efficient and environmentally friendly.
b. Incentivizing Circular Economy Practices: Provide incentives for companies to adopt circular economy practices, ensuring that materials are reused and recycled to the maximum extent possible.

- Increasing Domestic Supply:
    a. Streamlining Permitting Processes: Address regulatory hurdles and streamline the permitting process for new mining projects. This includes legislative changes to reduce the time it takes to open new mines and recover critical minerals.
    b. Environmentally Responsible Mining: Promote mining methods that are less intrusive and more acceptable to communities, such as extracting lithium from geothermal brines. This method can be less environmentally damaging and more socially acceptable than traditional mining.
    c. Community Engagement: Engage with local communities and tribal nations early in the planning process to ensure that mining projects are developed with their input and benefit-sharing agreements.

- International Partnerships:
    a. Diversifying Supply Chains: Strengthen alliances with countries that have abundant critical minerals, such as Australia (lithium and rare earth elements) and Canada (nickel and cobalt). The Mineral Security Partnership (MSP), which includes 13 countries and the EU, is an initiative aimed at securing and managing the supply of critical minerals through international cooperation.
    b. Commercial Diplomacy: Enhance the role of U.S. commercial diplomacy agencies, such as the Export-Import Bank and the Development Finance Corporation, to support international projects that align with supply chain security goals. Legislative changes can provide these agencies with more funding and tools to facilitate these efforts.
    c. Trade Agreements: Develop and strengthen trade agreements that facilitate the secure exchange of critical materials between allied nations. This includes ensuring that supply chains are resilient and not overly dependent on any single country, particularly those with adversarial relations.

SCHOLARS' ESSAYS

The Role of Natural Gas in Energy Security, Decarbonization, and Food Security

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The recent global energy crisis – the result of Russia's war on Ukraine and its ripple effects – has placed energy security at the center of global energy concerns and debates. This crisis and the heightened focus on energy security has not diminished the need for deep decarbonization and the clean energy transition. It has, however, added the need for energy solutions that address both energy security and decarbonization goals. In this context, natural gas is playing – and can play–an essential role.

To inform the role of natural gas in energy security more fully, some historical perspective is instructive. As it is now, energy security was at the forefront of serious concerns in 2014, when Russia invaded Crimea. Then U.S. Secretary of Energy Moniz was alarmed by the implications these events had for global energy security and, in response, advanced the concept that the oil-centric definition of energy security used by the U.S. and its allies was antiquated and needed updating.

The Department of Energy (DOE) staff drafted a proposed set of modernized energy security principles that were then refined in negotiations with the G7 energy ministers in Rome in May 2014. They were then adopted by the G7, EU and European Commission leaders in Brussels later that year. Excerpted text from the Brussels' declaration offers some valuable guidance about a collective responsibility for energy security and how the U.S. and its allies should view and respond to Russia's most recent invasion of Ukraine:

> "Under the Rome G7 Energy Initiative, we will identify and implement concrete domestic policies by each of our governments separately and together, to build a more competitive, diversified, resilient and low-carbon energy system. This work will be based on the core principles agreed by our Ministers of Energy … in Rome:
>
> - Developing flexible, transparent, and competitive energy markets, including gas markets;
> - Diversifying energy fuels, sources and routes, and encouragement of indigenous sources of energy supply;
> - Reducing our greenhouse gas emissions and accelerating the transition to a low carbon economy as a key contribution to sustainable energy security;
> - Enhancing energy efficiency in demand and supply, and demand response management;
> - Promoting deployment of clean and sustainable energy technologies and continued investment in research and innovation;

- Improving energy systems resilience by promoting infrastructure modernization and supply and demand policies that help withstand systemic shocks; and
- Putting in place emergency response systems, including reserves and fuel substitution for importing countries, in case of major energy disruptions

Based on these principles we will take the following immediate actions:

- Promote the use of low carbon technologies (renewable energies, nuclear in the countries which opt to use it, and carbon capture and storage) including those which work as a base load energy source; and
- Promote a more integrated Liquefied Natural Gas (LNG) market, including through new supplies, the development of transport infrastructures, storage capabilities, and LNG terminals, and further promotion of flexible gas markets, including relaxation of destination clauses and producer-consumer dialogue."[2]

The recommendations for these "immediate actions" at that time addressed both climate needs and natural gas in the form of LNG. This approach is also needed today as the U.S. and its allies are working to address the impacts of the Russian invasion of Ukraine on European energy supplies.

Importantly, since the 2014 invasion of Crimea, the U.S. has become the largest gas producer and LNG exporter in the world. The value of this resource and the U.S. role was demonstrated after the most recent Russian invasion of Ukraine in 2022. After Russia's aggression, Europe lost 22 bcm of natural gas and the U.S., with its large supply, export capacity, and unique feature of its LNcontracts – the lack of destination clauses – was able to replace 19 bcm of those lost volumes. This, however, raised availability and price concerns for Asian customers. While they understood the urgency of the situation in Europe, they faced the loss of supplies from the U.S. and significant price spikes. Because of the implications of natural gas for energy security and affordability in Europe and Asia and the critical role played by the U.S., the rest of this essay will focus on these three regions/countries.

These actions and impacts underscore the value of and need for natural gas for energy security and additional LNG supplies in the near- to mid-term. A range of forecasts suggest that in Europe, near-term demand for natural gas (via LNG) will continue, although the long-term demand for natural gas in Europe is likely to decline, driven by accelerated decarbonization efforts and energy security concerns. In meetings to inform a global gas study by the EFI Foundation, many Western European countries saw the most recent Russian-induced energy crisis as an opportunity to accelerate the energy transition by pursuing electrification and increasing domestic energy production. Eastern European countries, however, regarded natural gas as a critical fuel source for the energy transition, especially in the industrial sector, but viewed LNG as expensive and difficult to source in a tight global market.

In Asia – driven in part by China –mid- to long-term demand for natural gas is expected to increase. The long-term demand forecasts for natural gas in China are, however,

[2] Excerpted text from the Brussels' declaration

challenging due to complex factors affecting supply and demand, including continued investments in renewables, the government's pursuit of coal for energy security, growing domestic natural gas production, and imports from Russia via pipelines. Southeast Asia and South Asia are expected to have increased demand for natural gas in both the near -and longer-term. Southeast Asia's long-term energy demand and natural gas demand are driven by economic and population growth. In South Asia, declining domestic production and rising demand for natural gas will boost the region's reliance on imported LNG.

Differing forecasts of global long-term demand for natural gas discourage investment in LNG supply infrastructure. The decreasing scale of investment in LNG supply infrastructure has already led to concerns about a potential supply shortage starting around 2030. In the longer-term, however, Europe, China, and Northeast Asia could have a substantial amount of underutilized assets since the capacity of the existing, under construction and announced, LNG import infrastructure far exceeds projected LNG demand through 2050.

This and other data underscore the potential impacts of uncertain natural demand forecasts on natural gas infrastructure investments. Global gas plants under construction worldwide, as of February 2024, were almost 200,000 MW, with another 255,741 MW in the preconstruction phase, for a total of 454,559 MW. Of this total, 10% is in SE Asia, 32% in East Asia (32% of the total) and another 7% in the rest of Asia; 49% of natural gas power generation capacity in the construction or pre-construction phase in the world is in Asia. In February 2024, Europe had almost 50,000 MW of natural gas generation in the construction or pre-construction phase and in North America, there was 27,479 MW. Total natural gas generation in the construction or pre-construction phases in these three regions represented almost 300,000 MW or 65% of the world total.[3]

Important for the growing gas demand reflected in the large increases in natural gas power generation, the United States will continue to be the world's top exporter of LNG through 2050. To meet growing international demand, the United States needs additional LNG export terminal capacity in the near- and mid-term, especially as Europe continues to move away from importing Russian natural gas. In addition to uncertain demand forecasts, U.S. LNG suppliers have faced and will continue to face numerous challenges in building LNG export infrastructure. These include net zero targets, legal and regulatory requirements, and reducing the greenhouse gas emissions, and the environmental impacts of new infrastructure.

This data on Europe, the U.S., and Asia underscores the investments being made in natural gas use. It also underscores investment risks and the potential for stranded assets where policies would restrict, reduce, or eliminate the use of fossil fuels, including natural gas.

In this context of natural gas supply and demand growth and the associated infrastructure needs and investments, it important to underscore another key energy

[3] Global Energy Monitor (2024)

security principle adopted by the U.S., EU, and European Commission in 2014: "Reducing our greenhouse gas emissions and accelerating the transition to a low carbon economy as a key contribution to sustainable energy security."

As of June 2023, 73% of all countries had net zero commitments with target dates ranging from 2050 to 2070. The U.S. has a 2050 target, and the Biden Administration has committed to a target for the United States to achieve a "50-52% reduction from 2005 levels in economy-wide net greenhouse gas pollution in 2030," and has set a goal of "creating a carbon pollution-free power sector by 2035 and net zero emissions economy by no later than 2050." Also, at COP28, in addition to the communique's focus on the transition away from fossil fuels, 50 oil and gas companies announced that they would reduce methane leaks from their systems to "near zero" by 2030. This follows the *Global Methane Pledge*, launched at COP26 in 2021, in which 150 countries committed to reducing methane emissions from all sectors by at least 30% by 2030.

These goals create a natural tension between current demands for natural gas and net zero targets by mid-century. In Europe, near term options for addressing this tension include delaying planned retirements of nuclear power plants, efficiency (another G-7 principle) and energy conservation policies and practices such as demand response. Deploying more wind and solar, while a longer-term option, is also desirable.

On the U.S. side of the Atlantic this issue is being managed in several ways including the Biden targets noted earlier, the methane rule. The EU is actively working to phase out fossil fuels, with programs like the *European Green Deal, Fit for 55*, and *REPowerEU*; it is not yet clear how it will manage the potential issue of stranded assets or Eastern European concerns.

Asia is much more complicated. Many countries in Asia have net zero targets, although five do not and the dates vary. There are also major differences between developed and developing countries in the region, where in developing countries, energy affordability is a primary concern. Importantly, the population in the Asia Pacific region is projected to increase by almost half a billion people in the next 26 years and account for 25% of the total increase in global population. Population increases in developing parts of the Asia/Pacific will require significant amounts of energy and electricity to support economic and social development.

In addition to meeting rising energy demand, developing countries face other energy-related development and equity challenges, such as providing universal electricity and energy access, reducing air pollution, or establishing infrastructure in urban areas. In 2022, the number of people who live without electricity reached nearly 775 million.[4] According to the World Bank, progress has been made in electricity access in Asia and said, "The number of people without electricity access plummeted in Central and Southern Asia, falling from 414 million in 2010 to 24 million in 2021, with much of

[4] Laura Cozzi et al., "For the first time in decades, the number of people without access to electricity is set to increase in 2022," November 3, 2022, https://www.iea.org/commentaries/for-the-first-time-in-decades-the-number-of-people-without-access-to-electricity-is-set-to-increase-in-2022

the improvement occurring in Bangladesh, India, and other populous countries. The number without access to electricity in Eastern and South-eastern Asia declined from 90 million to 35 million during the same period. In Northern Africa and Western Asia, the unserved population decreased less markedly — falling from 37 million in 2010 to 30 million in 2021."[5]

Also, while climate change raises existential concerns, air pollution and air quality are also significant issues, affecting health and quality of life, especially in regions and countries that lack air quality standards. It is estimated that in 2019, for example, that long-term exposure to PM 2.5 was responsible for 4.1 million deaths worldwide in 2019.[6]

Importantly, these different drivers will affect the long-term trajectory for natural gas in the region. Globally, in 2022, coal was responsible for over 44% of CO_2 emissions, oil was responsible for 33%, and natural gas for 22.7%, and Asia is a substantial coal consumer. While in the Energy Information Administration's reference case, Japan and South Korea are forecast to reduce their coal consumption by 20% between 2022 and 2050, all other sub-regions/countries in the Asia Pacific will see increases in coal consumption. India's coal consumption, for example, would increase by 232% in that period.[7] Even in Energy Information Administration's low-cost net zero technology scenario, India's emissions from coal increase by over 56% in that time frame, and "Other Asia Pacific" (excludes Japan, S. Korea, China, India, Australia, New Zealand) increase even more dramatically by almost 77%.[8]

This data suggests several pathways for reducing emissions in the Asia Pacific Region. Because of this increased demand for coal, coal-to-gas fuel switching for power generation could have significant impacts on regional emissions. An International Energy Agency (IEA) analysis indicated that in 2018, coal to gas fuel switching could reduce CO2 emissions in China's power sector by 8%, prompting China to support incentives for coal to gas fuel switching.

Coal to gas fuel switching also has air quality benefits, particularly important to developing Asia. SO2 emissions from natural gas, for example, were 0.7% of the total in 2019, compared to 58% for coal. Particulate emissions from natural gas (PM2.5) were 17% of the total compared to about 63% for bioenergy. An example of the benefits of natural gas for air quality: in the cities in China that implemented a coal-to-gas

[5] IEA, IRENA, UN Statistics Division, The World Bank, and World Health Organization, *Tracking SDGs: The Energy Progress Report 2023*, 2023, https://trackingsdg7.esmap.org/data/files/download-documents/sdg7-report2023-full_report.pdf
[6] McDuffie, E.E., Martin, R.V., Spadaro, J.V. *et al.* Source sector and fuel contributions to ambient $PM_{2.5}$ and attributable mortality across multiple spatial scales. *Nat Commun* **12**, 3594 (2021). https://doi.org/10.1038/s41467-021-23853-y
[7] EIA International Energy Outlook 2023, Reference Case
[8] EIA International Energy Outlook 2023, Low-cost Zero Emissions Technology Case, 2022-2050

switching policy, on average, SO_2 and $PM_{2.5}$ dropped by 5.9 and 1.2% per year, respectively.[9]

In addition, carbon capture is critical, especially in Asia Pacific where coal generation dominates and for industrial emissions, a hard to abate sector. Carbon capture and storage could dramatically reduce emissions from coal- and gas-fired power generation and industrial uses of natural gas. The value of and need for CCS were highlighted by the G-7 ministers in Brussels when they adopted the modernized energy security principles. At that time, as noted, the ministers urged immediate action on, among other things, promoting "…the use of low carbon technologies", including "carbon capture and storage". In a similar vein, in 2020, IEA analysis concluded that "Reaching net zero will be virtually impossible without CCUS [carbon capture, utilization, and storage]."

It should be noted that in this regard, natural gas plays a major role in industrial processes, providing high temperature heat that cannot be achieved via electrification, which currently can provide heat at about 400°C. Around 50% of industrial sub-sector processes require temperatures of 500°C or greater. For iron and steel, it is around 93%, non-metallic industries around 75%, chemicals around 68%, and nonferrous metals, e.g., aluminum, around 45%.[10]

Even where processes can be electrified, electricity relative to natural gas prices are much higher. In the U.S., the electricity to gas price ratio is 3-5 times higher for electricity. In Germany, in 2021, the difference in electricity vs. natural gas prices for industry was 123%, in Turkiye, it was 96% and in Korea, it was 71%.[11]

These price differentials raise both emissions and competitiveness issues. In the U.S. for example, collectively the glass, aluminum, iron, steel, plastics, and chemicals, including agricultural chemicals, represent approximately $1.09 trillion in value to the economy and around 1.8 million U.S. jobs.[12] Technologies are being developed to produce high temperature heat with electricity, but these are in the relatively easy stages. Until these become affordable and available, natural gas, coal, and petroleum will continue to be used for industrial processes. In the U.S. in 2019, natural gas was approximately 90% of the fuel used in glass manufacturing (this does not include energy for electricity where natural gas is 39% of electricity generation); roughly 50% of the fuel used for aluminum, and around 30% of the fuel needed for making steel. In other regions of the world where natural gas is less plentiful, coal supplies the heat needed for most industrial processes.

It should be noted that early gains are essential for addressing the existential threat of climate change and that these materials – glass, aluminum, and steel – are needed for the clean energy transition to make, among other technologies, wind turbines and solar

[9] Jingjing Zeng, Rui Bao, and Michael McFarland, "Clean Energy Substitution: The Effect of Transitioning from Coal to Gas on Air Pollution," *Energy Economics* 107 (2022): 105816.
[10] Rissman, J. "Decarbonizing Low-Temperature Industrial Heat in the US Energy Innovation Policy & Technology." (2022).
[11] https://www.iea.org/reports/key-world-energy-statistics-2021/prices
[12] U.S. Bureau of Labor Statistics, Employment, and output by industry, https://www.bls.gov/emp/tables/industry-employment-and-output.htm

panels. There is also a significant need for near-term actions to mitigate emissions from these industrial processes; CCUS will likely be essential for managing emissions from these processes, in the near- to mid-term.

It is often said that CCUS is not ready for deployment. However, globally, in 2022, there were 30 operating CCUS projects and 77 projects in the advanced development stage. Operating projects supporting industrial decarbonization included capture from gas processing facilities, fertilizer production, and iron, steel, and chemical production.[13]

Finally, it is important to understand the role of natural gas in food security. According to the IEA "… About 70% of ammonia is used for fertilizers, while the remainder is used for various industrial applications, such as plastics, explosives, and synthetic fibers… Since the early 20th century, mineral fertilizers have formed an integral part of our food system. … around half of the global population is sustained by mineral fertilizers."[14][15] There are two main production methods – from renewables ("green ammonia") or from natural gas. Green ammonia is promising but expensive to produce and currently only accounts for 2% of current global production. Options for decarbonization include electrolysis, methane pyrolysis, and CCUS. Pilot projects are encouraging but green ammonia will only be market viable when production costs come down compared to production from natural gas.

Specifically, ammonia production disruptions can lead to local availability limitations and price increases, interrupted transport conduits, and diminished food safety.[16] Food insecurity increased from 135 million people in 2019 to 345 million in 2022 due in large part to the "war in Ukraine, supply chain disruptions, and economic fallout of the COVID-19 pandemic that pushed food prices to all-time highs."[17] The World Bank notes that "rising food commodity prices in 2021 were a major factor in pushing approximately 30 million additional people in low-income countries toward food insecurity."[18]

Decarbonization of the ammonia industry is directly tied to food security as fertilizer production directly impacts food prices and therefore food security. As the IEA notes

[13] Global CCS Institute, GLOBAL STATUS OF CCS, 2022
[14] IEA, Ammonia Technology Roadmap, 2021, https://www.iea.org/reports/ammonia-technology-roadmap, License: CC BY 4.0
[15]
[16] Climate change, Global Food Security, and the U.S. Food System Assessment Report, USDA. 2015, Available at: https://www.usda.gov/oce/energy-and-environment/food-security, Accessed: February 1 2024.
[17] World Bank Group, Climate explainer: Food Security and climate change, 2022, World Bank. Available at: https://www.worldbank.org/en/news/feature/2022/10/17/what-you-need-to-know-about-food-security-and-climate-change, Accessed: February 1, 2024.
[18] World Bank Group, Climate explainer: Food Security and climate change, 2022, World Bank. Available at: https://www.worldbank.org/en/news/feature/2022/10/17/what-you-need-to-know-about-food-security-and-climate-change, Accessed: February 1, 2024.

“higher energy and fertilizer prices therefore inevitably translate into higher production costs, and ultimately into higher food prices.”[19]

This provides a very brief overview of the role of natural gas in energy security, decarbonization, and energy equity, including food security. More analysis is needed on the range of issues discussed in this essay.

[19] Levi, P. and Molnar, G. “How the energy crisis is exacerbating the food crisis – analysis,” IEA. June 14, 2022, https://www.iea.org/commentaries/how-the-energy-crisis-is-exacerbating-the-food-crisis

Nuclear Energy in the United States

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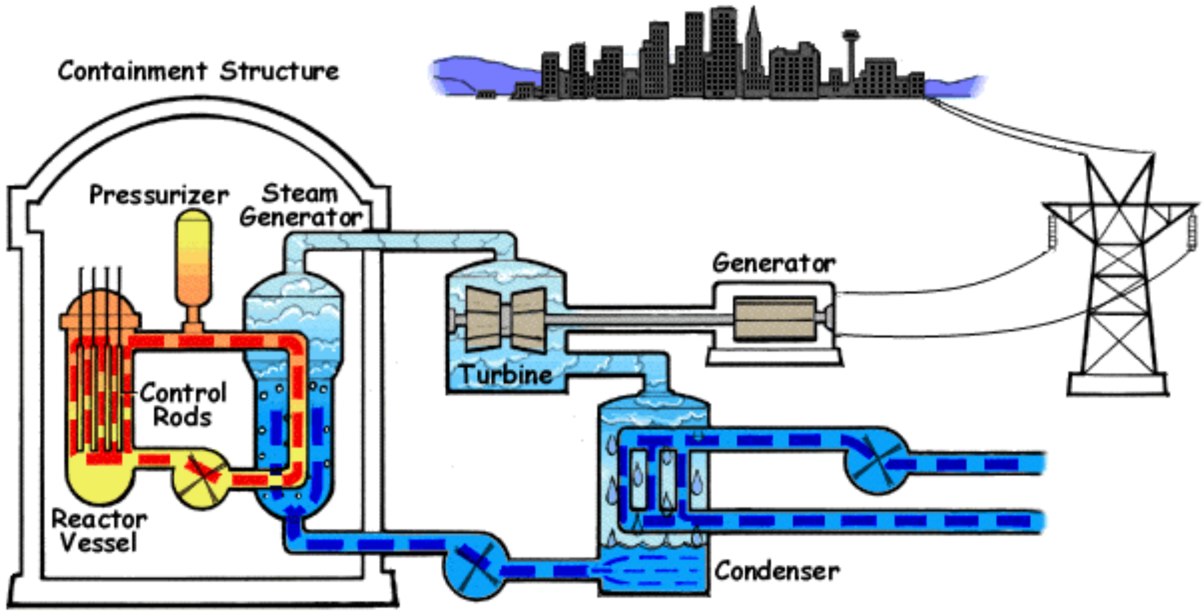
Summary

Nuclear energy is increasingly valued by electricity producers and consumers, policymakers and the public because it is highly reliable, clean, and affordable. It also contributes to U.S. energy security and global influence, and creates thousands of well-paying, long-term jobs in the communities that host our 93 (soon to be 94) operating commercial nuclear power reactors.

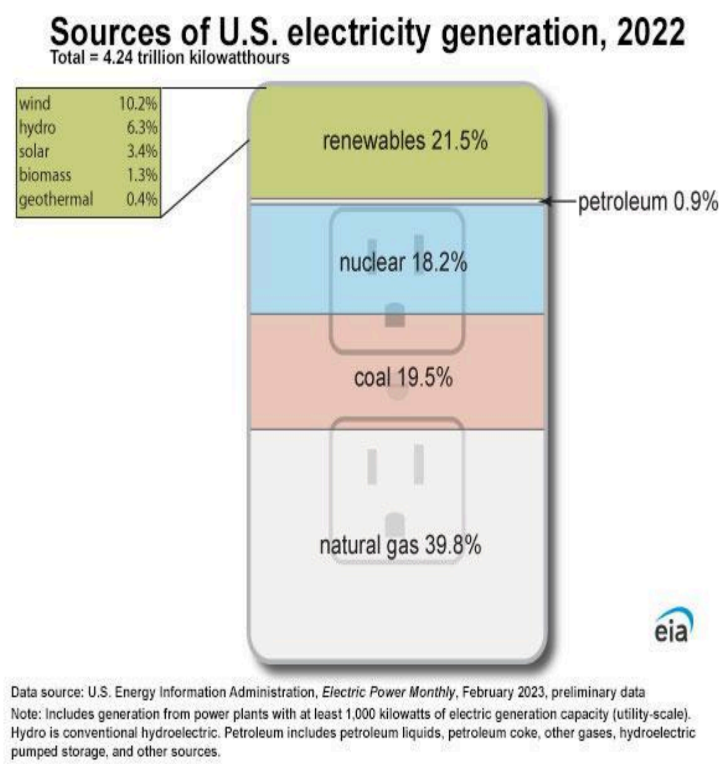
The construction and export of next-generation nuclear power plants will expand on these many contributions. Congress has enacted supportive policies in recent years that have helped to ensure the long-term operation of existing nuclear power plants and will assist in the demonstration and commercialization of next-generation nuclear energy technologies. Additional policy proposals are under consideration that would ensure these benefits are realized by eliminating reliance on Russian nuclear fuel supply, addressing first-of-a-kind challenges associated with building new reactors, and modernizing the regulatory system.

Introduction

Nuclear power plants convert the energy released from splitting atoms of uranium (or plutonium) into heat, which can either be used directly – such as to heat a city or an industrial complex – or can be converted into electricity, as in the diagram below (Source: U.S. Nuclear Regulatory Commission).



Nuclear energy is used to generate about 18% of U.S. electricity, making it our largest source of clean, carbon-free electricity generation. Twenty-eight states host commercial nuclear power reactors; most are located in the Mid-Atlantic, Midwestern and Southeastern states (Map source: Nuclear Energy Institute). Because the types of reactors used in the U.S. (and most of the rest of the world) rely on water for cooling, nuclear power plants are typically located adjacent to rivers, oceans, or natural or artificial lakes.



The Nuclear Fuel Cycle

The heart of a nuclear reactor is known as the reactor core. That is where nuclear fuel containing uranium (and plutonium, for some types of nuclear fuel not currently used in the U.S.) is located. Under the right conditions, the uranium atoms can be made to split, or "fission," releasing very large amounts of energy. The amount of energy in one nuclear fuel pellet – about the size of the tip of your finger – equals the energy in about 17,000 cubic feet of natural gas.

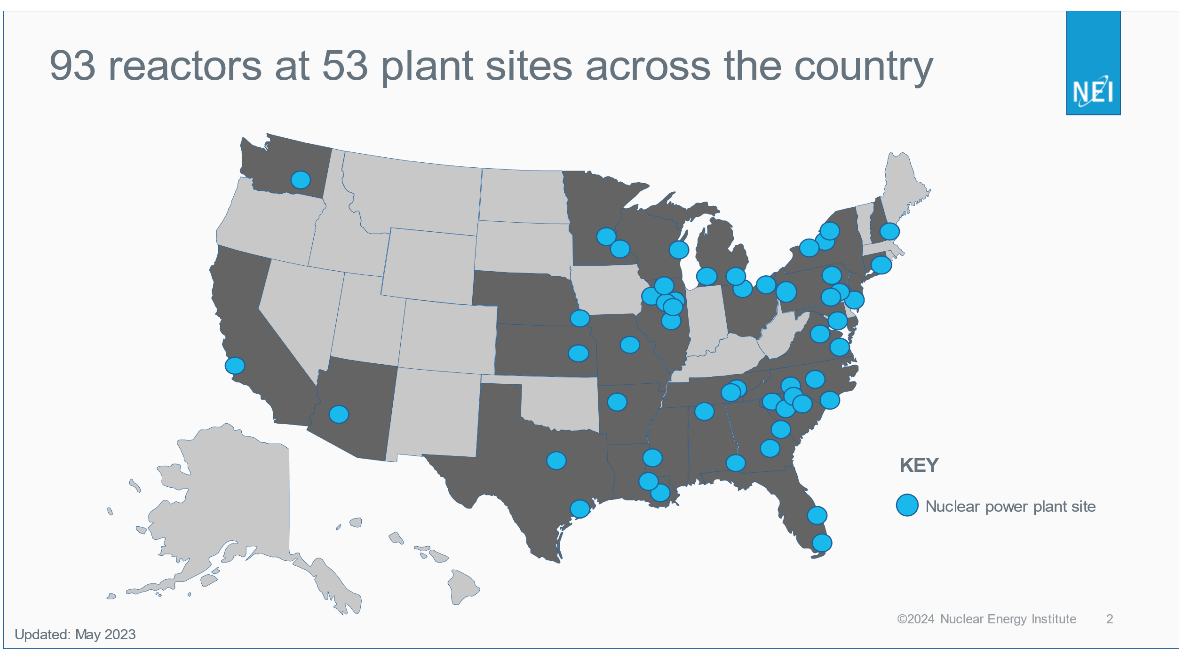
Uranium can be found in rocks and soils around the globe. Several states in the Mountain West host uranium mines, with Wyoming being the largest source of U.S. uranium, but the vast majority of uranium used in the U.S. is imported. That is because the concentration of uranium in ore bodies found in places like Canada and Kazakhstan is higher than in the U.S.

Sources and percentage shares of total U.S. purchases of uranium in 2022 were:

27% Canada	25% Kazakhstan	12% Russia	11% Uzbekistan
9% Australia	16% Six other countries combined		

Data source: *Uranium Marketing Annual Report*, Table 3, June 2023
Note: The six other countries include Germany, Malawi, Namibia, Niger, South Africa, and the United States with country data withheld to protect individual company data.

Last updated: August 23, 2023, with data available from source reports as indicated.



Mined uranium contains two different types, or "isotopes," of uranium. The most common type, uranium-238, makes up about 99.3% of natural uranium, while about 0.7% is uranium-235. It is easier to split atoms of uranium-235 than it is to split uranium-238 atoms, so the reactors used in the U.S. today run on fuel that is "enriched" to between 3% and 5% uranium-235; some next-generation reactors will use so called High-Assay Low-Enriched Uranium, which is up to 19.75% uranium-235. Enrichment is accomplished by first converting the purified uranium ore from a solid into a gas, and then feeding the gas into a uranium enrichment facility, which houses a series of fast-spinning centrifuges that create two streams – one with an increased concentration of uranium-235 and one with a reduced concentration.

World enrichment capacity – operational and planned

Country	Company and plant	2020 capacity (thousand SWU/yr)
France	Areva, Georges Besse I & II	7500
Germany-Netherlands-UK	Urenco: Gronau, Germany; Almelo, Netherlands; Capenhurst, UK.	13,700
USA	Urenco, New Mexico	4900
Russia	Tenex: Angarsk, Novouralsk, Zelenogorsk, Seversk	27,700
China	CNNC, Hanzhun & Lanzhou	6300
Other	Various: Argentina, Brazil, India, Pakistan, Iran	66
	Total SWU/yr approx	**60,166**
	Requirements (*WNA reference scenario*)	50,205

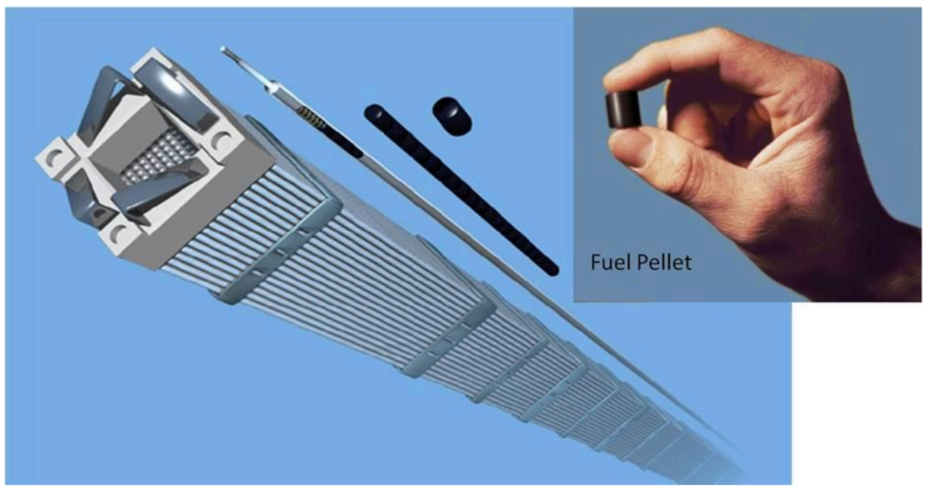
Source: WNA Nuclear Fuel Report 2021 and company websites

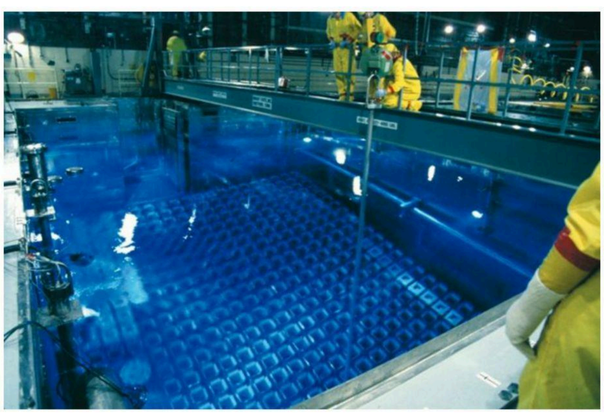
While the U.S. has the largest number of commercial power plants of any nation – China and France are tied for second with 56 reactors each – we house less than 10% of the world's uranium enrichment capacity, at a UK/German/Dutch-owned facility in New Mexico. Russia has by far the largest uranium enrichment capacity, representing nearly half the global total, and supplies about 20-25% of the enrichment used by U.S. utilities; the U.S. nuclear power industry is committed to ending this reliance on Russia and has worked with Congress to secure funding to establish alternate, secure, domestic sources of supply.

Once uranium has been enriched to the proper uranium-235 concentration, it is then de-converted to a solid and is pressed into nuclear fuel pellets. The pellets are inserted into long metal tubes called "cladding," and several dozen tubes are bundled together to form a "fuel assembly." Depending on the reactor type, between 200 and 500 assemblies are inserted in the reactor core. (Image source: Duke Energy)

A fuel assembly will remain in the reactor core for about five years. Every 18 to 24 months, the reactor will be shut down and about 1/3 of the fuel assemblies will be replaced with fresh fuel. These refueling outages average about 4 to 5 weeks and are conducted in the spring or fall when electricity demand is lowest.

The "spent" fuel that has been removed from the reactor is both thermally and radioactively hot. That is because when uranium fissions, it is transformed into lighter elements referred to as "fission products" that in many cases are highly radioactive. All of these byproducts remain in the spent fuel when it is removed from the reactor core. So spent fuel must be stored in a way that keeps the fuel cool and protects workers from the radiation. Initially, the spent fuel is placed into an isolated water-filled pool adjacent to the nuclear reactor. After a couple of years or more, the fuel reaches a cooler temperature and is moved into a dry, air-cooled storage container called a spent fuel cask. The casks are rugged containers made of steel-reinforced concrete. The U.S. Nuclear Regulatory Commission determined that dry casks can be used to store spent fuel at reactor sites for at least a century. (Image source: Duke Energy)





Ultimately, this spent fuel – even if recycled to extract the useful uranium and plutonium remaining in the fuel – will need to be disposed of in a "repository," a mined underground facility that relies on both the conditions at the site and man-made barriers like disposal casks to protect people and the environment from the residual radiation (which reduces as time passes due to the radioactive decay of the elements in the spent fuel). The Nuclear Waste Policy Act (NWPA) Amendments of 1987 established the Yucca Mountain site in Nevada as the only site to be characterized as a candidate to host a repository for both commercial spent fuel and federal spent fuels and high-level radioactive wastes (such as from the nuclear navy and nuclear stockpile production).

The NWPA assigned responsibility for repository development to the U.S. Department of Energy (DOE), which in 2008 submitted an application to the U.S. Nuclear Regulatory Commission to construct a repository at Yucca Mountain. However, DOE sought to withdraw the application in 2010, and the program has been in a stalemate ever since, with no funding provided by Congress to resume Yucca Mountain licensing and no legislation passed to pursue a new repository program (though Congress has given DOE limited authority to pursue a consent-based approach to identify sites for interim storage of spent fuel until a final repository is available).

Sustaining Current Nuclear Plant Operations

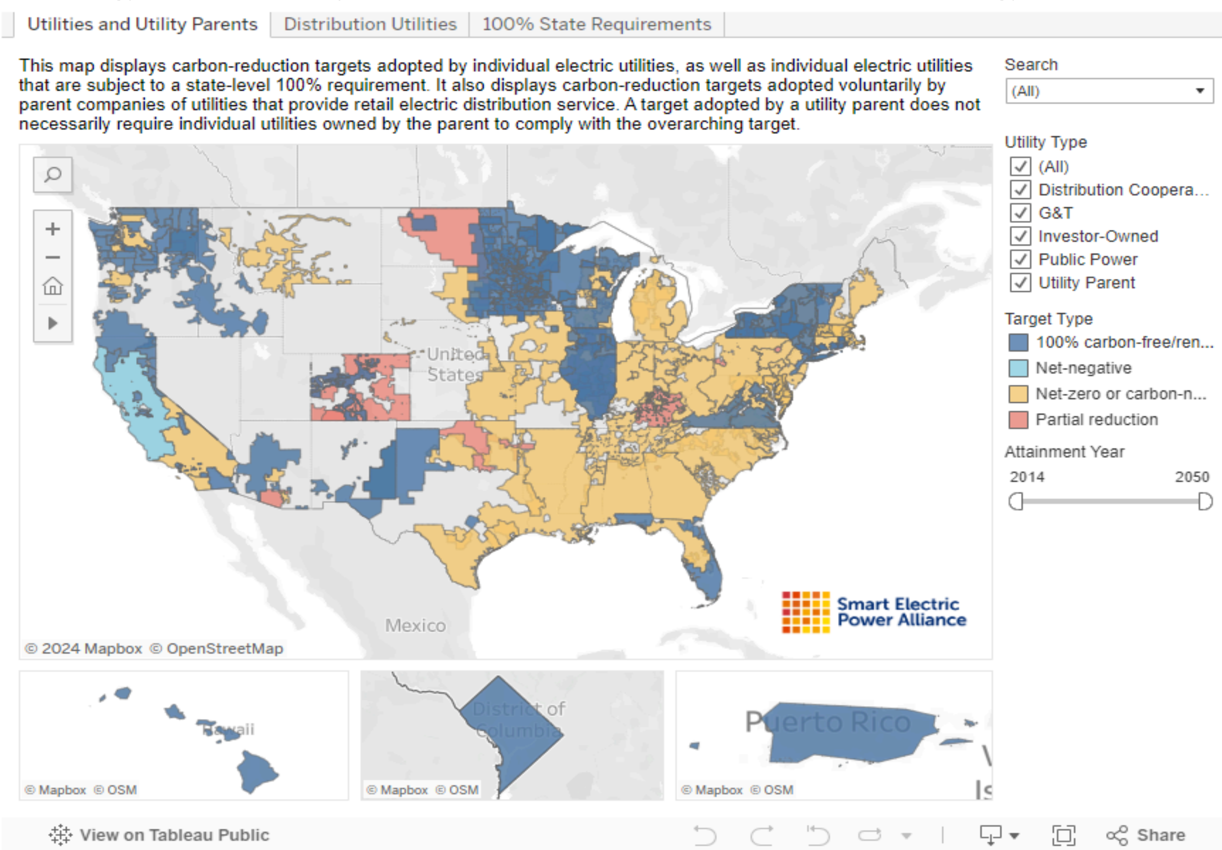
The 93 commercial nuclear reactors in the U.S. produce nearly 20% of U.S. electricity and are by far the nation's largest source of carbon-free generation. While the average U.S. reactor is about 42 years old, nearly all have been licensed to operate for 60 years and most plan to seek approval to operate for 80 years or more. As a result, current reactors can play a central role in a reliable, affordable, cleaner energy system for decades to come.

Despite the many benefits provided by existing reactors, more than a dozen were forced to close prematurely over the past decade, largely due to financial pressures. This figure would have been far higher if not for policymakers in Connecticut, Illinois, New Jersey and New York who took action to prevent premature closures. More recently, Congress enacted both a Civil Nuclear Credit Program and a Production Tax Credit (PTC) for existing nuclear generation that have existing reactors on more solid footing, at least into the 2030s. However, extending operations out to 80 years will require significant investments to upgrade older equipment and install newer instrumentation and control systems. As discussed below, Congress can take action to incentivize the necessary investments.

Next-Generation Nuclear Energy

While the U.S. does not have a national clean energy standard or a federal price on carbon, large electricity customers are increasingly demanding reliable, affordable, and carbon-free electricity. As a result of both customer preference and a growing number of state laws aiming to decarbonize electricity production, most major U.S. utilities have pledged to go largely or completely carbon-free by 2050 or sooner. The map below shows the service territories of these utilities, which all-told service nearly 85% of U.S. electricity customers.

Transitioning to a low carbon electric grid will require either capturing carbon emitted from our coal- and natural gas-fired generators or closing many of those facilities. This is an enormous challenge, to say the least. Fossil fuels are presently used to produce about 60% of U.S. electricity, and importantly, these plants provide "firm" or "dispatchable" power, meaning (as with nuclear power) these plants can be turned on when needed. As the U.S. adds more generation from wind and solar power to the grid, we will need to retain enough dispatchable generation to keep the grid both reliable and resilient. For those utilities planning to shut down fossil-fueled generators, next-generation nuclear power is an attractive alternative. As a result, more than a half-dozen utilities (and a growing number of large industrial users, including technology firms and major manufacturers) have included nuclear energy in their

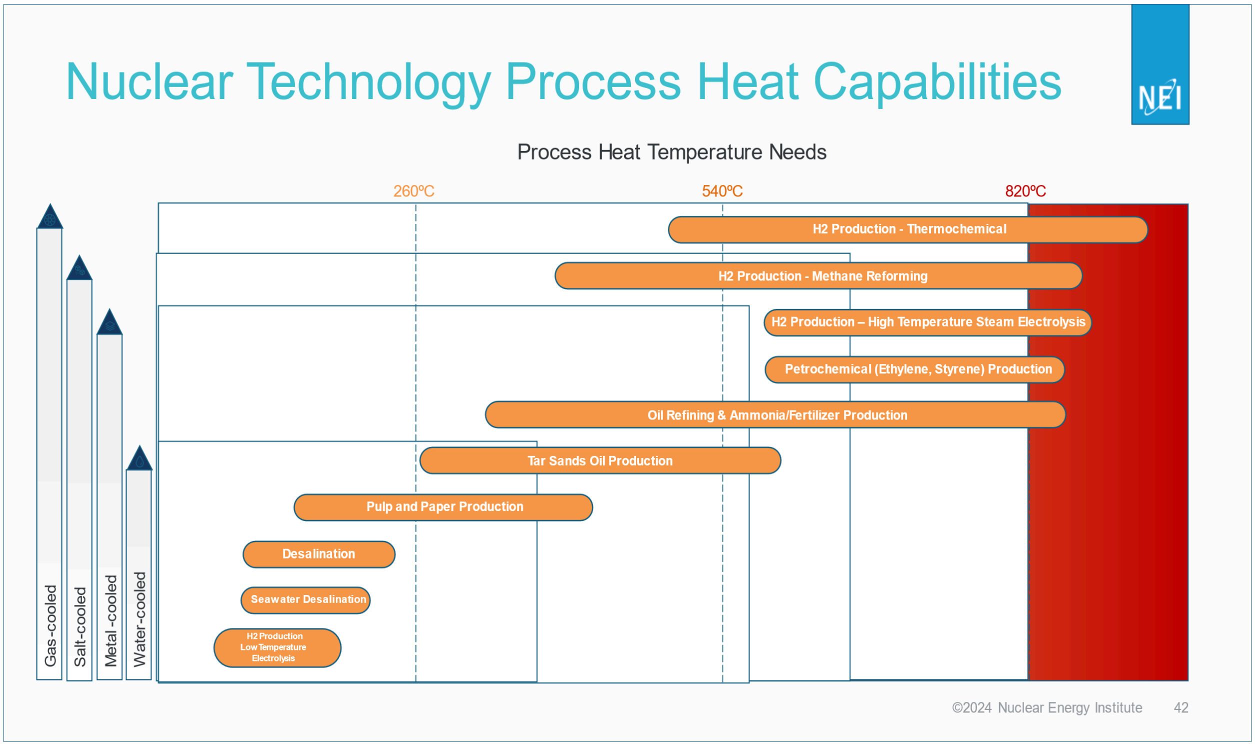


near-term resource plans. Depending on which forecast you believe, anywhere from 100 to 300 gigawatts of new nuclear will be online by 2050 – that means adding hundreds of nuclear power reactors and doubling or even quadrupling U.S. nuclear energy generation.

Congress has played an indispensable role in getting next-generation nuclear energy ready for the marketplace. For example, the Westinghouse AP1000 reactors recently completed in Georgia and the GE-Hitachi BWRX-300 reactors planned for construction by multiple companies trace their origins back to a 2000's-era federal program called Nuclear Power 2010, and construction of the AP1000s in Georgia received significant support from the DOE loan guarantee program included in the Energy Policy Act of 2005. More recently, substantial federal funding for the DOE Advanced Reactor Demonstration Program was appropriated via the 2021 Infrastructure Investment and Jobs Act, with projects now underway to build a next-generation Terrapower Natrium reactor in Wyoming (to replace a coal plant slated for closure) and X-energy Xe-100 reactors in Texas (to provide both electricity and heat to a Dow Chemical facility). Dozens more innovative reactor technologies have benefitted from federal research funding, access to DOE national laboratory facilities and expertise, and a host of other Congressionally directed activities.

Many of these next-generation reactors are designed to use coolants other than water, which will allow them to operate at higher temperatures than today's reactors. As a result, such as with the X-energy/Dow collaboration, large industrial energy users are increasingly looking to nuclear energy as a source of carbon-free heating to replace fossil fuels. As shown in the graphic below, the higher operating temperatures of liquid metal-cooled, molten salt-cooled and high-temperature gas-cooled reactors will allow them to serve a growing range of applications that are currently served using fossil fuels, opening up potentially enormous new markets for next-generation nuclear energy systems.

In addition to supporting the advancement of nuclear energy technology, Congress has played a major role in spurring recent improvements in the federal regulatory system. The past few years have seen Congress extend the Price-Anderson federal liability framework and pass legislation like the Nuclear Energy Innovation and Modernization Act (NEIMA), which directed the Nuclear Regulatory Commission to modernize the regulatory processes to ensure our regulations keep pace with nuclear energy innovation.



Export Markets

The interest in new nuclear energy extends far beyond the U.S. In late 2023, more than two dozen nations signed a pledge to triple nuclear energy by 2050. As Nuclear Energy Institute CEO Maria Korsnick recently said in testimony before the House Financial Services Committee, "When U.S. companies compete and win in the global nuclear energy market, our country wins. Commercial exports are the principal vehicle for promoting world-leading U.S. standards on nuclear safety, security, and nonproliferation. The best way for us to raise global standards is for us to be the ones on the ground, working alongside our partner nations to safely build, operate and maintain U.S.-designed, NRC-reviewed nuclear power plants. And of course, building more nuclear plants overseas reduces global carbon emissions and creates thousands of U.S. jobs. Nuclear power exports are a win for American security, a win for American workers, and a win for the environment."

The U.S. once dominated the global civil nuclear energy sector, yet today, Russia is the world's dominant supplier. Rosatom, Russia's state-owned nuclear energy conglomerate, currently has 70% of the global export market for new reactor construction. China is also seeking to capture a large share of this market for new nuclear, which could total north of $3 trillion in construction and operations investments between now and 2050. Fortunately for us, many nations at present do not want to do business with Russia and China, because they understand the importance of reliable energy partners. The time is now for the U.S. to reassert its leadership of the global civil nuclear energy marketplace.

Issues for Policymakers

Congress has an opportunity to build on its recent accomplishments to ensure the U.S. takes full advantage of all that nuclear energy has to offer:

- *Establish a Secure, Reliable Supply of Nuclear Fuel* – Congress took a major step toward resolving nuclear fuel supply concerns via the inclusion of $2.72 billion for supply of fuel to meet the needs of both today's reactors and the next-generation reactors that will require High-Assay, Low Enriched Uranium fuel. However, availability of this funding is contingent on a ban on Russian fuel imports, either via legislation or executive action. The best next step would be for Congress to enact a ban, as legislation brings with it the greater certainty that will help spur private-sector investment in new enrichment capacity.

- *Ensure Long-Term Operation of Existing Reactors* – Congress can ensure the long-term financial viability of existing reactors by demanding that the Internal revenue Service ensure existing reactors are eligible to receive the clean hydrogen PTC, as provided by law; by clarifying that power uprates to existing reactors are eligible for the PTC for new clean generation; and by finding that reactors than receive approval for extended licenses should be considered a new source generation eligible for the clean generation PTC.

- *Enable Timely Deployment of Next-Generation Nuclear Energy Systems* - A recent DOE analysis found that the U.S. "nuclear industry today is at a commercial stalemate between potential customers and investments in the nuclear industrial base needed for deployment." This situation has arisen due to concerns over high costs for early deployments, and the potential for significant cost and schedule overruns with the first few deployments of a new design. Congress could stimulate the widespread adoption of next-generation nuclear – and bolster the ability of U.S. companies to compete with Russian and Chinese state-owned nuclear energy enterprise - through policies that bridge the cost hurdle for first movers and mitigate the risk of cost overruns.

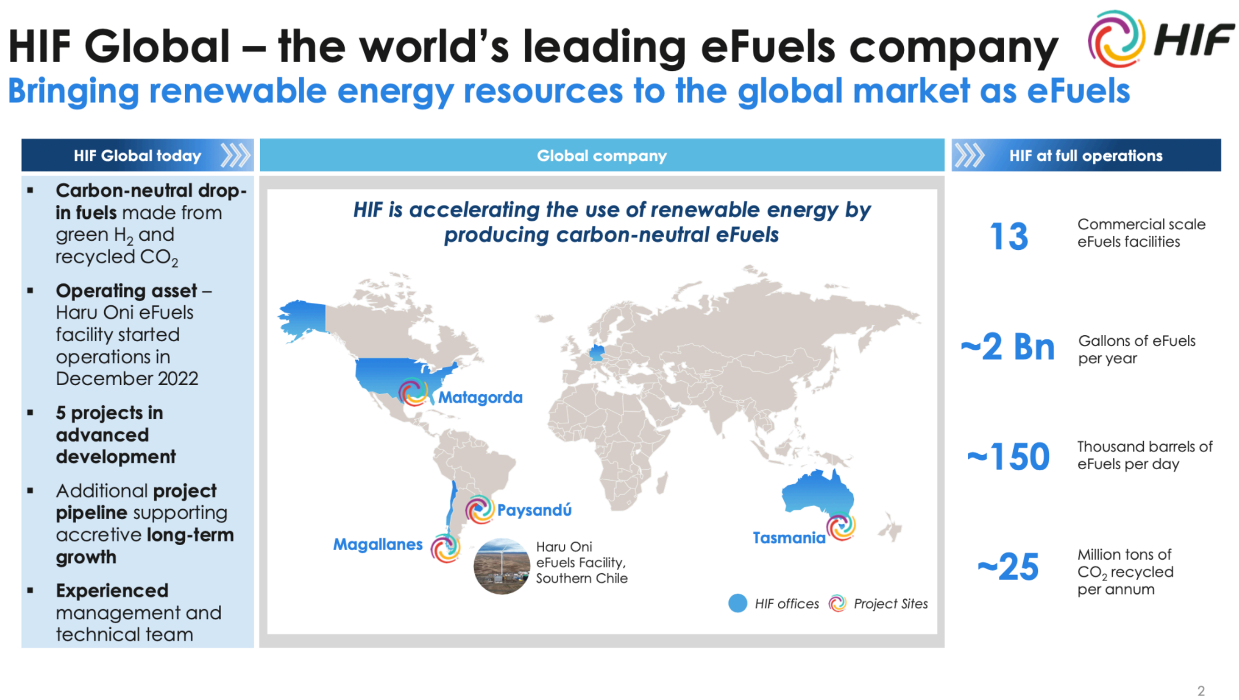
- *Ensure Regulatory Reform* - To meet the skyrocketing demand for nuclear energy, we need a modern, streamlined regulatory process that maintains the gold standard of safety — while paving the way for new builds. There will soon be a rush of large-scale site permits, construction permits, and licensing applications in the coming years. These processes run directly through the Nuclear Regulatory Commission. Yet right now, the NRC is not operating efficiently enough to meet the rising rate of demand for next-generation technology. Congress can ensure continued improvement through sustained oversight and through passage of legislation such as the ADVANCE Act and Atomic Energy Advancement Act, which would overhaul the NRC's regulatory process, reduce licensing fees, and accelerate advanced technologies.

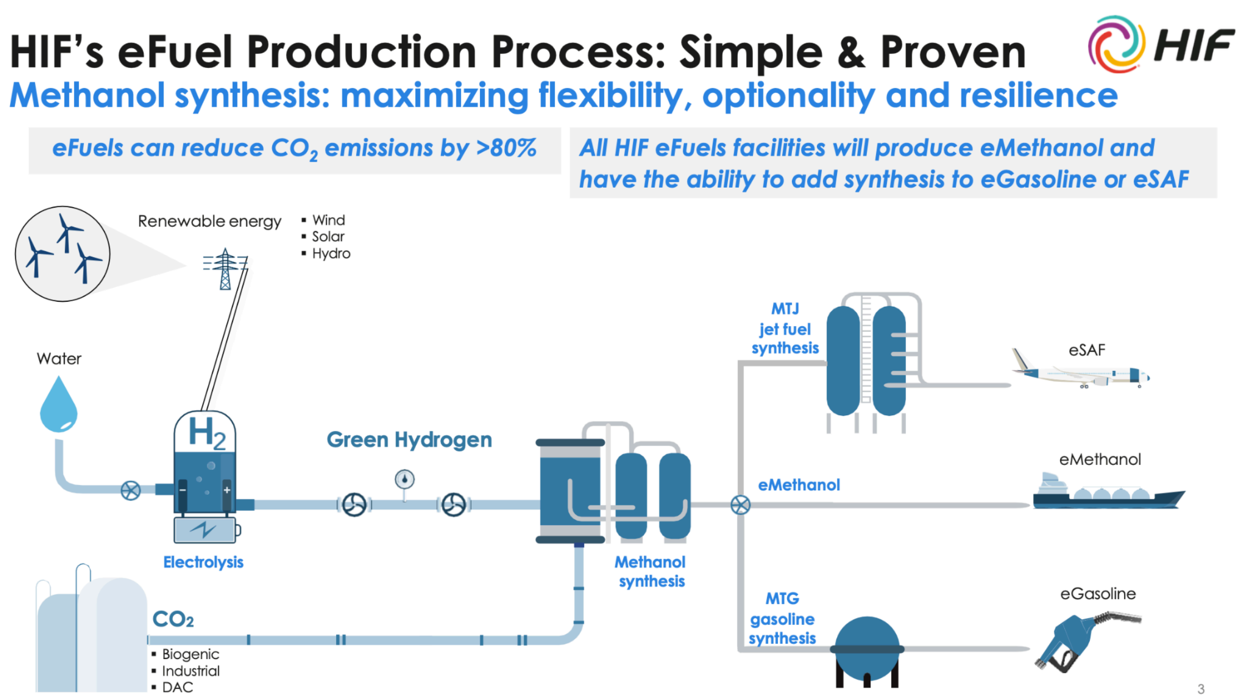
- *Break the Spent Fuel Stalemate* - Solving the spent fuel issue is not a technical challenge, but it will take thoughtful leadership from Congress. Other nations have shown us the way, having identified and licensed sites for spent fuel disposal with plans to begin operating those facilities in the 2020s. The administration and Congress need to break the current stalemate and resume a program to develop a durable solution for long-term spent fuel management. Until that time, spent nuclear fuel can be safely stored at existing and new nuclear power plant sites.

- *Compete and Win in the Export Market* - The U.S. must place significant strategic value on nuclear energy exports. We must support our companies with the necessary financing tools to compete and win. Of particular concern is that Russia offers terms and conditions that, at present, the U.S. and other OECD-member supplier nations cannot match. By enacting the International Nuclear Energy Financing Act, Congress can strengthen America's hand and help ensure the U.S. remains a strong and influential participant in the global nuclear energy market, safeguarding our national security interests.

Introduction to HIF Global

Meg Gentle
Executive Director of the Board, HIF Global





What are eFuels & why are they carbon neutral?

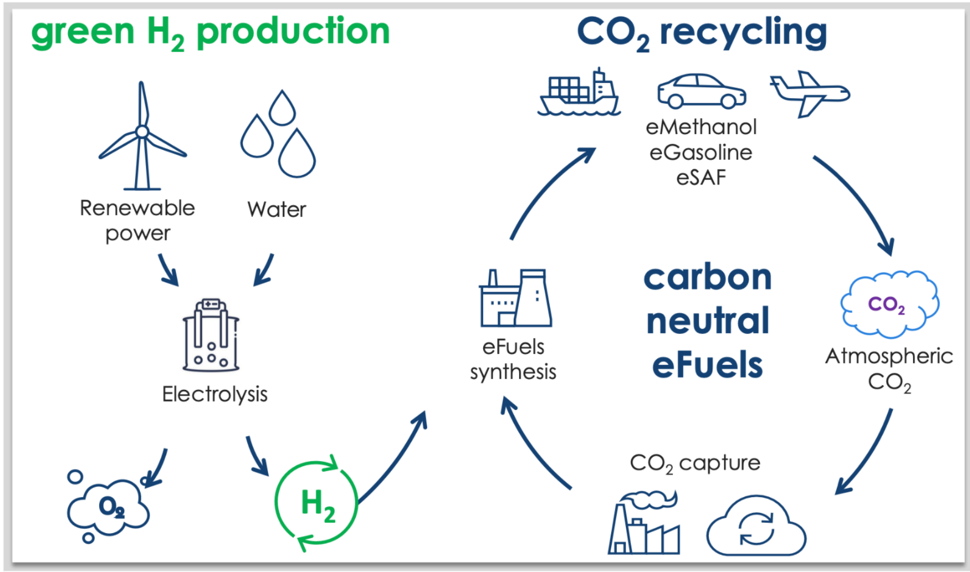
HIF

HIF uses renewable energy to produce green hydrogen through electrolysis

Carbon dioxide (CO_2) captured from industrial emissions as feedstock, biogenic sources and Direct Air Capture

Captured CO_2 and green hydrogen are combined to produce synthetic eFuels; cleaner than traditional refining

eFuels replace fossil fuels. Release of CO_2 completes the carbon-neutral life cycle

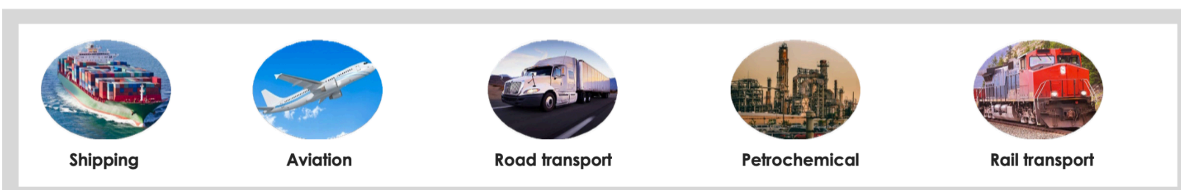


4

Why eFuels?

HIF

Expected demand for eFuels of ~800 mtpa by 2050[(1)]



Carbon neutral substitute with >80% reduction in net carbon emissions

No impact on existing engines due to being chemically equivalent

Lower emissions than traditional fuels; fewer particulates, no SOx

Uses **existing infrastructure** without modifications

Efficient storage and transportation **without any energy loss**

Identical maintenance; no changes to crew operations

eFuels provide **higher emission reduction** potential than biofuels, are **easier to scale**, and **economically competitive** in the mid/long term

Source: McKinsey Report

STRICTLY PRIVATE AND CONFIDENTIAL

5

Haru Oni Chile: Full Operations

Demonstrated production track record

- HIF began as a simple idea: using stranded **Chilean wind**, the world's **best renewable resource,** to create a product that will help the planet reduce carbon emissions
- **We have been conducting studies for eFuel production** in the Magallanes region **in Chile over the last 8 years**
- Haru Oni is the **first fully-operating eFuels facility in the world** and demonstrates the feasibility of the large-scale production of green fuels

Porsche 911 with no modifications loaded with first gallons of synthetic fuel	**Haru Oni eFuels will be used for Porsche Mobil 1 Super Cup and Porsche Experience Centers**	**Transforming remote renewable energy to a useful eFuel for the global transportation sector**

Location: Tehuel Aike Estate, Punta Arenas, Magallanes Region, Chile

Collaborating companies

PORSCHE Research provider and offtaker	SIEMENS energy Plant design and technology integration	enel Green Power Involved in wind power generation and green hydrogen production
ENAP Supports with infrastructure and logistics	EMPRESAS GASCO R&D provider for production of eLG	ExxonMobil Provider of methanol-to-gasoline (MtG) Technology

Project highlights

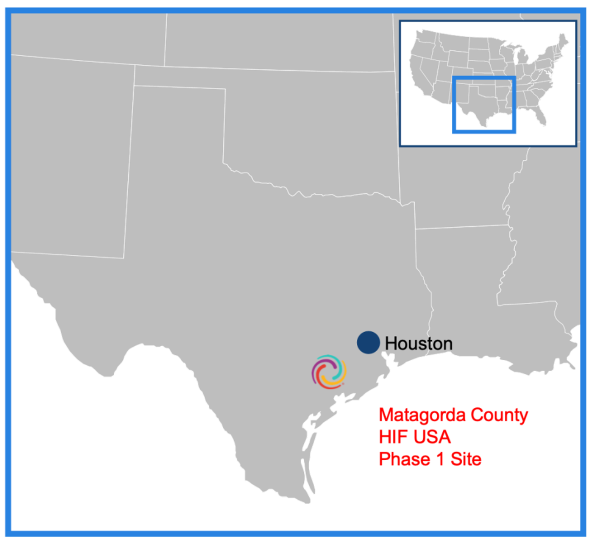
350 tpa *eMethanol production*	**35k gal/yr** *eGasoline production*	**Dec 2022** *First eFuel production*
1.2 MW *Electrolyzer capacity*	**5.7 acres** *Plant surface*	**3.4 MW** *Wind turbine capacity*

6

HIF Matagorda TX: Ready for Construction

Fully permitted commercial scale eFuels production

Potential eMethanol production[2]	1.4 million tonnes per year
Carbon capture	2 million tonnes per year
Hydrogen production	0.3 million tonnes per year
Renewable Power Capacity Additions	5 GW
Construction Capex	~$7.5 billion
Construction jobs	4,000 – 5,000 jobs
Begin construction	2024 / 2025
Ship conversion to carbon-neutral	~40 container vessels, Houston to Antwerp
Relevant policy	§45 tax credits; LCFS; IMO EU REDIII, Fuel EU Maritime;



1 ALL CALCULATIONS ARE PRELIMINARY, SUBJECT TO REVISION AND CONFIDENTIAL. THE NUMBERS LISTED SHOULD NOT BE RELIED UPON FOR ANY DECISION, REQUIRE ADDITIONAL DILIGENCE, AND MAY BE INCORRECT.
2 ~200 million gallons / year of total production capacity of all products combined

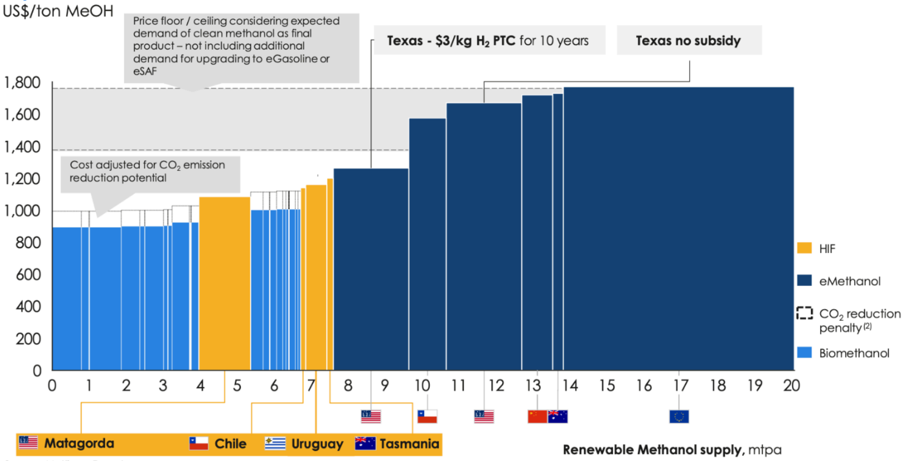
7

HIF is Developing the Most Cost Competitive eMethanol Projects in the World

HIF

Expected Methanol Cost, FOB 2030 (1)

US$/ton MeOH



Source: McKinsey Report

Notes:
1. Lifetime: 20 years, 10% IRR, CO_2 cost included | Real values excl. inflation
2. Emission reduction of biomethanol on average 10% less than HIF eMethanol projects, considering different types of bio feedstock such as wood waste, biogas, etc

Synthesis

- **Biomethanol remains the most cost competitive alternative until ~2035 but won't be able to meet all demand** and challenges remain in feedstock sourcing and emissions reduction
- **HIF Matagorda is the cheapest eMethanol project in the world** and, considering adjustment for CO_2 emission reduction, competitive with biomethanol projects
- **HIF projects are most cost competitive compared with projects developed in similar geographies**
- **Shifts in cost curve could occur if regulatory policies from other countries impact US H_2 PTC** e.g., tariffs on US imported green fuels, regional incentives for green H_2 production

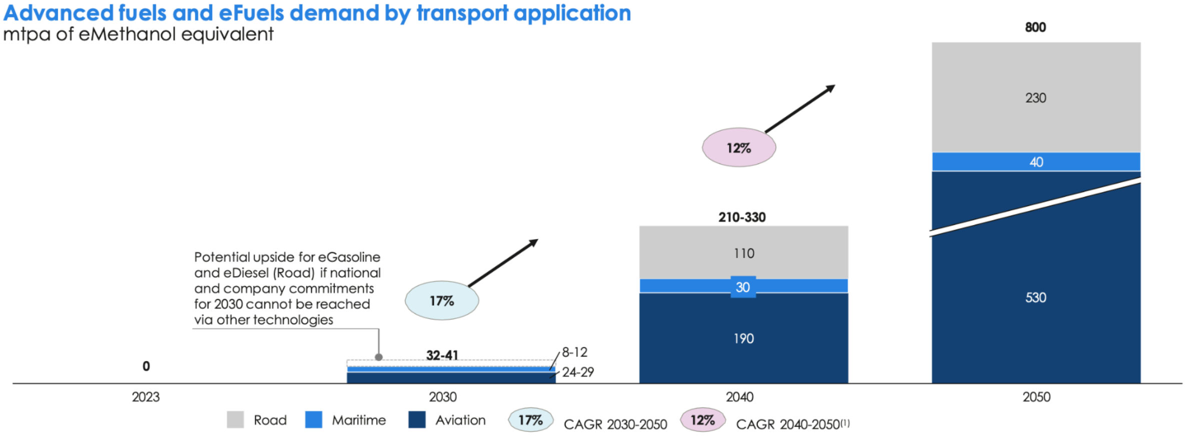
8

The Market For Sustainable Fuels is Rapidly Growing to 800 mtpa by 2050

HIF

Advanced fuels and eFuels demand by transport application

mtpa of eMethanol equivalent



Source: McKinsey Report

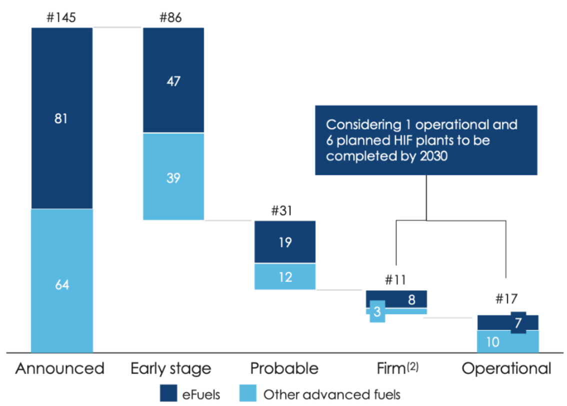
Notes:
1. Calculated using midpoint in 2040

9

Announced Sustainable Fuel Projects for 2030 are Insufficient to Meet Expected Demand

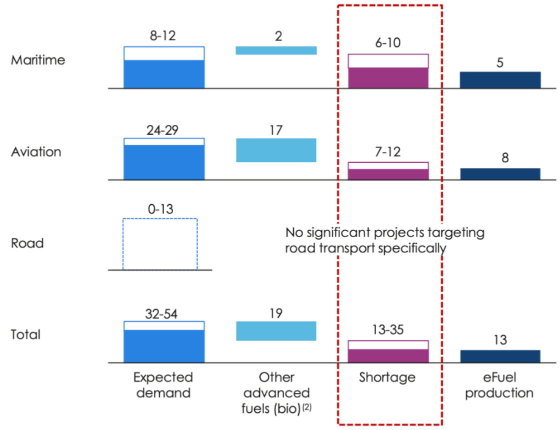
HIF

Announced operational plants for 2030
Number of projects by completion likelihood



Source: McKinsey Report

Supply shortage based on expected demand and supply(1)
mtpa of eMethanol equivalent



Notes:
1. Applying expected supply considering project status
2. Firm as post FID

10

SAF Production Expectations

HIF

HIF is developing the capability to deliver eSAF by 2030

- HIF Global has current eMethanol and eGasoline production in southern Chile
- eMethanol is the base feedstock for eSAF, sustainable aviation fuel derived from renewable power, green hydrogen, and recycled carbon dioxide
- HIF does not currently produce eSAF but is developing projects to do so
- HIF and Honeywell UOP are conducting preliminary engineering on the eMethanol to Olefins to Kerosene synthesis process and evaluating installation of the MTJ unit, which could be added in any of our global projects including:
  - USA: Matagorda County
  - Australia: Tasmania
  - Chile expansion
  - Uruguay: Paysandu
  - Local market refineries
- Honeywell UOP is securing ASTM certification for the MTJ process

11

Partners are Paramount

HIF

Long-term commitment to solutions is critical for success & cost reduction

EQUITY	TECHNOLOGY	POWER & GRID	CO_2	OFFTAKE	FINANCING
AME	Siemens Energy	enel Green Power	Baker Hughes	Porsche	Morgan Stanley
EIG	Baker Hughes	AEP Texas	Porsche	Gasco	Societe Generale
Porsche	Bechtel	AB Power Advisors	Volkswagen Group	Non-binding MOUs	
idemitsu	Topsoe	Teyma	Denbury	ENEOS	
Baker Hughes	JM Johnson Matthey	ventus energy	ALUR Alcoholes del Uruguay	idemitsu	
Gemstone Investments	Honeywell UOP	akuo energy uruguay		eFUEL	
	ExxonMobil	CIEMSA		uniper	
	Sinopec	TasNetworks			
	T.EN Technip Energies				
	wood.				
	MAN				

INFRASTRUCTURE: LAND, ENAP, MAX, GRUPORAS

12

Conclusions

HIF

USA poised to be a major global eFuels supplier

- eFuels are carbon-neutral, drop-in substitutes for fossil fuels using existing infrastructure
- HIF Global is producing eFuels today in southern Chile
- HIF Global's project in Texas will be the first commercial scale eFuels facility to be built
- HIF project in Texas is fully permitted and fully engineered: $7.5 billion capex, 5,000 construction jobs, >20,000 indirect jobs, 200 permanent full time operations jobs, 1.4 million tonnes per annum of eMethanol to decarbonize the shipping sector
- USA eFuels production lowest cost in the world due to Section 45 tax credits: renewable electricity, hydrogen, carbon capture
- Must break down barriers to entry in EU renewable energy policy (REDIII, FuelEU, Fit for 55)
- Must support USA state, federal, and international policy based on simple CO2 accounting by life cycle analysis, technology neutral with few rules
- USA is the leader on energy security and energy supply and must lead on eFuels as well

13

Launching New Opportunities: U.S. Clean Hydrogen Leadership and What It Means for Global Shipping

Stephen Metruck
Executive Director, Port of Seattle

Introduction: Maritime Energy Sea Change

The global maritime industry is at a turning point. The world is transitioning away from fossil fuels to stem the worst impacts predicted from global climate change,[20] in ways that will lead to significant disruptions[21] and new dynamics.[22] Driven by new international and regional targets for shipping decarbonization, first movers in the maritime sector are seeking sustainable alternatives to fossil fuels that can lower greenhouse gas (GHG) emissions, and clean hydrogen is seen as key.[23] While this is a major global challenge, it is also an opportunity for the United States to become a primary destination for clean hydrogen technology investment and implementation and to demonstrate innovation, create economic opportunity, advance national and energy security interests, and build resilience.[24] U.S. Ports serve as a natural nexus that can help our country lead these efforts across the maritime sector.

The Importance of the Global Maritime Energy Transition

The maritime industry plays an essential role facilitating global trade and powering economic growth. Annually, cargo vessels transport$4 trillion worth of goods, which is about 80%of global trade by volume.[25] For the United States, this represents 1.9%, or USD$432.4 billion, of the U.S. gross domestic product in 2021.[26] In addition, the global cruise industry generates over$150 billion in economic activity and supports 1.17 million jobs across many sectors.[27] For the United States, combined commercial and recreational fisheries support$253 billion in sales and 1.7 million jobs.[28] Yet, the

[20] AR6 Synthesis Report, Intergovernmental Panel on Climate Change (IPCC) (2023)
[21] Decarbonizing The Maritime Shipping Industry: Starter Guide to Reducing Greenhouse Gas Emissions from Maritime Shipping, U.S. Department of Transportation (2023)
[22] Insight Brief: National and regional policy for international shipping decarbonisation, Global Maritime Forum (GMF) (2024)
[23] Mapping of Zero-Emission Pilots and Demonstration Projects: Fourth Edition, GMF (2023)
[24] Hydrogen RD&D Collaboration Opportunities: United States, Commonwealth Scientific and Industrial Research Organisation (2022)
[25] Maritime Decarbonization, Pacific Northwest National Laboratories (2021)
[26] Marine Economy, Bureau of Economic Analysis (2024)
[27] Economic Impact Fact Sheet, Cruise Lines International Association (2020)
[28] Fisheries Economics of the United States, National Oceanic and Atmospheric Administration Fisheries (2020)

international maritime industry is currently dependent on fossil fuels and relies upon an affordable global network of fuel sources. Maritime is a hard to decarbonize industry and uses an estimated 105 billion gallons of fuel annually, which is expected to double over the next decade with the expansion of global trade.[29] In 2023, international shipping was responsible for 2-3%of global energy-related carbon dioxide (CO2) emissions, an emissions impact that has increased by 20% over the last decade.[30] Without interventions, shipping emissions are expected to rise through the next several decades.[31] The magnitude of global action needed to stem the worst impacts of climate change will require monumental levels of coordinated action across the maritime sector and many others.[32]

Technological improvements and operational efficiencies can decrease carbon intensity but ultimately low and zero emission fuels will be necessary for the maritime industry to reach the goal of net zero GHG emissions by 2050.[33] The International Maritime Organization's (IMO) 2023 GHG Strategy includes milestones for a reduction in the carbon intensity of international shipping by at least 40% by 2030 and for the uptake of zero or near-zero emissions GHG emission technologies, fuels and/or energy sources to achieve at least five%—striving for 10%—of the energy used by international shipping by 2030.[34] The Fourth IMO GHG Study projects that after implementing successful energy efficiency measures, 64%of the total amount of CO2 reduction from shipping in 2050 will be from low and zero emission fuels.[35]

While new low and zero emission maritime energy pathways are emerging, the pros and cons of each alternative fuel type is still a topic of global debate.[36] At present, 98.8%of the global maritime fleet is still sailing on fossil fuels.[37] Ultimately, meeting the demand for low and zero emissions fuels will require scalable technologies and hydrogen inputs as a part of a multi-fuel future. Methanol and ammonia derived from clean hydrogen are expected to play a critical role in future maritime fuel supply.[38]

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[29] Sustainable Marine Fuels, U.S. Department of Energy (DOE) (2024)
[30] Global Warming of 1.5°C: an IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty, IPCC (2018)
[31] Ibid
[32] AR6 Synthesis Report, IPCC (2023)
[33] The International Maritime Organization (IMO) is a United Nations special agency made up of 176 Member States, and additional non-government observers, that creates international standards for commercial shipping. In 2023, the IMO adopted a revised strategy to reduce greenhouse gas emissions from international shipping in line with goals of the Paris Agreement to limit global temperature rise to 1.5° Celsius.
[34] 2023 IMO Strategy on Reduction of GHG Emissions from Ships, IMO (2023)
[35] Ibid
[36] The shipping industry's fuel choices on the path to net zero, GMF (2023)
[37] Review of Maritime Transport 2023, United Nations Conference on Trade and Development (UNCTAD) (2023)
[38] The shipping industry's fuel choices on the path to net zero, GMF (2023)

National Security Implications

The transition to clean energy for the maritime sector is also a security issue that requires a whole-of-government approach to maintain resilience.[39] Climate change is affecting the U.S. Department of Defense's missions, plans, and infrastructure and is viewed as a threat multiplier to national security.[40] In 2023, the United States Department of the Navy consumed 42.6 million barrels of fuel and the Navy expects fuel consumption to increase in future years and changes in global energy dynamics may disrupt existing supply chains.[41] Accordingly, the United States' ability to adapt to changing geopolitical conditions caused by the transition to clean fuels and resource distribution will provide an opportunity to increase resiliency. In peacetime, the global maritime industry and ports support economic supply chains that are essential to United States national security and economic prosperity. In wartime or during a significant natural disaster, these same maritime assets play a crucial role in delivering military cargos supporting global security or carrying out relief missions. Proactively engaging in the global maritime clean energy transition directly supports United States' goals for supply chain security: to promote efficient and secure movement of goods and to foster a global supply chain system that is prepared for and can withstand evolving threats and hazards, and rapidly recover from disruptions.[42] Given the significant energy demand, and the important role the federal government plays as early adopters of new technology, military investments in clean energy options like hydrogen and hydrogen-derived fuels could be a significant driver for development and deployment of domestic alternative energy sources.

Launching New Opportunities: The Hydrogen Opportunity for U.S. and Global Shipping

Successful decarbonization of international shipping is as much a technical challenge as it is a policy and economic challenge. Globally, nations must act in coordination and at multiple levels to enact measures to promote ambitious action, transparency and accountability, and spur research, development, and safety across the full supply chain.[43] The United Nations Conference on Trade and Development estimates that decarbonizing the global maritime fleet by 2050 could require an investment of$8 billion to$28 billion annually while the infrastructure needed to support the global network of zero emissions fuels could require an investment of$28 billion to$90 billion

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[39] DOD Officials Highlight Climate and Energy Security Issues at International Conference, U.S. Department of Defense (DOD) (2023)
[40] Department of Defense Climate Risk Analysis, DOD (2021)
[41] Annual Energy Performance, Resilience, And Readiness Report, DOD (2022)
[42] National Strategy for Global Supply Chain Security, U.S. Department of Homeland Security (2012)
[43] Insight Brief: National and regional policy for international shipping decarbonisation, GMF (2024)

annually.[44] Furthermore, despite uncertainty and the significant cost of action, policymakers must act quickly to address the urgent need for climate action while avoiding solutions that create unintended consequences, delay investment, or miss desired outcomes.[45]

Maritime vessel owners are already making investments in engine technologies and onboard fuel storage to prepare for alternative low and zero emission fuels and 21%of vessels on order today will be capable of using cleaner energy sources.[46] Clean fuel availability, however, will be slow to develop due to the multibillion-dollar investment needed across the sector and significant uncertainty about the future, including supply, demand, and regulation. Hydrogen is a key input to future marine fuels, including methanol and ammonia, and when produced from renewable resources, significant reductions in carbon intensity are possible. The United States has an opportunity to be a global leader in hydrogen-derived maritime fuel production, a destination for cleaner ships, and to support early adopters that are already committing to and using low and zero emission fuels. The World Economic Forum estimates the transition to a low and zero emission global economy will create tens of millions of new jobs, of which, 38.2 million will be related to the renewable energy industry and hundreds of thousands for mariners worldwide.[47]

Congress has made a down payment on clean hydrogen leadership in the United States through early, significant investments in seven regional hydrogen hubs and globally leading tax credits for hydrogen production. However, the United States needs to continue to prioritize investments in the clean energy sector to achieve its national goals. The World Economic Forum notes that while the demand for clean fueled vessels is on the rise, more than 95% of projects focused on producing clean methanol and ammonia have not passed the final investment decision phase.[48] To support investment, action is still needed to send clear demand signals and bridge gaps for higher cost clean fuels, mitigate risk and high infrastructure investment costs, provide clear mandates on carbon pricing, increase access to biogenic carbon for methanol production, and address underdeveloped last-mile transport and storage.[49] Hydrogen hubs are expected to help form the foundation for a national clean hydrogen network, while tax credits are helping to drive global interest in private sector investment in the United States. Together, these tools unlock new opportunities for supplying low carbon solutions for essential parts of the economy, including shipping. The United States also can continue to lead by investing in research and development, regulations and standards, and in maritime fuel

[44] Review of Maritime Transport 2023, UNCTAD (2023)
[45] Review of Maritime Transport 2023, UNCTAD (2023)
[46] Ibid
[47] Why skills development is vital for shipping's green transition, World Economic Forum (WEF) (2023)
[48] Insight Report: Fueling the Future of Shipping: Key Barriers to Scaling Zero Emission Fuel Supply, WEF (2023)
[49] Ibid

supply infrastructure, which will help shipping companies mitigate costs of alternative fuels and increase certainty about future marine fuel availability. The bipartisan Hydrogen for Ports Act, introduced in 2023, is a great example of the specific policies that Congress can move forward, and highlights how federal policy can help ports play a central role in demonstrating hydrogen uses for the maritime sector and supporting investments in future fuel supply infrastructure. Additionally, support for green shipping and cruise corridors proposed by the COP26 Clydebank Declaration, can demonstrate and accelerate adoption of low and zero emission fuels and technologies across the maritime sector toward full decarbonization by 2050.[50]

Ports provide a critical land/sea interface that enables global travel, trade, and commerce. Ports are economic engines but can also serve as strategic conveners to advance policy, technological innovation, and help build national resilience to disasters and the impacts of climate change. Within the United States, ports can help lead and implement national priorities across the maritime sector. Ports can influence clean energy supply and demand and accelerate progress toward full decarbonization of the maritime industry by working within their authority as either landlords or regulators and by collaborating across the value chain.

Port of Seattle: An Example of Regional Action toward U.S. Global Maritime Leadership

The Port of Seattle is an example of a mid-sized U.S. port striving to use regional action to demonstrate national and global maritime environmental leadership. Through voluntary and collaborative action, the Port is advancing national priorities and informing global discourse toward a just and secure transition to a zero-emission maritime future.

The Port of Seattle is the largest cruise port on the U.S. West Coast and the starting point for 290 sailings to Alaska and over 1.75 million revenue passengers in 2023. The Northwest Seaport Alliance (NWSA), a marine cargo operating partnership between Port of Seattle and Port of Tacoma, is one of the largest container gateways in North America, and manages container, breakbulk, auto, and bulk cargo terminals. The Port of Seattle is also homeport to the North Pacific fishing fleet, and a variety of other boating, fishing, and related maritime activities. In total, the Port of Seattle and NWSA are responsible for$16.8 billion in maritime-related economic activity and 121,200 regional jobs.

Led by its elected leadership, the Port of Seattle and The NWSA have ambitious goals for air quality and decarbonization through the Northwest Ports Clean Air Strategy

[50] Green Shipping Corridors Framework Fact Sheet, U.S. Department of State (2022)

(NWPCAS), aiming to phase out emissions from seaport-related activities by 2050, supporting cleaner air for our local communities and fulfilling our shared responsibility to help limit global temperature rise to 1.5°C. The NWPCAS covers six sectors of port activity: oceangoing vessels, cargo-handling equipment, trucks, harbor vessels, rail, and port administration and tenant facilities.

The Port has taken a variety of steps toward this climate and air goal, from aggressively implementing shore power at both cruise and cargo terminals to studying various aspects of the energy transition. For example, the Port is involved in two studies with the Pacific Northwest National Lab, Sandia National Labs, and Seattle City Light looking at hydrogen for trucking as well as electrical distribution, and a follow-on study that considers hydrogen storage at scale and a risk assessment methodology relevant to urban and industrial areas with applications for widespread fueling, energy distribution, maritime fuels, long duration energy storage and resiliency.

In 2023, the Pacific Northwest was awarded $1 billion in federal funds to create a Clean Hydrogen Hub, which will help the region build the hydrogen ecosystem needed to support several industrial sectors. These multiple and connected efforts on hydrogen in the Puget Sound region position us well to be a national and global leader on this energy transition.

The Port of Seattle is also a hub for three green shipping corridor feasibility studies: a Pacific Northwest to Alaska cruise corridor, and Pacific Northwest to the Republic of Korea car carrier and container ship corridors. Green shipping corridors are a concept introduced at COP26 to support the establishment of zero-emission maritime routes between two (or more) ports. The United States is a signatory to the Clydebank Declaration, which aims to support the establishment of at least six green shipping corridors by the middle of this decade.[51] In support of its green shipping corridors and the maritime energy transition, Port of Seattle is also a founding partner of the Pacific Northwest Sustainable Maritime Fuels Collaborative, which brings together supply and demand stakeholders to accelerate production and use of sustainable maritime fuels and technologies in Washington State.

With a greater focus on hydrogen-derived marine fuels, these voluntary efforts present a unique and significant opportunity to use the developing clean hydrogen production capabilities in the Pacific Northwest to inform the United States' role in future maritime fuels.

[51] Policy paper: COP26: Clydebank Declaration for green shipping corridors, U.K. Department of Transport (2023)

What Can Congress Do?

Congress can help by providing policy leadership, continued federal funding, technical assistance, and convening key stakeholders to support this maritime industry transition. Investments in future maritime fuel supply—including production, transport, storage, bunkering, and end-use—will be critical to leverage existing federal clean hydrogen investments and to support the future uptake of this new energy resource. Programs focused on the emergence and diffusion of alternative fuel and vessel technologies will also be an essential leadership opportunity for federal and state governments.[52]

The choices nations and industry make to secure their roles in the nascent clean maritime energy economy carry significant social, economic, environmental, and national security implications. At this moment in time there is a clear opportunity for the United States government to implement a robust, holistic, and bipartisan national agenda to ensure a leadership role in the global maritime energy future. Doing so will advance national environmental, economic, and security priorities.

Optional Readings:

1. **National and regional policy for international shipping decarbonization:** National and regional policy for international shipping decarbonization
2. **Implications of the 2023 IMO GHG Strategy for the Shipping Industry:** https://cms.zerocarbonshipping.com/media/uploads/documents/MEPC_v8.pdf
3. **Shipping industry's fuel choices on the path to net zero:** https://www.globalmaritimeforum.org/content/2023/04/the-shipping-industrys-fuel-choices-on-the-path-to-net-zero_final.pdf
4. **The Role of Ports in the Energy Transition:** https://maritime-executive.com/editorials/the-role-of-ports-in-the-energy-transition

[52] Assessing Lifecycle Greenhouse Gas Emissions Associated with Electricity Use for the Section 45V Clean Hydrogen Production Tax Credit, DOE (2023)

U.S. Innovation, Energy Security, and Electricity Demand Growth

Anna Foglesong
Managing Director, Clean Grid Initiative

Rob Gramlich
Grid Strategies

[Attachment: The Era of Flat Power Demand is Over, just slides 1-12 (2300 words), not the case studies or appendix (would be 5800 words total).]

For American prosperity and security, it is advantageous to host chip manufacturing, data centers, artificial intelligence hardware and software, and other manufacturing facilities in the U.S. That is a big reason the CHIPS and Science Act and Infrastructure Investment and Jobs Act passed on a bipartisan basis. It is a widely shared view across the aisles of state and federal legislative bodies that the U.S. does not want sensitive industries on which we rely to be based abroad, especially when they provide jobs and local tax base where they are located.

Higher demand for electricity is one effect of CHIPS, IIJA, and other industrial strategy initiatives to bring manufacturing back to the U.S. Chip manufacturing and data centers are electricity-intensive activities. Artificial intelligence requires calculations by microprocessors that train models by continuous algorithm running and testing with massive datasets; those calculations are performed in data centers and are contributing to significant growth in power demand. Decarbonization initiatives are also increasing demand for electricity through electrification of other sectors and likely hydrogen production. The Clean Grid Initiative report attached entitled *The Era of Flat Power Demand is Over* describes this recent, sudden, and significant increase in U.S. power demand.

U.S. power grid was already becoming inadequate, for three main reasons:

1) Most of the transmission assets are over 50 years old and in need of replacement to remain reliable.
2) Areas well suited for new renewable and other generation resource need to be connected to thousands of new loads around the country. Currently 2 Terawatts (TW) of generation are stuck waiting to connect to the grid (compared to 1.2 TW of generation currently operating).
3) Increasingly frequent and severe weather threatens generation sources of all types, and the best protection is a robust power system that is "bigger than the weather." Available power in neighboring regions can be shipped (at the speed of light) to areas where generation is lost as we have seen in Winter Storms Uri and Elliott, and a dozen others over the last decade and a half.

To expand and modernize the power grid, the U.S. needs to address the "3 Ps": planning, permitting, and paying.

- *Planning* is needed to proactively plan for the right scale and scope of power lines and paths, while respecting communities and environmentally sensitive areas.
- *Permitting* reform is needed to speed up development from 10-15 years down to 4-6 years for large scale, long-distance lines.
- *Paying*, or determinations of which electricity users pay how much (called "cost allocation" in regulatory policy contexts), is critical to make sure there is a way for investors to be paid back, and to fairly allocate costs to the beneficiaries.

The U.S. has an opportunity to grow its economy, attract strategic industries, keep sensitive industries from security purposes located in the country, and improve the reliability and resilience of the grid as the U.S. simultaneously enables an energy transition to a decarbonized future. The best thing to contribute to American prosperity and security is to expand and modernize the U.S. transmission system.


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CLEAN GRID INITIATIVE
GridStrategies
The Era of Flat Power Demand is Over
John D. Wilson and Zach Zimmerman
DECEMBER 2023


EXECUTIVE SUMMARY
Findings, Context and Implications
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2

$630 Billion in Near-Term Investment in "Large Loads" is Increasing Expectations for Load Growth

THE STORY IS SIMPLE …

Over the past year, grid planners nearly doubled the 5-year load growth forecast.

- The nationwide forecast of electricity demand shot up from 2.6% to 4.7% growth over the next five years, as reflected in 2023 FERC filings.
- Grid planners forecast peak demand **growth of 38 gigawatts (GW) through 2028**, requiring rapid planning and construction of new generation and transmission.
- This is likely an **underestimate**: Several more recent updates are adding additional GWs to that forecast. Next year's forecast is likely to show an even higher nationwide growth rate.

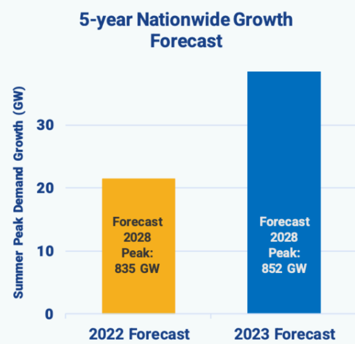
The main drivers are investment in new manufacturing, industrial, and data center facilities.

- Since 2021, commitments for industrial and manufacturing facilities have totaled about $481 billion, and over 200 manufacturing facilities have been announced this past year.
- Data center growth is forecast to exceed $150 billion through 2028.

The U.S. electric grid is not prepared for significant load growth.

- The U.S. installed 1,700 miles of new high-voltage transmission miles per year on average in the first half of the 2010s but dropped to only 645 miles per year on average in the second half of the 2010s.
- Low transfer capability between regions is a key risk for reliability if load growth outpaces deployment of new generation in some regions.

AND THE FORECASTS ARE SHOCKING …



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3

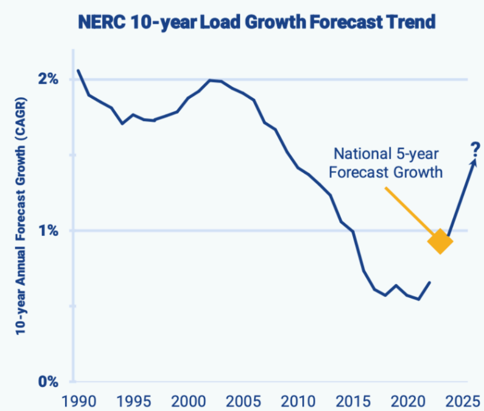
A Scramble to Reflect Growing Load

Over the past decade, grid planners have been forecasting a mere 0.5% annual growth rate, as summarized by NERC.

Yet in 2023, annual peak demand growth is up to at least 0.9%, driven by data centers, industrial facilities, and other near-term investments. **This is likely to be an underestimate:**

- Since these forecasts were filed with FERC, utilities like Puget Sound Electric, Duke Energy, Georgia Power Company and Tennessee Valley Authority have stated that their load expectations have grown even higher.
- Some planning area forecasts, like MISO, don't clearly explain how large load development will impact peak demand. In contrast, Georgia Power and PJM's latest load forecasts reflect increases in industrial and data center investment, respectively.
- Utilities such as Arizona Public Service and Portland General Electric are factoring in the impacts of higher temperatures and extreme weather events on future load. These practices are far from universal – when other utilities adopt these practices, load forecasts will increase.

As several regional profiles show, since filing these data with FERC, **planners are continuing to increase their near-term expectations for load growth**. Annual peak demand growth forecasts appear headed for growth rates that are double or even triple those in recent years.



SOURCE | NERC, 2022 Long-Term Reliability Assessment (December 2022), p. 20 and Supplemental Table F.

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4

Challenges in the New Era of Power Demand Growth

CONTINUED ON NEXT PAGE

In just one year, the forecast of cumulative electricity growth over the next five years increased from 2.6% to 4.7%. Since their 2023 FERC load forecast filings, several major utilities have **further increased near-term electricity demand forecasts.**

It may take only one or two years to connect new load to the grid, while it may take over four years to bring new generation online and even longer to build new transmission connections between regions to enable power sharing during peak periods.

Ample generation resources are under development across the country, but projects are often bogged down in technical review processes that were built for a different age and different technologies.

It's worrisome that a resurgent American manufacturing sector may face headwinds from the limited ability of the nation's electricity systems to respond. Electricity systems need to supply new generation, connect that generation to load, and – of course – connect new load to the system. There are real risks that **some regions may miss out on economic development opportunities because the grid can't keep up**.

Meeting the electricity requirements of new manufacturing and data centers through new, nearby generation could result in capital investments of **billions of dollars per GW** of new load. A more valuable and less costly approach to ensuring reliability is ensure the same reliability with increased transmission capacity to transfer power from one region to another. Capacity delivered through inter-regional transmission is likely to cost less than $300 million per GW of new load. With this added reliability, less new generation is required and it doesn't need to be located close to new facilities.

SOURCES | Edison Electric Institute, *EEI Industry Capital Expenditures with Functional Detail*, published October 2021, September 2022 and September 2023.

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Challenges in the New Era of Power Demand Growth

CONTINUED FROM PREVIOUS PAGE

Transmission investments are a particular challenge. Investor-owned utility investment in transmission to serve new load has actually decreased over the past three years, according to data from Edison Electric Institute. In 2021, expansion-related transmission capital expenditures were forecast at $9.2 billion but declined to $8.8 billion for 2023.

With 38 GW (or more) of new electricity demand likely to come online during the next five years, transmission investments need to increase just to keep up with demand. Transmission takes years to build, and current planning and regulatory practices make inter-regional transmission particularly difficult to build. Even though investing in transmission could save tens of billions of dollars in bringing on the new 38 GW of electricity demand, changes in policy and practice are required across the country to make this possible.

The drivers of electricity demand growth are diverse:

Federal legislation encouraging '**domestic content**' is leading to increased industrial load;

- **Data center growth** is being supercharged by the rise of artificial intelligence;
- **Electrification of transportation and buildings** is building momentum, already the dominant source of growth in some regions; and
- Emerging investments in **hydrogen fuel plants** could emerge as a major factor in future electric load forecasts.
- Increases in the frequency and severity of **extreme weather events** is driving record peak demands in many regions.

If grid planners are not accounting for these drivers, load forecasts will be too conservative, and the system will not be ready to meet growth in electricity demand. Transmission planners need long-term forecasts of both electricity demand and sources of electricity supply to ensure sufficient transmission will be available when and where it is needed. Such a failure of planning could have real consequences for investments, jobs and system reliability for all electric customers.

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SECTION ONE

Overviews of the Key Drivers of Load

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7

Data Centers and Industrial Facilities Driving Load Growth

... a surge in data center and industrial development caused sudden, shockingly large increases in 5-year load growth expectations.

For the past several years, numerous load forecasts have identified general economic growth, population growth, temperature trends, and electrification (building and transportation) as drivers of load growth.

However, beginning in 2022 and especially in 2023, a surge in data center and industrial development caused sudden, shockingly large increases in 5-year load growth expectations.

For seven of the load forecasts examined in this report, data centers (including crypto and AI) and industrial facilities (mainly battery and automotive sectors, but also hydrogen plants) are the key drivers of this sudden surge in load growth expectations. For planning areas anticipating gigawatt-scale load growth, these are the key drivers.

Other growth drivers, including building (heat pumps, water heaters) and transportation electrification (EV charging), tend to be less volatile and more impactful in the 2030s.

As more utilities and planning areas update their load forecasts over the next several months, it is possible that tens of gigawatts of load growth may be added to near-term load forecasts.

	Data Centers	Industrial Facilities	Hydrogen Plants	Electrification
ERCOT	●	●		
PJM	●			
Duke Energy	●	●		
Georgia Power	●	●		
NYISO	●	●	●	●
Arizona Public Service	●	●		
CAISO				●
Portland General Electric	●	●		

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8

Three Regions Hosting Most New Industrial Load

According to the U.S. Department of Energy, over 200 new manufacturing facilities for transportation and clean energy industries have been announced since the Inflation Reduction Act (IRA) was passed. These facilities represent over $100 billion in new investment.

These investments are concentrated in the following planning areas:

- **Southeast**, especially Georgia and the Carolinas
- **MISO**, especially Michigan and Indiana
- **Southwest**, especially Arizona and Nevada

Near-term load growth associated with these facilities is appearing in several of these regions (Georgia, the Carolinas, and Arizona), but does not yet appear in MISO or Nevada's load forecasts.

SOURCE | U.S. Department of Energy, Building America's Clean Energy Future (accessed November 16, 2023).

Announced Manufacturing Facilities since August 2022

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Load Forecasts May Be Understating Data Center Load Growth

According to the Boston Consulting Group (BCG), data centers currently represent 2.5% of U.S. electricity consumption. By 2030, BCG expects energy use to grow from 126 TWh to 335 TWh, or demand of 17 GW to 45 GW.

According to JLL, siting for "power hungry" data centers depends on land *and* power availability. Data center growth is forecast to exceed $150 billion through 2028.

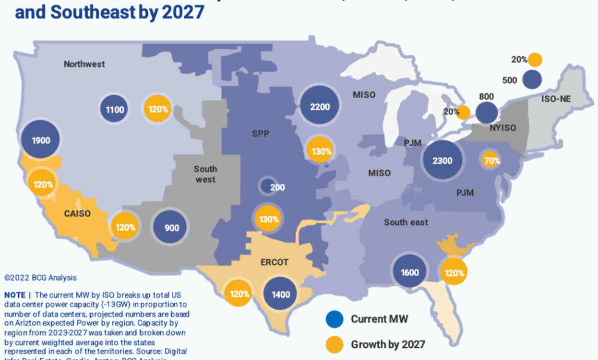
New generative artificial intelligence (GenAI) is a significant driver of BCG's estimate, with 2 GW of GenAI-related load in the base case and possibly an *additional* 7 GW of GenAI load online by 2030. At this higher end, BCG estimates that data centers could consume 7.5% of all electricity in the U.S.

Seven case studies in this report identify data centers as one driver of near-term load growth. Forecasts of 5-year growth vary: BCG projects 13 GW, while Schneider Electric's 9 GW forecast anticipates further efficiency gains.

However, neither MISO nor CAISO appear to have included substantial data center growth in their 2023 forecasts. Based on BCG's forecast, this could mean 3-5 GW of load growth is missing from the national load growth forecast.

By 2030, BCG expects energy use to grow from 126 TWh to 335 TWh, or demand of 17 GW to 45 GW.

>60% of Data Centers Expected in MISO, CAISO, PJM, and Southeast by 2027



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NOTE | The current MW by ISO breaks up total US data center power capacity (-13GW) in proportion to number of data centers, projected numbers are based on Arizton expected Power by region. Capacity by region from 2023-2027 was taken and broken down by current weighted average into the states represented in each of the territories. Source: Digital Infra Real Estate, Omdia, Anzton, BCG Analysis

SOURCES | Arizton, *US Data Center Construction Market – Industry Outlook and Forecast 2023-2028* (February 2023).
Avelar, Victor et. al., *The AI Disruption: Challenges and Guidance for Data Center Design* (September 2023).
Boston Consulting Group, *The Impact of GenAI on Electricity* (September 2022).
JLL, *North America Data Center Report* (H1 2023).
Mordor Intelligence, *U.S. Data Center Construction Market Size* (2023).

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Virginia Data Centers Driving Gigawatt-Scale Load Growth

Since 2019, the Company has connected 75 data centers with an eventual capacity of 3 GW.

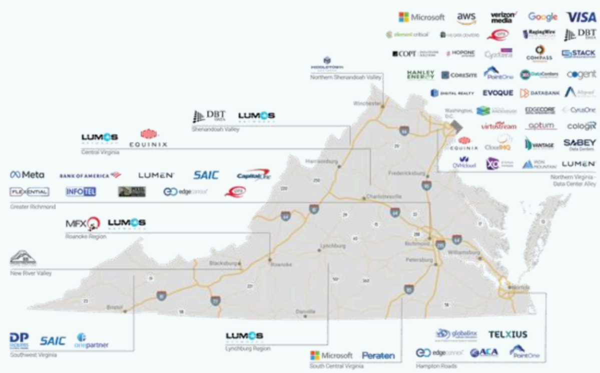
As discussed later in this report, PJM's load forecasts and transmission plans are evidence of rapid growth in the data center market. Ground zero for this growth is in Loudoun County, Virginia – "Data Center Alley."

According to the Virginia Economic Development Partnership, "Virginia hosts the largest data center market in the world and is home to more than 35% (~150) of all known hyperscale data centers worldwide."

Much of this load is served by Dominion Energy Virginia. Dominion describes the impact as follows:

"The data center industry is one of the fastest growing industries worldwide. In the Company's service territory, the industry has grown on average 0.5 GW a year in the last three years. Since 2019, the Company has connected 75 data centers with an eventual capacity of 3 GW. These data centers will ramp up to this capacity over time, so the Company expects this growth to materialize over the next 3 to 5 years."

"The big drivers of current and future growth include: migration to the cloud as companies outsource information technology functions, smartphone technology and apps, 5G technology, digitization of data, and artificial intelligence."



SOURCES | Dominion Energy Virginia, *2023 Integrated Resource Plan* (May 1, 2023), Virginia State Corporation Commission Case No. PUR-2023-00066, p. 55.
Virginia Economic Development Partnership, *Data Centers* (accessed November 2023).

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Planned Hydrogen Fuel Plants Aren't in Most Load Forecasts

A majority of the projects in the figure, 3.6 GW, are announced or planned, 50 times present capacity.

Federal hydrogen production incentives could lead to substantial new demand for power over the next few decades. However, hydrogen production is not currently a driver of growth in 5-year peak demand forecasts in most regions.

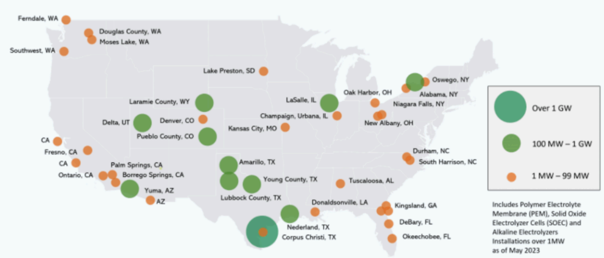
The Inflation Reduction Act included a tax credit which provides up to $3 per kilogram of hydrogen produced and the DOE in October 2023 awarded $7 billion from the Bipartisan Infrastructure Law to seven different regional hydrogen hubs which are expected to increase hydrogen production 1000 times over today's levels.

The figure at right shows hydrogen production projects greater than 1 MW that are operational or have been announced as of May 2023. Installed capacity in the U.S. is currently 67 MW, equal to one orange bubble. A majority of the projects in the figure, 3.6 GW, are announced or planned, 50 times present capacity.

Over two-thirds of the planned investments are in ERCOT and the Intermountain West (CO, UT, and WY). Almost 2 GW or just over 50 percent of the announced investments are in ERCOT, with the Intermountain West having planned 700 MW or approximately 20 percent of investments announced.

However, other than NYISO, load forecasts don't appear to be explicitly considering the implications of hydrogen fuel plants.

Planned or Operational Hydrogen Production Projects



SOURCES | DOE, U.S. National Clean Hydrogen Strategy and Roadmap (June 2023).
DOE, Regional Clean Hydrogen Hubs Selections for Award Negotiations (accessed November 2023).
DOE, Electrolyzer Installations in the United States (June 2, 2023), p. 1.

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Reconductoring With Advanced Conductors Can Save Electricity Customers Billions

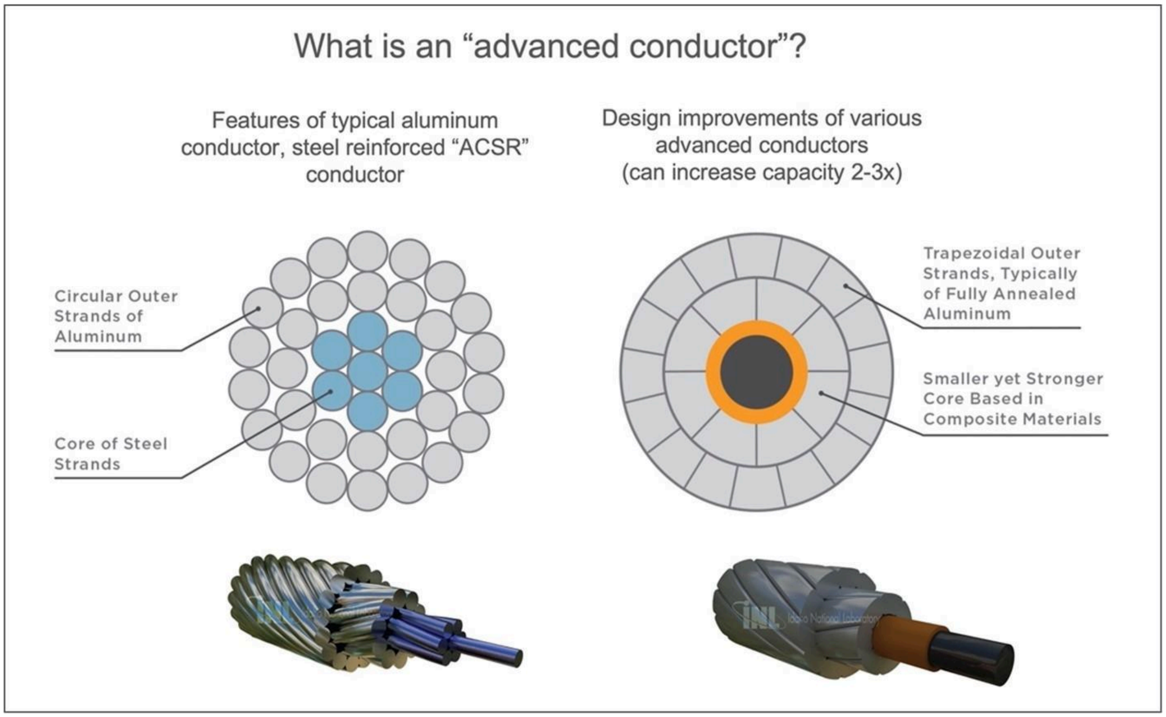
Anand Gopal
Executive Director, Policy Research, Energy Innovation

Transmission lines are the lifeblood of the United States' electricity grid, and recent research has shown the importance of expanding transmission capacity to add new generation in to meet rapidly growing demand for electricity, enhance reliability, and keep costs down for electricity customers. The U.S. Department of Energy found that we need to double transmission capacity within regions and increase capacity between regions by six-fold in the next 15 years.

However, the U.S. has become a difficult place to build new transmission, and commissioning high-voltage lines along new paths takes seven to ten years, with complex interstate lines taking even longer. As a result, the U.S. has averaged a paltry 1 percent annual increase in transmission capacity.

The U.S. Needs New Transmission Capacity, Quickly

Luckily, an innovative solution that replaces existing wires with high performance wires within existing transmission paths can up to double transmission line capacity in as little as 18 to 36 months. While this approach, called reconductoring with advanced conductors, does not eliminate the need for new transmission lines along additional paths, research shows it can quadruple the transmission capacity added by 2035 while saving $85 billion in system costs.



Unfortunately, while utilities around the country use advanced conductors for niche applications like river crossings and wildfire mitigation, they are not in widespread use, partially due to higher initial costs. The higher costs are quickly paid back in lower electricity losses and higher capacity to transport electricity, but utility incentives do not prioritize these benefits. Many decisions about investment happen at the state level, but the federal government also has a big role to play to accelerate the use of high-performance wires along existing transmission paths, including the following:

Efficiency Standards

Along with carrying significantly more electrical current, advanced conductors reduce transmission losses between 10 and 30 percent. Estimates show nationwide adoption of this technology could save consumers $2.2 billion annually via loss reduction, in addition to the consumer benefits of access to lower-cost power providers.[53] Efficiency standards would form a backstop to ensure adoption of this vital technology where utility adoption is too slow or regulatory support is lacking.

The DOE has authority under 42 U.S. Code Subchapter III, Part 1-A to promulgate efficiency standards for industrial equipment. The law provides general authority to promulgate efficiency standards for industrial equipment, but does not specifically require a standard for transmission conductors. To resolve any legal ambiguity, Congress should further clarify the DOE's authority to promulgate standards specifically for transmission conductors, as it did in 1992 for distribution transformers, another key

[53] https://acore.org/wp-content/uploads/2022/03/Advanced_Conductors_to_Accelerate_Grid_Decarbonization.pdf

piece of electric grid infrastructure.[54] In the FY-23 Energy & Water Development Appropriations bill, the U.S. House of Representatives directed the DOE to study the benefits of such an efficiency standard, so Congress will soon have agency recommendations to consider.[55]

Defense Production Act for Transformers

Long lead times for new large power transformers are creating a supply chain bottleneck across the electricity system, as they are needed to install new generation and transmission as well as for many projects that involve reconductoring with advanced conductors. Currently, only eight companies in the U.S. produce transformers, accounting for just 20 percent of national transformer supply.[56] To date, a declaration that transformers are essential to national defense has been made,[57] and the DOE subsequently issued a Request for Information on use of the Defense Production Act for transformer manufacturing.[58] The DOE should finalize this process, and Congress should appropriate funds to increase production at U.S. transformer facilities as soon as possible to ensure that the U.S. grid can supply the reliable, affordable electricity needed to support continued economic growth.

Federal Funding

The federal government has allocated modest funds to transmission infrastructure resilience through the Inflation Reduction Act and the Infrastructure Investment and Jobs Act (IIJA), but the funds are barely reaching projects that aim to reconductor existing transmission lines with advanced conductors. Nor is the funding at the scale to leverage the national potential of advanced conductors. IIJA funding available for reconductoring largely flows through the DOE's Grid Resilience and Innovation Partnerships program, which has $10.5 billion available to upgrade the transmission and distribution system. Only 1 percent of the first tranche of funding went to advanced reconductoring, but DOE has increased focus for the second round and the remaining $6.5 billion. Congress should encourage DOE to continue to prioritize advanced conductors through this program, as well as expand funding opportunities specifically for advanced conductors.

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[54] https://www.law.cornell.edu/uscode/text/42/6317.

[55] https://energycentral.com/c/gr/advancing-efficiencies-us-power-grid-doe-update.

[56] https://www.energy.gov/sites/default/files/2022-02/Electric%20Grid%20Supply%20Chain%20Report%20-%20Final.pdf.

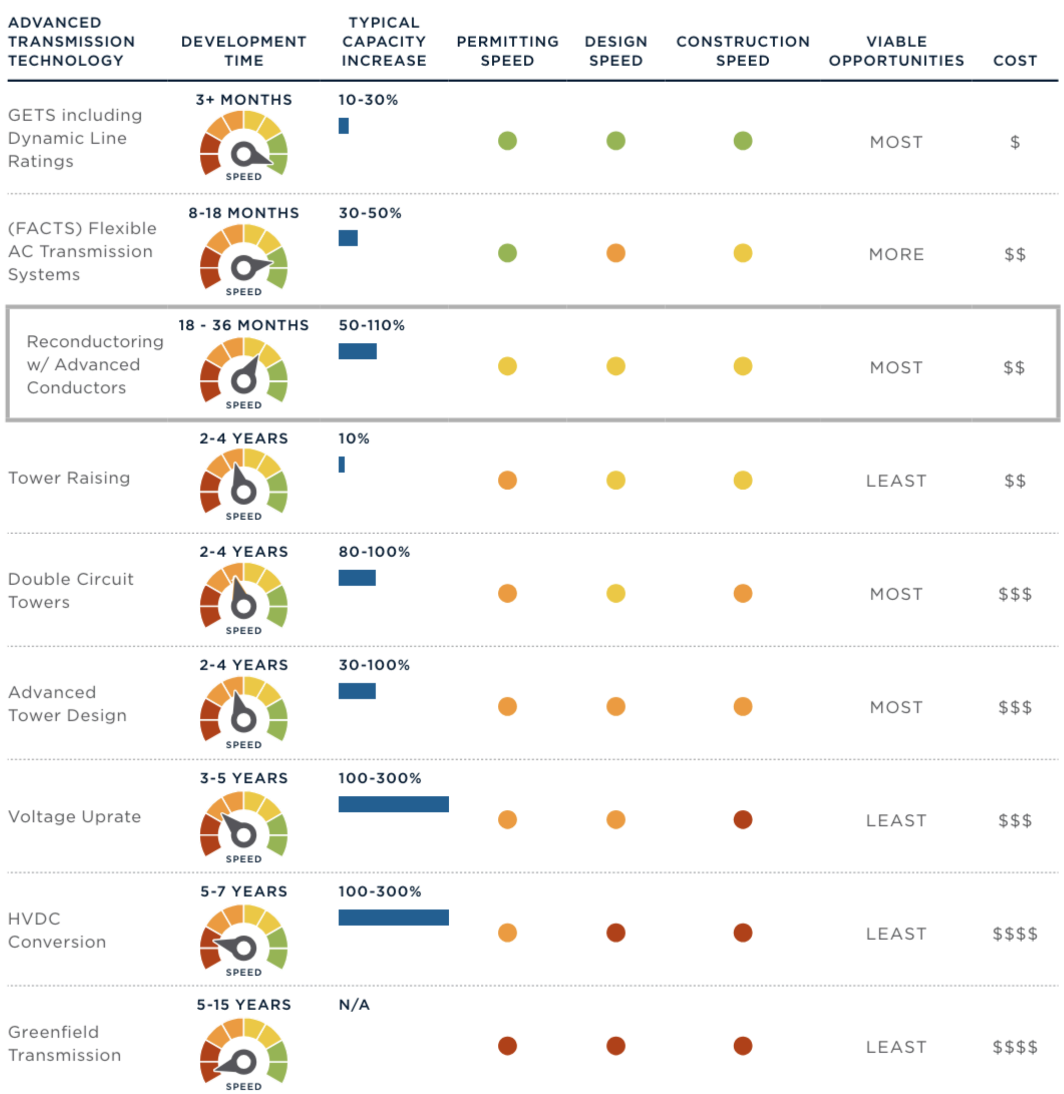
[57] https://www.whitehouse.gov/briefing-room/statements-releases/2022/06/06/memorandum-on-presidential-determination-pursuant-to-section-303-of-the-defense-production-act-of-1950-as-amended-on-transformers-and-electric-power-grid-components/.

[58] https://www.energy.gov/mesc/defense-production-act-request-information.

Tax Incentives

Beyond grant funding, tax policy has an important role to play. Both the U.S. House of Representatives and the Senate have proposed bills to expand the investment tax credit to transmission lines. Expanding the tax credit to new or reconductored transmission and requiring new lines above 69 kilovolts to use advanced conductors to qualify for this incentive would help overcome the higher cost of using an advanced conductor compared to a traditional conductor. The tax credit should be technology neutral, based on the resistance of the conductor. For example, the incentive could apply to conductors that have a direct electrical resistance at least 10 percent lower than existing conductors of a similar diameter, an approach with precedent at the state level.

Fig 2. Advanced conductors can rapidly increase transmission line capacity



Select Energy Innovation Resources

The 2035 Report: Reconductoring With Advanced Conductors Can Accelerate The Rapid Transmission Expansion Required For A Clean Grid. April 2024: https://energyinnovation.org/publication/the-2035-report-reconductoring-with-advanced-conductors-can-accelerate-the-rapid-transmission-expansion-needed-for-a-clean-grid/

Meeting New Electricity Demand Reliably and Affordably without Stranded Assets

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After 15 years of stagnant electricity load, new electricity demands from factories, data centers, and electric vehicles are pushing the utility industry to grow again. To serve rising electricity demand, most of which is hugely beneficial to the United States' economy and the climate, utilities have a broad range of options to consider. An increasing number of utilities are defaulting to building new gas plants because that's the solution they are most comfortable with, despite the role of gas system failures in recent Winter Storms Uri and Elliot.[59]

However, the technology landscape has evolved to a point where many more reliable and affordable ways exist to meet new demand. Therefore, new gas plants create considerable risk of increasing consumer costs and exacerbating the reliability risks associated with overreliance on the natural gas system. Alternatively, several affordable, near-term solutions can meet the demand growth challenge while using investments in expensive fossil fuel infrastructure only as a last resort.

Option One: Keep Improving American Energy Efficiency

In 2007, the U.S. Energy Information Administration (EIA) predicted a 21 percent increase in electricity demand over 15 years, driven in part by data centers. However, this growth never materialized, in large part due to a massive increase in energy efficiency.

According to the American Council for an Energy-Efficient Economy (ACEEE), between 2006 and 2021 utility efficiency programs avoided 30 percent of projected demand growth. Unfortunately, since 2019 annual spending on the programs has declined.[60] And while 15 states are leveraging utility efficiency programs to reduce annual energy consumption 1-2 percent, some states including where demand is spiking still spend almost nothing on these programs. Efficiency codes and standards also played a big role in the demand pause.[61] ACEEE projects the U.S. Department of Energy can further reduce peak demand 90 gigawatts (GW) – 13 percent of current total peak demand – by 2050 by updating those standards.[62] Voluntary industry efficiency efforts can and will reduce demand growth as well. In 2007, forecasts predicted data center power use would double within a decade.[63] In reality, data center

[59] See generally, NERC/FERC Final Report on Lessons from Winter Storm Elliot. https://www.nerc.com/news/Pages/FERC,-NERC-Release-Elliott-Report.aspx
[60] https://www.aceee.org/sites/default/files/pdfs/u2206.pdf
[61]https://www.edisonfoundation.net/-/media/Files/IEI/publications/IEE_RohmundApplianceStandards EfficiencyCodes1209.p
[62] https://www.aceee.org/researchreport/a2001.pdf
[63] https://www.energystar.gov/ia/partners/prod_development/downloads/EPA_Report_E xec_Summary_Final.pdf

demand remained flat over that time.[64]

While the power demands driven by the current artificial intelligence boom may be different than those from data centers in the 2010s, industry incentives remain to find innovative ways to reduce energy consumption, as evidenced already by announcements that new chips will use less power.

Option Two: Build Renewables and Storage Where You Can

Even though new power plants, particularly wind and solar, face long waits to connect to the grid in clogged interconnection queues, plenty of locations can connect to the grid by reusing existing interconnection infrastructure, starting with the sites of retiring coal plants.

While regions implement Federal Energy Regulatory Commission reforms like Order 2023, utilities and grid operators can take a proactive approach to identify and prioritize reuse of these sites. Research indicates 250 GW of clean energy projects could leverage existing or retiring fossil interconnection rights to connect to the grid, with the greatest opportunities in the Southeast.[65] Projects under development can also add storage to bolster peak reliability value, as demonstrated in a recent contract for solar-plus-storage that quadrupled the storage amount in response to growing demand in Utah,[66] with battery prices now at all-time lows.[67]

Option Three: Generate Electricity Close to Demand

Distributed solar photovoltaics reduced U.S. demand by 62 terawatt-hours (TWh) per year from 2014 to 2022, but deployment is uneven across states and regions. Reducing obstacles and increasing support for these resources, including with storage, could mitigate overall system growth. Additionally, large new customers should have the option to add resources onsite and offer peak demand reduction services to offset the need for additional gas. The same goes for existing customers. For example, a steel mill in Pueblo, Colorado structured a deal for 300 megawatts of solar in partnership with Xcel Energy.[68]

Option Four: Work with Big Customer to Flex Demand

While large new customers add to electricity demand throughout the year, the push for new gas capacity, especially so-called "peaker" units that run only during times of high electricity demand, is often responding to the relatively few hours per year when the grid is stressed. For example, in South Carolina, projections for short-duration winter

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[64] https://doi.org/10.2172/1372902.
[65] https://rmi.org/cleanrepowering-a-near-term-ira-powered-energy-transition-accelerant/
[66]https://www.canarymedia.com/articles/batteries/utahdeveloper-quadruples-battery-storage-to-meet-new-electricity-demand
[67] https://about.bnef.com/blog/lithium-ion-battery-packprices-hit-record-low-of-139-kwh/
[68]https://www.constructiondive.com/news/worlds-largest-solarpowered-steel-mill-breaks-ground-in-colorado/619381/

peaks are driving calls for new gas.[69] These short-duration peaks are well suited to demand response—an event during which a large customer voluntarily, and ideally automatically, reduces consumption, mirroring the impact of turning up power production. Google, one of the large drivers of new data demand, said in 2023 that it is working on automated ways to flex data center electricity demand because many computational tasks can be shifted in time and location.[70]

Option Five: Instal New Technologies to Increase the Capacity of Existing Transmission Pathways

Expanding transmission capacity is another way to expedite more low-cost electricity and to access resources from neighboring utilities or regions. While new transmission can take 5-15 years to develop, grid-enhancing technologies like dynamic line rating, power flow controllers, and storage devices can be installed in a matter of months at a fraction of the incremental cost. Reconductoring existing lines with advanced conductors can nearly double transmission capacity and come online in one to three years. Each is widely commercialized and utilities can leverage these technologies to open the market for additional resources in the near term while new transmission projects develop apace.

Option Six: Broaden Regional and Interregional Power Markets

When one utility falls short on capacity, it can lean on neighbors that may have some spare capacity, but only if arrangements exist for that real-time access. This efficiency is one major benefit of a regional market. While regions with a regional transmission organization (RTO) are already coordinating on regional resource adequacy, non-RTO regions like the Southeast and West (where demand growth is also highest) still have big opportunities for more efficient use of capacity across the region.

In this regard, the Western Resource Adequacy Program is a promising initiative, as are efforts to expand real-time markets in the West. The Southwestern Energy Exchange Market, by contrast, has yet to yield meaningful results, including failing to facilitate adequate regional transactions during Winter Storm Elliott.[71] Research from Energy Innovation and Vibrant Clean Energy found that sharing capacity between non-RTO states in the Southeast would yield more than $10 billion in cost savings annually, revealing a region replete with spare capacity if utilities can figure out how to share it.

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[69]https://dms.psc.sc.gov/Attachments/Matter/ca573211-bb5f-4117-ac93-84f2c80e1619
[70]https://cloud.google.com/blog/products/infrastructure/using-demand-response-toreduce-data-center-power-consumption
[71]http://www.southernrenewable.org/2/post/2023/11/seems-first-year-broken-promisesdisappointing-results.html

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Economic And Clean Energy Benefits Of Establishing A Southeast U.S. Competitive Wholesale Electricity Market. August 2020:
https://energyinnovation.org/publication/economic-and-clean-energy-benefits-of-establishing-a-southeast-u-s-competitive-wholesale-electricity-market/

Providing Zero-Emission Industrial Heat with Electrified Technologies

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The industrial sector is on track to become the United States' largest source of greenhouse gas (GHG) emissions by 2030, and as of 2022 accounted for 30 percent of the country's emissions. Most of these emissions come from generating heat needed for industrial processes such as vulcanizing rubber or making glass. In fact, producing industrial heat accounts for 91 percent of U.S. industrial fossil fuel use.

However, existing technologies can utilize clean electricity instead of fossil fuels to meet industrial demand for process heat, negating the pollutant emissions and public health impacts of industrial heating. Two technologies, industrial heat pumps and thermal batteries, are particularly well-suited to fulfill this role. With the right policy support, electrified technologies can scale economically and help the U.S. meet its climate targets while creating jobs and improving public health.

Industrial Heat Pumps

Direct electrification using heat pumps is the most efficient and cost-effective method of supplying low-temperature heat (up to 165˚C), which covers about a third of U.S. industrial heating needs, such as food processing and the production of textiles, plastic products, and wood products. Heat pumps can be several times more efficient than combustion technologies because they move heat like a refrigerator or air conditioner, rather than creating heat from their input electricity, and they do not lose heat in combustion exhaust gases. Other zero-carbon solutions, such as burning electrolytic hydrogen, burning sustainably grown bioenergy, or carbon capture and sequestration, cannot economically compete with heat pumps at supplying heat in the low-temperature range.

Shifting from fossil fuel combustion to industrial heat pumps for low-temperature industrial process heat would benefit the U.S. economy and workers, increasing GDP by more than $42 billion and creating more than 275,000 additional jobs by 2030 relative to a business-as-usual (BAU) case. The transition would reduce industrial GHG emissions by 5 percent in 2030 and 16 percent in 2050, relative to BAU. Associated reductions in non-GHG pollutants prevent more than 1,000 premature deaths in 2030 and more than 3,000 deaths in 2050.

Thermal Batteries

Thermal batteries convert electricity to heat and can store this energy for hours to days, releasing it when needed. They can deliver heat at temperatures up to 1,700 °C, making them a viable option for most of the U.S.'s industrial heat needs. Thermal batteries can provide reliable heat at $35 to $62 per megawatt-hour (MWh) of thermal output, making them cost-competitive with existing natural gas equipment. The technology can theoretically displace an extremely large share of fossil fuels, on the order of 75 percent of U.S. industrial non-feedstock energy demand.

Thermal batteries can be used in off-grid or grid-connected applications. An off-grid thermal battery enables an industrial facility to turn inexpensive wind and solar power into reliable, 24/7 heat. A grid-connected battery charges in hours when electricity prices are low, enabling the industrial facility to avoid buying electricity in hours when prices are high. This charging flexibility also helps utilities to balance the electric grid, integrate renewables, and avoid costly electric grid upgrades.

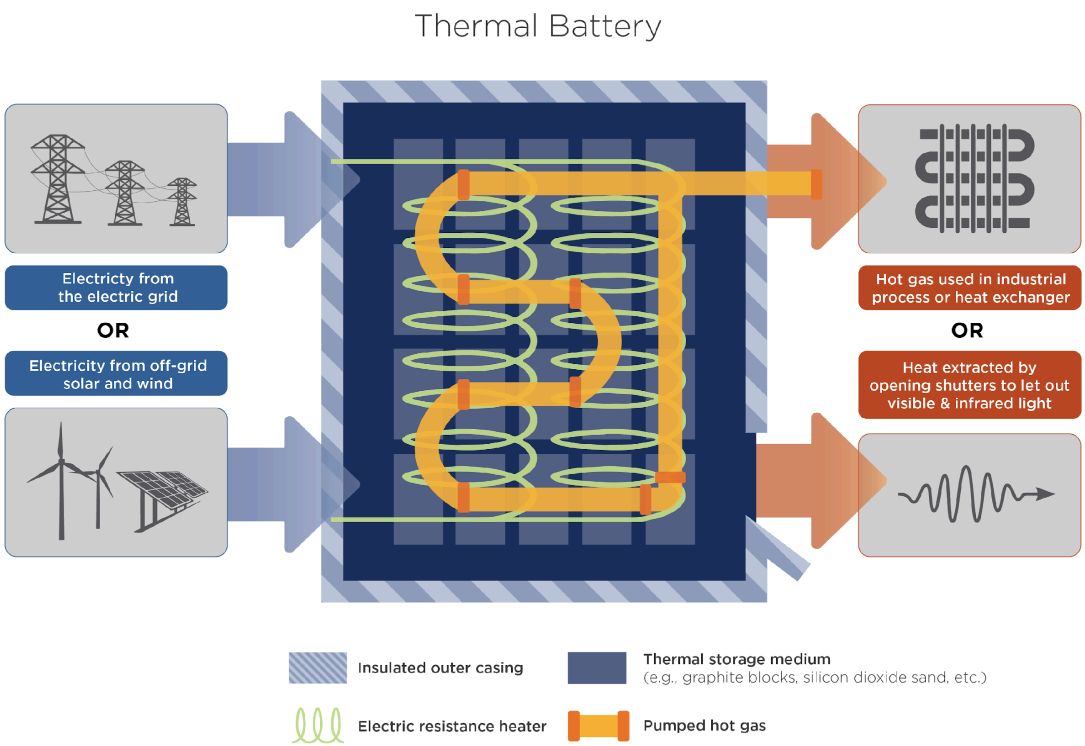

Figure 1. Diagram of an industrial thermal battery.

Policies to Scale Zero-Emission Heat

Financial Incentives

Smart policies can accelerate the adoption and scaling of these electrical technologies. Financial support is the most important near-term option, including R&D support, grants and tax incentives, and facilitating access to low-cost financing. For instance, the Inflation Reduction Act authorized $16 billion to support clean industry, and these investments are already starting to pay dividends. New national green banks can use co-lending, loan loss reserves, and bonds to leverage private capital and provide affordable financing for industrial electrification. More financial support is needed to ensure new industrial technologies are commercialized and deployed widely across many industries.

Reforming Industrial Electricity Rates

Federal and state regulators should require utilities to create a rate class for highly flexible loads that transparently passes real electricity costs through to thermal battery users at 5- to 15-minute increments, enabling them to better support the grid and procure cheap power. Industrial facilities can then properly optimize their demand on the grid to maximize production while improving reliability and reducing peak load for utilities.

Carbon Border Adjustment Mechanisms

At least four bills have proposed carbon-sensitive border tariffs similar to the European Union's, but none became law. Enacting carbon-based tariffs would help ensure U.S. manufacturers compete on a fair playing field with highly emitting producers overseas.

Performance Standards

Standards on industrial greenhouse gas emissions and energy efficiency can also incentivize direct electrification and drive innovation. Standards can also be set within green public procurement programs such as Buy Clean initiatives, creating a large, dedicated market for cleaner products specifically for government-purchased goods. This serves as a protected starter market for clean industrial technologies, enabling them to scale up and drive down costs, and may be more politically feasible than enacting market-wide standards.

Select Energy Innovation Resources

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Hydrogen Policy to Improve U.S. Competitiveness

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Today, hydrogen is almost exclusively made from fossil fuels and used to refine oil, make chemicals, and purify iron ore for steelmaking. As countries seek to meet ambitious climate goals, hydrogen has gained attention given it *can* be produced without greenhouse gas emissions and *can* be used in place of fossil fuels.

However, while hydrogen could be an important climate change mitigation tool, its production is highly energy intensive and can raise emissions reduction costs in many applications where competing technologies are better suited. Thus, policymakers must walk a tightrope to grow the industry in a manner that advances—rather than hinders—goals related to domestic manufacturing, cleaning our economy, energy security, and energy affordability.

Hydrogen Production Policy Design That Plays to U.S. Strengths

Low-emissions hydrogen production is possible by capturing carbon dioxide emissions from the traditional steam methane reformation process or by using clean electricity to split water molecules into hydrogen and oxygen via machines called electrolyzers. Electrolysis has advantages of being capable of undercutting today's fossil-based hydrogen production costs, producing zero-emissions hydrogen, and supporting the integration of renewable resources on the grid.

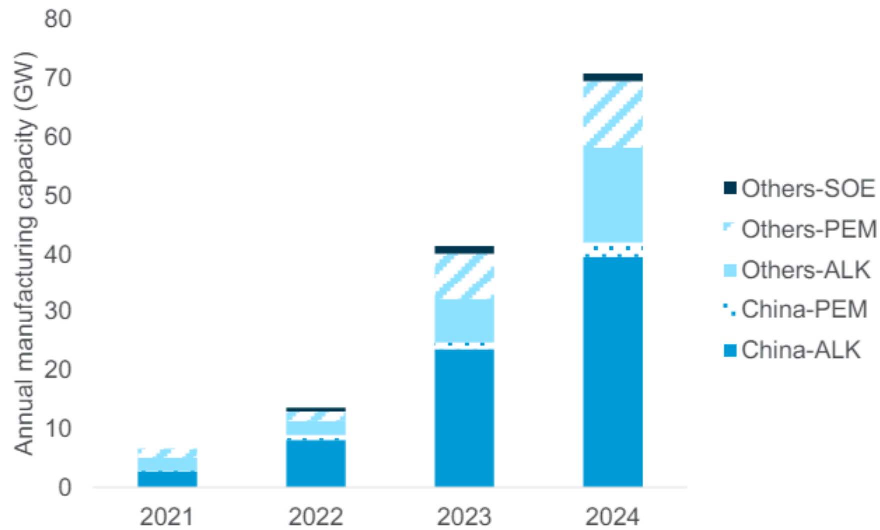
However, capitalizing on these advantages depends on establishing accurate emissions accounting guidelines for electrolyzers' power consumption. The U.S. Treasury Department's final rules on what qualifies as clean hydrogen for the production tax credit (45V) can make or break the domestic electrolyzer industry.

Requiring the use of new, local, hourly-matched clean energy will reward U.S. innovation in cutting-edge, flexible electrolyzer technologies. Loosening these rules would result in hydrogen production that is far dirtier than how it is made today and encourage the use of older electrolyzer technology that will be incapable of bringing production costs below that of fossil-based hydrogen.

This robust definition of clean electrolytic hydrogen is critical to ensuring U.S. competitiveness. China leads the world in the production of alkaline electrolyzers, which are cheap but inflexible; weak rules in the U.S. would encourage hydrogen developers to buy from this glut of Chinese electrolyzers, thus ceding the domestic market.

By contrast, U.S. companies are leading the development of proton exchange membrane (PEM) electrolyzers, which have higher capital costs today but are far more flexible. Requirements to use new, time-matched clean energy for hydrogen production would drive greater investment in domestic PEM electrolyzer manufacturing, as these machines are better suited to adjust operations to follow clean energy generation. This framework also opens U.S. hydrogen production to international markets by aligning with other jurisdictions' rules (e.g., the European Union) and provides a runway for making hydrogen that is cheaper than today's methods.

Figure 20. Estimated Global Annual Electrolyzer Manufacturing Capacity by Region and Technology



Note: ALK refers to Alkaline Electrolyzer, SOE refers to Solid-Oxide Electrolyzer.
Source: BNEF, Citi GPS

Source. https://www.citifirst.com.hk/home/upload/citi_research/rsch_pdf_30174354.pdf

Appropriate Hydrogen End-Uses That Keep U.S. Energy Affordable

Hydrogen can be used as a chemical feedstock and as an energy carrier. The former uses the hydrogen molecule to create other useful molecules, such as in refining oil, purifying iron ore, and making chemicals (e.g., ammonia for fertilizer, e-kerosene as a sustainable aviation fuel). The latter either combusts hydrogen to produce heat or runs it through a fuel cell to generate electricity.

Hydrogen-as-a-feedstock is highly valuable, while hydrogen-for-energy is useful in some applications but is generally far inferior to other technologies that can accomplish the same goal with less waste and higher performance. For example, burning hydrogen in homes for space heating would require roughly three to five times as much clean electricity (for electrolysis) compared to using electric heat pumps while worsening public health and safety risks. Hydrogen is also much less efficient in fuel cell vehicles, power plants, and providing industrial heat relative to corresponding alternatives like electric vehicles, lithium-ion batteries (for intraday energy storage), and industrial heat pumps and thermal batteries.

However, massive subsidies for hydrogen may make it look deceptively attractive across this wide variety of end-uses, fueling hype around a potentially enormous market size. For example, industrial heat, heavy-duty trucks, and 20 percent hydrogen blending (with natural gas) in buildings are common misconceptions of hydrogen end-uses, representing approximately 100 million metric tons (MMT) of speculative U.S. demand. Light-duty vehicles, base- and intermediate-load power generation, and expanded use in buildings adds another 200 MMT of speculative hydrogen demand. Thus, the real market size for hydrogen in a clean U.S. economy may be on the order of 300 MMT per year smaller than what is often implied through industry hype.

Clean hydrogen will have a critical role to play in achieving a decarbonized economy, but likely only in select applications: production of aviation fuels, marine shipping fuels, steel, and other chemicals (e.g., ammonia, methanol). Hydrogen may also have relatively niche energy applications, such as providing seasonal or multi-annual energy storage in the power sector.

However, even these use-cases may be able to rely in part on alternatives, such as iron-air batteries for long-duration energy storage, molten oxide electrolysis for steelmaking, and reducing chemical fertilizer demand by directly fixing nitrogen in the soil via electricity or microbes.

The hydrogen industry's long-term success depends on ensuring uptake in these high-value applications and minimizing its penetration in low-value end-uses. This would allow hydrogen to compete on its merits when policy support either phases out or becomes balanced across all technology options, avoiding a potential wave of stranded investments (e.g., in hydrogen distribution pipelines or refueling stations). This outcome is unlikely to materialize on its own or merely through production subsidies—demand-side policies will be critical to boosting investor confidence in capital-intensive, long-lived assets like hydrogen-based steel production facilities.

Very High	High	Uncertain	Low	Very Low
Refining	Primary steel	Power (seasonal storage)	Long-haul tractor trucks	Power (intraday)
Ammonia	Long-haul aviation	Short-haul aviation	Short-haul marine shipping	Short-haul tractor trucks
	Long-haul marine shipping		Industrial process heat	Light-duty vehicles
	Petrochemicals			Buildings

Figure 2. Long-term competitiveness of hydrogen for decarbonizing different sectors.

Hydrogen production is very energy intensive, which makes it a valuable product. Wasting it on applications that have better options available for decarbonization is akin to using champagne to water your lawn—expensive, unnecessary, and not as good as water for accomplishing its task. Hydrogen should be supported as a means to clean up the trickiest parts of our economy, but it shouldn't be frivolously used where alternatives can be adopted more quickly and at lower cost.

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