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ENERGY INDUSTRY GROUP PAPER

"UNLEASHING AMERICAN ENERGY" - POSITIONING AMERICAN ENERGY FOR THE NEXT CENTURY

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Preface

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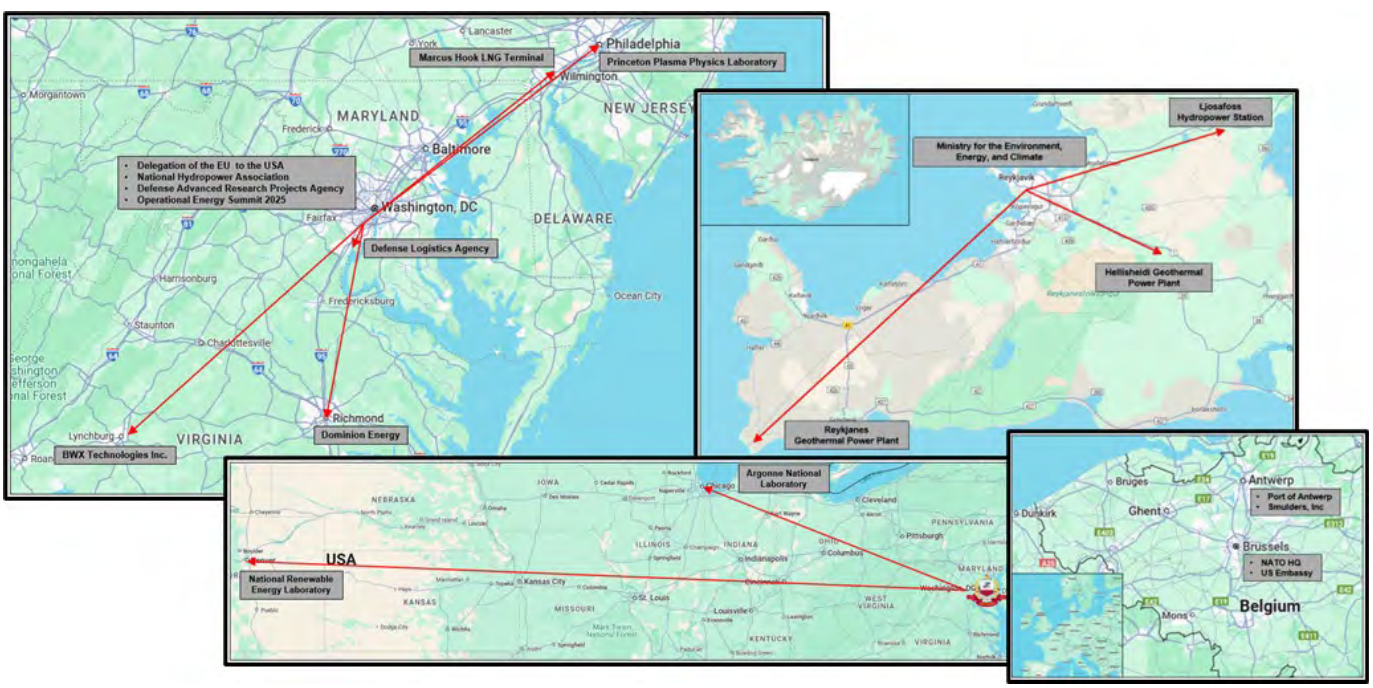
Energy Field Studies Map (Domestic and Overseas):



Domestic Field Visits:

- BWX Technologies Inc., Lynchburg, VA
- Defense Advanced Research Projects Agency, Arlington, VA
- Delegation of the European Union to the US, Washington, DC
- Defense Logistics Agency, Office of Logistics Operations, Fort Belvoir, VA
- Dominion Energy, Richmond, VA
- Marcus Hook Liquid Natural Gas Terminal, Marcus Hook, PA
- National Hydropower Association, Washington, DC
- National Renewable Energy Laboratory, Denver, CO
- Operational Energy Summit 2025, Bethesda, MD
- Princeton Plasma Physics Laboratory, Princeton, NJ

International Field Visits:

<u>Iceland:</u>

- HS Orka's Reykjanes Geothermal Power Plant, Reykjanes
- Landsvirkjun's Ljosafoss Hydropower Station, Pingyallayegur
- Ministry for the Environment, Energy, and Climate, Reykjavik
- Power's Hellisheidi Geothermal Power Plant, Hellisheidi

<u>Belgium:</u>

- Port of Antwerp
- Smulders, Inc, Antwerp
- NATO Headquarters, Brussels
- U.S. Embassy, Brussels

In-class guest speakers:

- Jim Ahlgrimm, Department of Energy, Wind Energy Technologies Office
- Trisha Curtis, PetroNerds
- Oliver Fritz, Office of the Secretary of Defense for Environment and Energy Resilience
- Rob Gramlich, Grid Strategies LLC
- Missy Henriksen, Center for Energy Workforce Development

- Katherine L. Konieczny, Department of Energy, Counsel for Energy Delivery and Resilience
- Dr. Salvatore R. Mercogliano, Campbell University, NC
- Garrett Nilsen, Department of Energy, Solar Energy Technologies Office
- Dr. Jeff Waksman, Department of Defense, Strategic Capabilities Office

What does the term "energy" mean?

Energy is a physical and strategic asset, essential to powering homes, industries, and national defense, while shaping global economic and geopolitical challenges.[1] Derived from the Greek for "acting force," energy refers to the capacity to do work, produce heat, or emit light, and exists in mechanical, thermal, electrical, chemical, nuclear, and radiant forms, which are governed by the law of conservation. In the United States, energy applications span transportation, manufacturing, and defense, supported by a vast infrastructure for generation, transmission, distribution, and storage. It is classified into primary sources (directly usable, like crude oil) and secondary sources (processed, like hydrogen), while further divided into non-renewable (*e.g.*, fossil fuels), renewable (*e.g.*, wind), and nuclear resources, each with distinct implications for energy security and economic stability.

Energy markets function through trade, supply-demand dynamics, and investment flows, influencing security strategies that prioritize energy independence from foreign dependencies. The United States aims to reinforce energy resilience by expanding domestic production, modernizing infrastructure, and advancing clean technologies.[2] Strategic policymaking aligns with broader defense initiatives to secure critical materials and ensure long-term access to energy resources. As the global energy transition accelerates, nations must balance technological innovation with the realities of shifting geopolitical risks, strengthening national security while sustaining economic growth.

Energy in National Security and Resource Strategy:

Security and energy policies are closely intertwined. Reliable energy sources and infrastructure are essential for military operations, industry, and society. Disruptions in energy supply weaken the armed forces' effectiveness and threaten U.S. economic stability—both key to national security. At the National Defense University's Eisenhower School, seminar participants had the unique opportunity to critically examine the strategic implications of security and energy policy over a period of months. Their findings from self-study, expert briefings, and trips to the U.S. domestic and international energy industries formed the basis for writing focused, scholarly papers that incorporated both multinational perspectives and agency aspects. This paper summarizes findings, evaluates the U.S. energy industry's challenges, and provides fact-based policy recommendations to strengthen its role in national security and 21st century readiness.

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Executive Summary

This paper synthesizes findings from independent research, briefings from subject matter experts, and field studies to assess the U.S. energy industry's strategic implications for national security and defense industrial base resilience, highlighting critical vulnerabilities and opportunities. The resultant actionable policy recommendations support U.S. aims for increased energy independence via a secure and robust energy industry.

Major energy sector findings are that the U.S. energy system is undergoing a momentous transition from legacy generative methods and grid infrastructure toward emerging technologies that promise cleaner, more sustainable, reliable, and cost-effective energy solutions. However, innovative technologies cannot thrive with fragmented governance, foreign supply chains, and aging, insecure grid infrastructure, compounding vulnerabilities and necessitating immediate policy action. The U.S. industrial capability includes natural energy reserves and innovation ecosystems, but there is a shortage of skilled labor, domestic critical materials (metals, minerals, and rare earth elements (REEs)), and sufficient research and development (R&D) funding compared to strategic competitors like China. Fortunately, opportunities exist with federal policy, public-private partnerships, and strategic alliances to adapt in areas of weakness.

The policy recommendations within this paper align with the National Security Strategy (NSS) and the National Defense Strategy (NDS) by focusing on national security through energy resilience and 21st-century mobilization readiness. They also support Executive Order 14154 (EO 14154), *Unleashing American Energy*, which establishes national-level reform in energy permitting and security, but this initiative must be centrally led and codified into law to ensure enduring support for meaningful advancements. Domestic supply chains should be strengthened with investments in critical materials. Cyber and physical infrastructure of the grid must be

upgraded to integrate new technologies for defense. The U.S. workforce needs federal support for training and credentialing in next-generation energy. Finally, the federal government must build support and trust from the public through an outreach campaign aimed at energy independence and excellence.

The National Energy Dominance Council (NEDC) is well-suited to lead the effort toward interagency coordination, regulation streamlining, and creating and implementing a national energy strategy. With the NEDC's mission and this blueprint for policy action, the United States can overcome its myriad obstacles and build an American energy system for the next century.

Strategic Environment[3]

The U.S. energy landscape is driven by advancing technology, shifting policies, rising demand, and strategic competition, all within a complex regulatory system where state governments hold significant power alongside federal agencies like the Department of Energy (DOE). While DOE plays a critical role in energy initiatives, its jurisdiction limits its ability to drive a cohesive national strategy. State-level disparities may hinder unified progress, whether through incentives for emerging technologies or legacy systems.

The broader economic transformation cannot be ignored as domestic priorities shift from traditional fossil fuels toward innovations such as small modular reactors (SMRs) and green hydrogen. The United States has moved from coal dependency to a natural gas-driven economy, transitioning from a net importer of cheap coal to a net gas exporter, fundamentally altering its trajectory from energy dependence to energy independence. This shift stands in stark contrast to adversaries, like China, that remain heavily reliant on coal and energy imports, revealing vulnerabilities in their economic stability and geopolitical leverage. This paper examines the current industry status, innovation trends, supply chain challenges, conditions, and regulatory complexities influencing the U.S. energy environment. Key subsectors such as nuclear power, renewables, and hydrogen fuel are assessed, alongside an exploration of national vulnerabilities, providing a comprehensive outlook on the future of U.S. energy security and economic growth. Also, to maintain U.S. leadership, investment in supply chain resilience and workforce development will be necessary and require policy frameworks to incentivize domestic production while guarding against external economic pressures threatening long-term sustainability.[4]

Overview of U.S. Energy Policy and Industrial Dynamics

Historically, U.S. energy policy has oscillated between ensuring affordable and reliable energy while balancing security, environmental, and industrial innovation objectives. Over the past decade, policy shifts have increasingly focused on the diversification of energy sources; a trend further accelerated with recent regulatory realignments and technological breakthroughs. The DOE's strategic publications, such as the Fiscal Year (FY) 2022–2026 Strategic Plan, illustrate the dual imperative: harnessing technological innovation while preemptively addressing vulnerabilities in legacy infrastructure.[5] All of this underscores the complex interdependence between traditional energy production and emerging energy technologies in a rapidly evolving global context.[6]

Current Industry Status, Key Issues, and Forecast

Large Nuclear Reactors

Large nuclear reactors remain a cornerstone for baseload power generation, especially as demand increases and regulatory and public concerns persist. Despite the steady demand for reliable energy, the industry grapples with significant challenges. Regulatory hurdles prolong construction and upgrade cycles, impeding timely capacity expansion. Dependency on high-grade uranium resources dictates fuel security and market volatility due to supply fluctuations. State-backed competition (China/Russia), supply chain constraints, and high costs hinder U.S. private nuclear investment, necessitating strategic policy and financial incentives for long-term viability.[7] Nuclear facilities remain high-value targets for cyberattacks, and vulnerabilities in control systems expose the grid to potential disruption.[8]

Small Modular Reactors (SMRs)

In contrast to their large counterparts, SMRs offer a decentralized energy model, particularly beneficial in remote areas where centralized grid extension is limited. SMRs are heralded by improved inherent safety features, largely due to passive cooling systems and smaller reactor sizes. Complex regulatory approval processes and limited domestic fuel supply chains have delayed the adoption of modular nuclear technology, despite growing interest in a solution for intermittent renewable energy.[9]

Fusion Energy

Fusion energy represents a frontier with the promise of near-limitless, clean power. Recent breakthroughs in high-temperature superconductors have improved the overall feasibility of fusion reactors by enhancing plasma confinement and reducing energy loss. Despite scientific advances, fusion energy faces extraction inefficiencies, engineering limits, and economic hurdles delaying commercialization. Public-private research has boosted investment, but high reactor costs, material limits, and scalability challenges hinder adoption. Fusion's dependence on advanced materials, precision engineering, and complex plasma control demands sustained funding and long-term planning. The uncertainty around net energy gain further complicates large-scale investment without clearer commercialization prospects.[10]

Renewable Energy (Wind and Solar)

Renewable energy, including wind and solar, continues to expand across the United States in keeping with current global demand that is projected to continue (*see* Figure 1, International Energy Agency (IEA)'s projected demand through 2050), though its trajectory remains uneven due to market pressures and infrastructure challenges.[11]

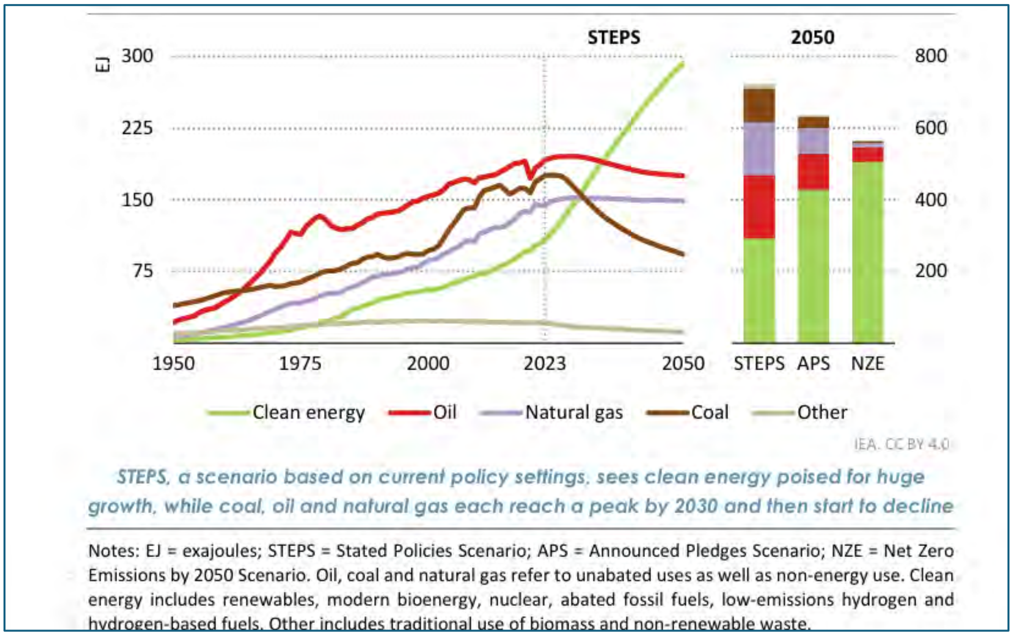

Figure 1. Global Energy Mix, by scenario, to 2050.

The wind and solar industries are at risk due to China's control over manufacturing and supply chains, resulting in vulnerable production costs, price volatility, and supply disruptions.[12] Meanwhile, wind power also holds significant growth potential but is constrained by transmission bottlenecks that restrict capacity expansion. Political and business uncertainty hinders renewable energy expansion. Despite falling costs increasing competitiveness, shifting priorities and regulatory instabilities create barriers to long-term investment.[13] The business environment also presents challenges, as fluctuating energy demand and supply chain constraints impact profitability. While investor interest remains strong, uncertainty around government incentives and market stability can deter large-scale commitments.[14]

Hydrogen Fuel Sector

The hydrogen fuel sector is undergoing transformation, with significant federal incentives catalyzing investments in green hydrogen production. Green hydrogen[15] initiatives are growing in the United States, but face competition from established gray[16] and blue hydrogen[17] methods. Other barriers to growth in domestic green hydrogen include limited infrastructure and regulatory fragmentation. Decarbonizing industrial processes through hydrogen-based solutions[18] will require addressing domestic production capacity and supply chain chokepoints.[19]

Oil & Gas Midstream/Upstream

Traditional fossil fuel sectors have not remained static amid the broader energy transition. The oil and gas industry has shifted focus towards petrochemical exports rather than crude production alone. While this strategy increases profit in a volatile market, it introduces new risks. Midstream infrastructure, especially pipelines, faces rising cybersecurity threats from ransomware attacks, highlighting vulnerabilities in resilience and emergency response. Pipelines, refineries, and fuel distribution networks are increasingly digital, and adversaries know this, as seen in the Colonial Pipeline attack in 2021.[20] The heavy reliance on Gulf Coast aviation fuel infrastructure increases national security risks, making disruptions from extreme weather or supply chain failures more dangerous..[21] While existing pipelines meet current demand, the U.S. Energy Information Administration (EIA) emphasizes that expanding capacity and diversifying fuel distribution networks could both mitigate vulnerabilities and create business opportunities for investment in redundant infrastructure, enhanced cybersecurity, and resilient supply chains.[22]

Grid Infrastructure Vulnerabilities

The U.S. grid, vital for transmitting power from generation to end users, was not designed for today's high penetrations of renewable energy. Compounding these structural issues is a persistent cybersecurity gap, exposing the grid to potential cyberattacks and physical disruptions. Additionally, a lack of high-voltage transmission capacity limits the ability to efficiently transport electricity from renewable-rich regions to areas of high demand, exacerbating reliability concerns. The National Renewable Energy Laboratory highlights that upgrading transmission infrastructure with higher-voltage alternating current and high-voltage direct current lines could significantly improve grid efficiency and resilience.[23] Significant investment disparities have culminated in a fragmented modernization effort, where the integration of advanced grid technologies is often impeded by outdated infrastructure and insufficient federal support.[24]

Innovation Trends in the U.S. Energy Sector

Innovation remains at the heart of the energy transition. The adoption of Artificial Intelligence (AI) has revolutionized energy forecasting and grid optimization, enabling operators to manage demand more efficiently and predict potential infrastructure failures. In the oil and gas industry, shale extraction has been a transformative innovation over the past decade, significantly increasing U.S. production and reshaping global energy markets. Companies like ExxonMobil and Chevron have adapted by consolidating operations and diversifying portfolios to include renewables and more efficient gas extraction methods.[25] The same technological momentum is evident in nuclear systems' evolution, where SMRs benefit from advancements in modular design and next-generation reactor safety technologies. Moreover, breakthroughs in high-temperature superconductors have propelled fusion energy research, offering promising yet incremental improvements in reactor efficiency. Lastly, the momentum in hydrogen research is amplified by strategic investments aimed at developing the infrastructure necessary to support an industrial decarbonization economy.[26]

Supply Chain Issues and Strategic Vulnerabilities

The energy industry is not immune to global supply chain challenges. A heavy dependency on Chinese-manufactured REEs, solar panel components, and critical materials (*i.e.*, lithium, cobalt, steel) underscores the vulnerability of U.S. critical energy sectors to international market disruptions (*see* Figure 2, China's supply chain dominance in critical materials).[27]

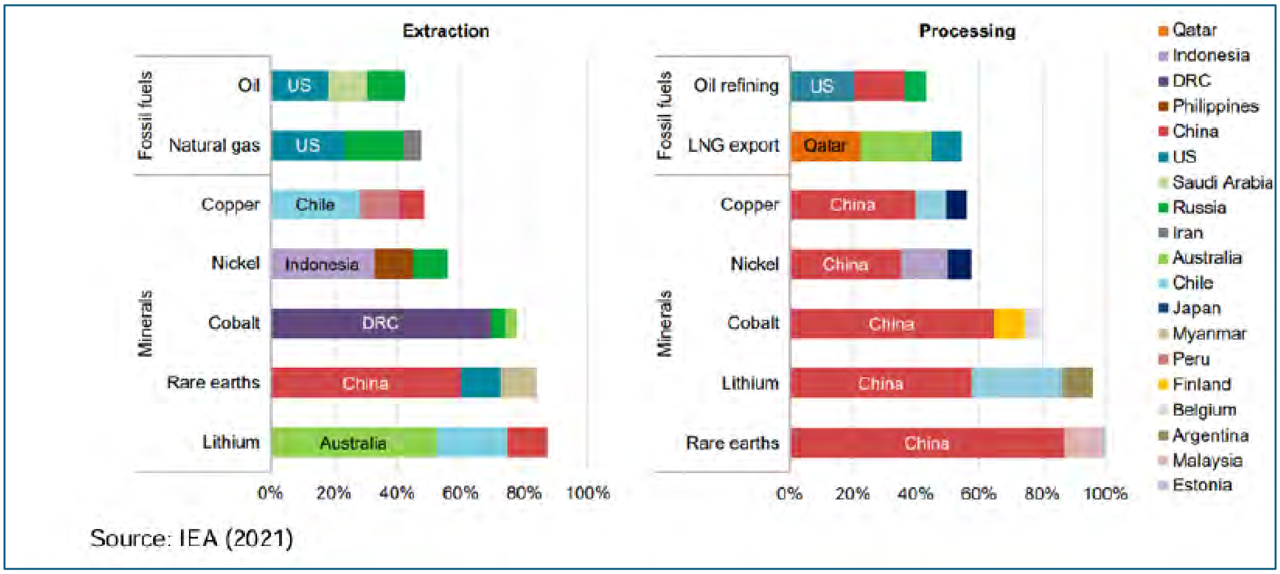

Figure 2. Share of Top Five Countries in Critical Element Extraction and Processing, 2019.

Domestic manufacturing shortages in nuclear fuel fabrication, electrolyzer components for hydrogen, and critical elements for solar technologies, along with reliance on Gulf Coast assets for aviation fuel processing, exacerbate supply chain issues. These dependencies are particularly problematic during geopolitical tensions, risking unforeseen interruptions to U.S. energy infrastructure.[28]

Conditions Affecting Industry Growth

The U.S. energy sector is confronted with structural challenges that impede innovation and project implementation. Extensive regulatory frameworks and permitting processes obstruct the advancement of nuclear and renewable energy projects. Additionally, a notable deficiency in skilled labor specializing in nuclear engineering and clean energy technologies restricts industry growth. The reliance on foreign supply chains presents significant risks for halting progress in renewables, hydrogen, and nuclear advancements, unless domestic production incentives and strategic partnerships are established.

The United States is also falling behind in R&D, with China's R&D spending up by 8.7% compared to 1.7% for the United States in 2024, and China also surpassing the United States in patents (*see* Figure 3 below).[29]

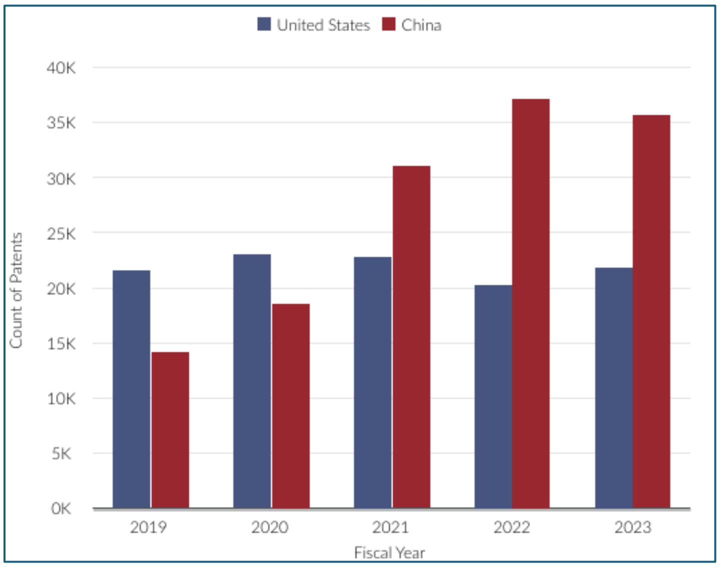

Figure 3. Year-over-Year Patents Granted, FY19-23.

Besides technological and logistical obstacles, cybersecurity and public perception issues further complicate energy expansion. The absence of standardized national cybersecurity protocols leaves critical infrastructure vulnerable to cyberattacks, exposing grids and pipelines to operational risks. Misinformation surrounding nuclear energy, coupled with skepticism about emerging technologies, slows adoption by policymakers and the public, delaying widespread deployment of next-generation energy systems.[30] Additionally, as China advances rapidly in R&D and becomes a leader in the energy sector, the United States must strive to retain its innovation edge.

Strategic Competition: The United States versus China and Russia

The China and Russia Challenges

China's Civil-Military Fusion (CMF) model has enabled dominance in energy manufacturing through state-controlled enterprises, forced technology transfers, and cyber intrusions that threaten U.S. grid security and critical infrastructure.[31] China's near monopoly on REEs, crucial for energy technologies, creates U.S. import dependencies, necessitating a national strategy to bolster domestic production, infrastructure resilience, and regulatory alignment, not just private sector initiatives.[32] Meanwhile, Russia exploits its global energy exports[33] for geopolitical leverage and deepens its strategic partnership with China to support its industrial base.[34]

Synthesis and Policy Implications

The multifaceted U.S. energy strategic environment requires a nuanced approach that navigates technological innovation, supply chain resilience, and geopolitical independence. Policy recommendations emerging from this analysis include:

1. **Streamlining Federal Regulations:** Establish expedited review processes and harmonize permitting procedures to reduce project and litigation delays, especially in nuclear and renewable energy sectors, as recent DOE strategic frameworks suggest.[35] Ensure new streamlined processes are codified to support longer-term investments.

2. **Enhancing Domestic Manufacturing While Fostering International Alliances:** Incentivize the domestic production of critical components, from high-grade uranium, electrolyzers, REEs, and solar panels, to mitigate reliance on monopolistic foreign supply chains.[36] Increase domestic mining for critical materials and strengthen partnerships with allies, such as Brazil, Canada, Norway, and Ukraine, to enhance energy security and supply chain stability.

Collaborative initiatives on renewable and hydrogen infrastructure can help buffer against geopolitical instability.

3. **Investing in Cybersecurity and Infrastructure Upgrades:** Strengthen both physical and digital security measures across energy assets through federal requirements for implementation of baseline security standards for energy producers and suppliers. Increased federal investments in grid modernization and cybersecurity standards are crucial to reducing vulnerabilities.[37]

4. **Improving Public Outreach and Messaging:** Increase public awareness of the need for additional energy sources to meet rising demand. Focus on outreach efforts to improve public perception of infrastructure projects, modernization efforts, and education on the national security importance of a secure energy system.

5. **Boosting Workforce Development:** Address the shortage of skilled labor across nearly every vital energy domain—from power generation and grid operations to nuclear, hydrogen, cybersecurity, and renewables through targeted federal and state education initiatives and training programs, particularly in advanced energy technologies, to support sustained sector growth.[38]

Implementing these recommendations will not only fortify the nation's energy security but also lay the groundwork for sustainable economic growth in an increasingly competitive global market.

The Road Ahead: Embracing Technological and Strategic Synergies

The strategic landscape of U.S. energy infrastructure is characterized by significant complexity. Integrating next-generation energy technologies with legacy systems demands an agile governmental and industrial response. Emerging trends such as AI-enabled grid optimization and modular nuclear systems have the potential to expedite this transition, provided that a cohesive national policy framework supports these advancements. Continued public-private partnerships in fusion research and hydrogen infrastructure lay the groundwork for breakthroughs that may redefine the nation's energy trajectory. Most importantly, addressing the interplay between domestic policies and international pressures, especially from rivals like China and Russia, will be critical for safeguarding and advancing U.S. energy interests.[39]

Stakeholder Interests

Various international, national, state, and private stakeholder interests continuously impact the energy sector. These interests can potentially drive positive change but also pose challenges for moving forward with a robust and secure energy sector for the United States. To develop a future energy strategy, it is necessary to map out each stakeholder to identify the challenges, threats, and opportunities. This section explores the influence of international stakeholders like China, Russia, Canada, and Europe; domestic entities including the U.S. government, military, and energy market participants; workforce groups such as labor unions, lobbyists, and educators; and federal and state regulatory bodies shaping the industry.

International Stakeholders

The U.S. energy sector is shaped by global stakeholders, presenting both opportunities and vulnerabilities for national security. Key competitors like China and Russia, along with partners such as Canada and European nations, influence the sector through supply chains, energy trade, cooperative frameworks, and geopolitical competition.

China controls about 70% of the global solar panel production, 80% of REEs, and 60% of battery cell manufacturing, posing a major vulnerability for the United States.[40,41] China's monopoly is reinforced by its Belt and Road Initiative (BRI), which secures critical energy resources and logistic routes, across Africa, Asia, and Latin America (*see* Figure 4, China's BRI investments by sector, with energy representing the majority).[42, 43]

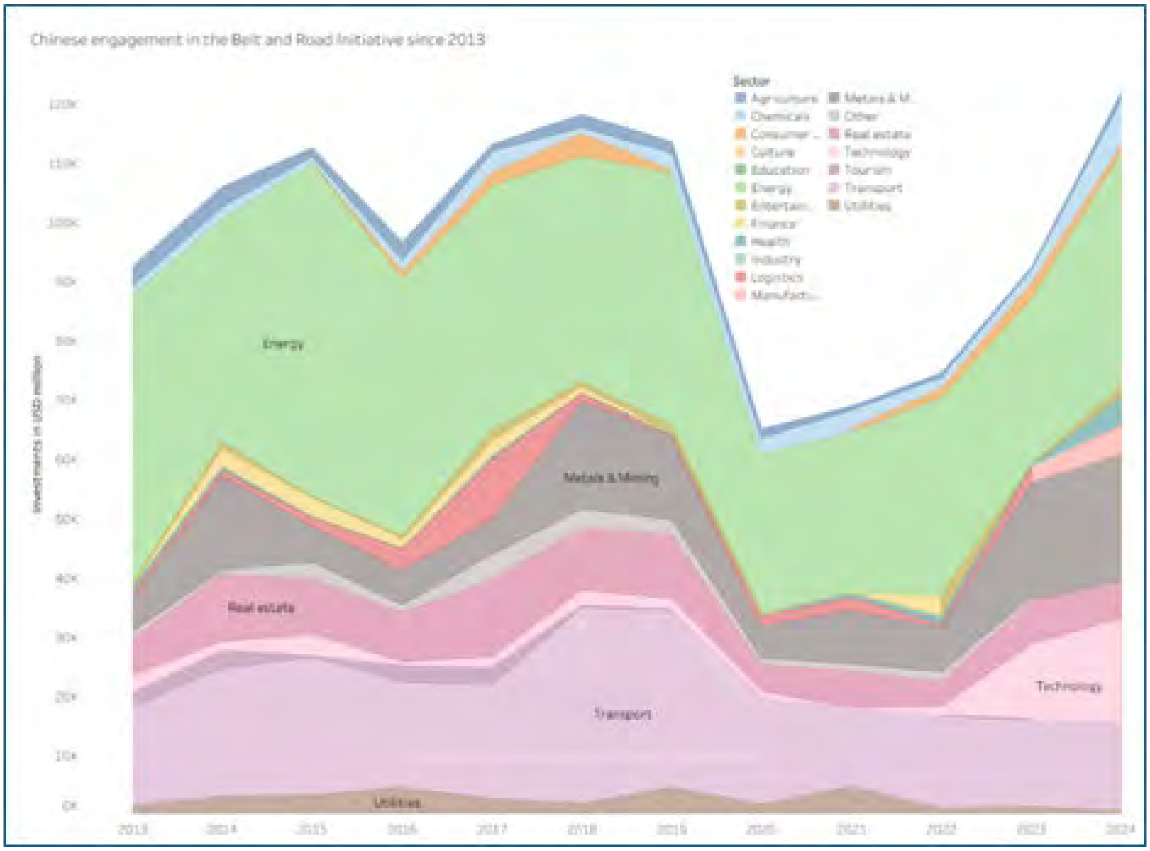

Figure 4. China's Belt and Road Initiative Investments, by sector.

As U.S.-China tensions continue to rise, dependence on materials from China presents strategic risks, underscoring the need to diversify supply chains and increase domestic manufacturing capacity.

Russia's position as a major energy exporter highlights the deep ties between energy and geopolitics. Amid its war with Ukraine,[44] Russia leverages energy as a strategic tool, exemplified by its 2022 gas cuts to Europe, leading the EU to seek alternative energy sources.[45] This shift resulted in the United States becoming the top exporter of LNG to Europe, with exports rising 305% since 2022.[46] Despite challenges posed by the Ukraine conflict, Russia's energy strategy, including Arctic expansion and a covert "shadow fleet" transporting oil/gas to avoid sanctions, remains a threat to U.S. and European energy security.[47]

Canadian interests are strongly connected to U.S. energy security through shared infrastructure and trade, with pipelines, like Keystone XL, supporting 60% of U.S. crude imports.[48] While the U.S.-Mexico-Canada Agreement (USMCA) ensures free trade, proposed new tariffs on non-compliant exports, such as electricity and natural gas, could prompt shifts in Canadian strategies.[49] Cross-border permitting coordination and joint interest in SMRs further reinforce North American energy cooperation.[50]

Europe navigates the balance between energy security and decarbonization by increasing reliance on U.S. LNG imports following reduced Russian gas exports, securing long-term agreements such as Germany's deal with Venture Global.[51] Like the United States, Europe faces China-related supply chain challenges and seeks U.S. cooperation to secure critical materials.[52] However, regulatory differences, such as those in the Paris Agreement, highlight tensions between Europe's environmental regulations and U.S. industrial priorities.[53] Overall, while Europe's clean energy goals create opportunities, the strict decarbonization timelines may strain transatlantic relations.

Domestic Stakeholders

U.S. domestic energy policy has wide-ranging and diverse stakeholders, including advocacy groups, private industry, the public, and government agencies, whose competing priorities often hinder progress aligned with U.S. national security interests.

Advocacy groups and lobbyists influence U.S. energy policy significantly, resulting in legislative gridlock with differing agendas. Pro-renewable organizations like the Solar Energy Industries Association and American Clean Power Association secured $369 billion in clean energy incentives through the 2022 Inflation Reduction Act (IRA).[54] In contrast, the American Petroleum Institute resists rapid decarbonization of the energy sector, advocating for pro-oil policies (*i.e*., touting U.S. record oil production of approximately 13 million barrels per day).[55]

Public messaging shapes policy and project implementation with mixed outcomes. DOE's "Better Buildings" initiative reduced energy usage by 25% across 3,600 facilities.[56] However, negative public sentiments, particularly for nuclear energy, have delayed projects like the Palisades nuclear plant restart in Michigan.[57] Misinformation, sometimes traced to Russia and China, undermines support for renewable infrastructure upgrades and grid expansion, risking national energy resilience.[58]

Private sector innovation strengthens civilian and defense energy capabilities with advancements like ExxonMobil's carbon capture investment (30% emissions reduction by 2030); Tesla's Gigafactory doubled battery production capacity since 2022; and G.E.'s AI-enabled grid management enhancing reliability.[59,60,61] The private energy sector also spurs technological advancements in related industries and national defense through resilient systems for forward bases and military-grade batteries.

State-level interests contribute to a fragmented energy policy. Highlighting the rivalry in perspectives, California targets 100% carbon-free electricity by 2045, but relies on imported power during peak demand.[62] In contrast, Texas, which produces 42% of U.S. crude oil, prioritizes fossil fuels but faces grid vulnerabilities, as seen during the 2021 winter storms.[63] This disparate approach to energy policies significantly weakens U.S. national preparedness for energy disruptions.

U.S. government and military perspectives prioritize energy independence and infrastructure security as national security imperatives. Operationally, projects like Project Pele, a mobile nuclear microreactor, provide deployable, independent power to reduce vulnerabilities at forward bases.[64] The DOE's Office of Cybersecurity, Energy Security, and Emergency Response (CESER) focuses on safeguarding critical energy systems from a multitude of threats and hazards.[65]

Workforce Stakeholders

As the energy sector evolves, a strong workforce is critical to ensuring infrastructure and energy security. Stakeholders include labor unions, trade groups, universities, lobbying organizations, non-profits, and federal agencies.

Labor unions advocate for higher wages, better benefits, safer conditions, and worker representation, with the U.S. energy sector maintaining strong union support for over a century.[66,67] Some notable unions include the International Brotherhood of Electrical Workers, the Utility Workers Union of America, and the Laborers' International Union of North America,[68] representing over 20% of utility workers, well above the national average. Workforce development efforts are led by the Center for Energy Workforce Development, a coalition of 140+ energy companies, unions, educational institutions, and government entities working to develop the talent pipeline needed for today and in the future.[69] Partnerships between utility companies and universities further strengthen training, especially in engineering majors. All these stakeholders are a critical tool for policymakers to understand the needs for a capable and future-ready energy workforce (*see* Figure 5 below).[70]

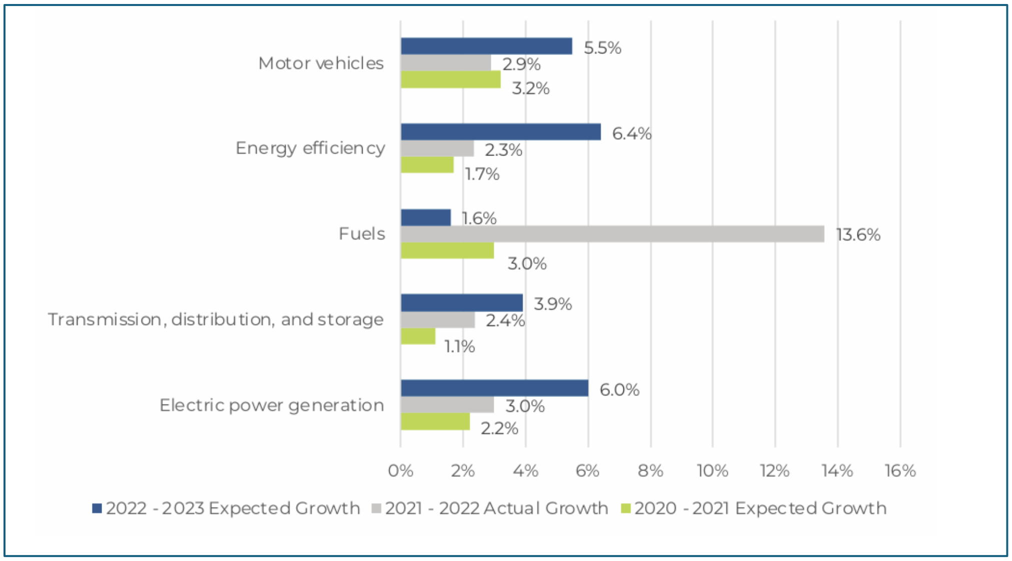

Figure 5. Anticipated and Actual Change in Employment by Technology.

Regulatory Stakeholders

Navigating the complex energy sector regulations at both federal and state levels remains a major challenge. At the federal level, the DOE provides broad-based policy, management, and funding for the national research laboratories and oversight of strategic energy reserves but does not have regulatory control over markets. The Federal Energy Regulatory Commission (FERC) oversees interstate electricity and gas markets,[71] while the Nuclear Regulatory Commission (NRC) oversees nuclear facilities, often through cumbersome processes. The Environmental Protection Agency (EPA), the Bureau of Land Management, and the Department of the Interior also influence energy policy through environmental and land-use oversight. At the state level, public utility commissions and state licensing/permitting authorities impose energy regulations, which can vary widely. Most utility companies operate across state boundaries, complicating compliance. Regional grid operators, such as PJM Interconnect, California Independent Systems Operator, and Electric Reliability Council of Texas (ERCOT), work with FERC and individual states to coordinate grid efficiency. Self-imposed governance inefficiencies hurt U.S. energy independence, which is discussed in the analysis section below.

Analysis Using Course Models

This section analyzes key areas of the energy sector with implications for U.S. energy security, industrial mobilization, and strategic competition. A PEST analysis identifies significant challenges and opportunities in five areas: regulation, workforce, security, public communication, and supply chains. Porter's Diamond compares the competitive advantages of the United States, China, and Russia in the global energy landscape.

Streamlining Regulations

The regulatory environment governing the energy industry is one of the biggest hurdles with the DOE, at the federal level, being the primary federal energy regulatory authority. Additionally, each state also has its own agency and regulations. The variation between different states' regulations and the fact that a state can stop a federally permitted energy project creates a significant burden.[72] These challenges create a financial burden on firms as well as delaying the progress of energy infrastructure.

There are significant opportunities for the energy industry to overcome many of the challenges discussed. The current political environment presents a significant opportunity for the energy industry. EO 14154 directs reductions in permitting timelines and regulations.[73] Additionally, public-private partnerships have an increasing role in the development and advancement of energy technology. One example is the DOE and NRC's work with private companies to further SMR development and deregulation.[74] Further, groundwork for rebuilding the industry in the United States has already begun with federal regulation streamlining in the ADVANCE Act of 2024.[75] Policymakers can use these openings to aid industry in overcoming regulatory challenges.

Supply Chain Conditions

The U.S. energy supply chain is characterized by aging infrastructure and fragmented governance, making it vulnerable to numerous disruptive conditions.[76] Availability of resources across the supply chain is uncertain with federal land-use disagreements and dependence on foreign, subsidized critical materials creating fragility during geopolitical tensions.[77, 78] Firms' profit margins are threatened by rising costs, leading to short-term capital investments in generation, over long-term infrastructure needs like storage and transmission.[79] Recent tariffs increased cost uncertainty, disrupting planning[80] and complicating efforts to secure new trade agreements for supply diversification.

The United States has severe restrictions on the siting of mines, REE processing facilities, transmission corridors (pipelines and electrical lines), as well as power plants.[81] Campaigns to stall infrastructure upgrades, like "Not in my backyard" or environmental activism, increase project costs and mobilization timelines. End-to-end supply chain efficiency is impeded by outdated infrastructure and poor integration of new technologies.[82, 83] These issues represent a small portion of the broader complexities challenging the energy supply chain.

Conversely, the strengths of U.S. energy supply chains include rich domestic reserves, resilience through innovative solutions, and strategic tying of national security with economic competitiveness. Recent U.S. legislation, like the IRA, the CHIPS and Science Act, and enabling emergency powers, provides opportunities for intervention and collaboration to resource efforts such as reshoring or prioritizing materials, processes, or infrastructure critical to national security. The United States has abundant natural gas, solar, and geothermal resources, and ensuring their availability can strengthen the energy generation portfolio, providing reliable solutions to address supply gaps. Advancements in AI, material sciences, and advanced manufacturing enhance logistics, enable alternative raw materials, and refine production lines for a more resilient supply chain.[84, 85] Despite these positive attributes, reaching national security goals regarding energy remains challenging due to supply chain globalization and an antiquated infrastructure that restricts responsiveness and future progress.

Security

The energy industry faces a critical cybersecurity threat. The U.S. power grid is increasingly digitized and interconnected while relying on outdated information systems and supported by weak information technology.[86] This leaves the grid vulnerable to cyberattacks. The ransomware attack on the Colonial Pipeline, one of the largest refined oil pipelines, demonstrates the energy industry's vulnerability.[87] Following the attack, the Transportation Security Administration (TSA) introduced cybersecurity regulations for the pipeline industry, but its guidelines have remained unchanged since 2021.[88] The United States is not keeping up with the cyber threat to the nation's energy infrastructure.

Despite the cyber risk, the Colonial Pipeline attack increased opportunities to overcome the threat. It created public awareness of the threat, which has led to a whole-of-government effort to harden infrastructure against attacks. One example is the Energy Modernization Implementation plan issued by the Office of the National Cyber Director in 2025.[89] In addition, the DOE's Office of CESER has developed guidance and is working with the National Association of Regulatory Utility Commissioners to create the baselines for best practices in grid cybersecurity.[90] The awareness of the threat to infrastructure has opened both the public and the government to finding ways to protect that infrastructure.

Public Perception/Public Messaging

The vastness of the energy industry and its variety of sources lead to an assortment of perceptions and opinions concerning energy. The vastness of the industry makes educating the public about all the aspects of the industry challenging. The politicization of different aspects has created negative perceptions on all sides of the industry.[91] Public support for nuclear energy has been challenged by accidents, such as Three Mile Island and Chernobyl, causing the public to question the safety of both large nuclear reactors and SMRs. Lastly, negative press about hydrogen-powered vehicles and recently renewed focus on hydrocarbons have led to questions about the viability of hydrogen projects.[92] The public perception and understanding of industry presents a hurdle for advancing technology and infrastructure.[93]

There is an opportunity to provide a clear message. Through mainstream information-sharing platforms like media and social media, the public is frequently exposed to positive information about renewable energy sources like wind and solar. This can be effective for other aspects of the industry as well. Further, up to 77% of the public would be in favor of more nuclear power.[94] A centralized federally led messaging campaign presents an opening for changing public perception, which is needed to advance the energy industry.

Workforce

The energy workforce is critical to industrial resilience, yet it is under stress with aging labor pools, increasing technical complexity, and a lack of training and resourcing priorities that are impacting perceptions, recruitment, and retention. There are significant resource constraints, including a shortage of available and capable workers and the lack of funding needed for instructors and training centers to establish an energy sustainment community.[95] Public perception of energy is politicized, which can cause radical swings in support for job creation, especially long-term management pipelines that allow for fruitful career paths.[96] Emerging skill demands in SMRs, fusion, solar, and digital grid modernization reveal that workforce development lags and requires complex, interdisciplinary expertise. These are found in fields like materials science, chemistry, nuclear and electrical engineering, computer-based technologies like AI and cybersecurity, and advanced manufacturing techniques like automation and robotics. As a result of these systemic vulnerabilities, the U.S. energy workforce faces limited scalability and readiness for future energy demands.

However, key strengths do exist in U.S. energy that may overcome the concerns of these challenges. Public-private partnerships between national labs, universities, venture capital firms, and startups, bolstered by injections of political support through recent executive orders, offer opportunities to expand the energy workforce with patient capital. Creative destruction and upskilling provide a higher standard of living by creating safer, more efficient, and higher-paying jobs. Technological opportunities like STEM and tech-sector focused jobs and career paths attract younger talent pools, and breakthroughs in the energy sector may spill over into other industries, such as defense and medical, broadening and strengthening the overall industrial base.[97, 98, 99] These workforce challenges and opportunities limit the capacity of the industrial base to scale innovation needed to meet national security milestones.

Porter's Diamond Analysis: United States, China, and Russia

To effectively evaluate global energy competitiveness, Porter’s Diamond model provides a structured framework to assess the strengths and vulnerabilities of the United States, China, and Russia. The model highlights key factors such as production resources, demand complexity, supporting industries, and strategic organization, revealing how each nation positions itself within the evolving energy landscape.

The United States competes with China in energy innovation and entrepreneurship but struggles with fragmented infrastructure, foreign supply chain dependencies, and changing regulations. In contrast, China has positioned itself as a global leader in energy manufacturing with

"National Champions" or SOEs dominating in critical sectors,[100] and benefiting from centralized R&D of its industrial clusters and subsidies. However, structural overcapacity and economic slowdown risks threaten its stability. Russia relies on fossil fuels for energy influence, but aging infrastructure, weak renewable investment, and geopolitical isolation hinder its global competitiveness.

Using Porter's Diamond model, U.S. policymakers can pinpoint weaknesses and leverage strengths to create industrial strategies that improve national energy security against strategic competitors (*see* Porter's Diamond summary table below).

Competitive Analysis of the United States

In terms of production factors, the United States has an excellent innovation ecosystem, supported by federal institutions (DOE/DARPA), and pioneering companies, such as Helion, a leader in fusion research. The United States is also among the world's foremost natural gas/oil producers and exporters, but this advantage is diminished by dependency on Chinese-sourced materials (*see* Figure 6 below for EIA data on U.S. natural gas shipments).[101]

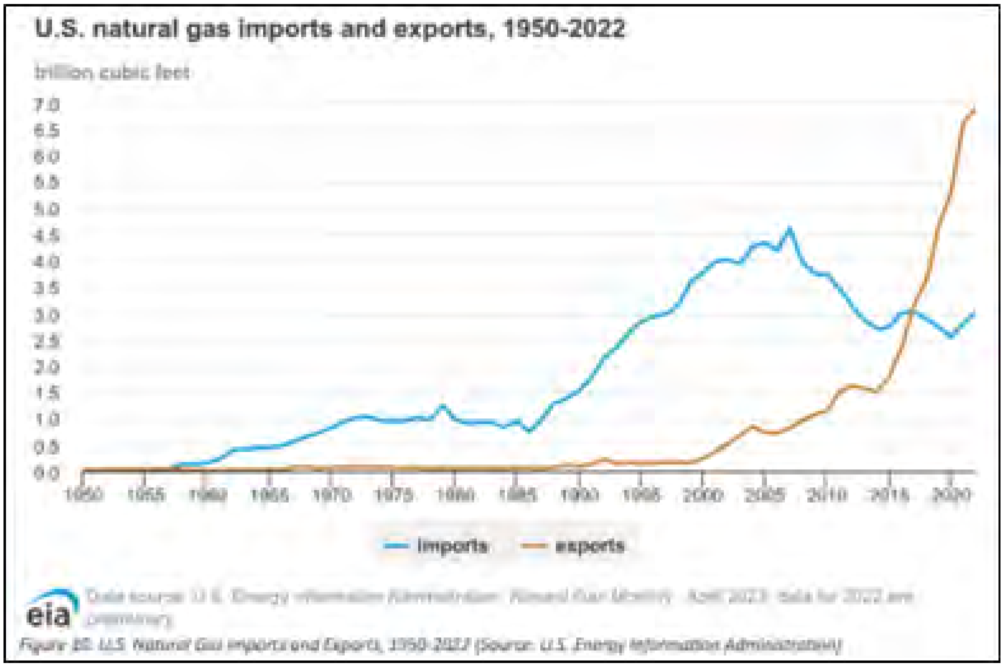

Figure 6. U.S. Natural Gas Imports and Exports.

Meanwhile, U.S. private sector innovation is constrained by short-term shareholder priorities, limiting long-term R&D in clean energy and advanced manufacturing.

Demand conditions in the United States are exceptional, particularly in critical infrastructure sectors, fostering innovation in dual-use energy technologies. Policies such as the IRA and Infrastructure Investment and Jobs Act (IIJA) aim to increase demand for technologies like "hydrogen hubs." However, strategic coordination between the federal government and key public partners is necessary to maintain the U.S. position in advanced energy innovation.[102]

The United States has a strong network of universities, startups, and R&D centers. However, the fragmented energy grid (Eastern Interconnection, Western Interconnection, and ERCOT) hampers coordination, impacting extreme weather responses and renewable energy integration (*see* Figure 7 below for the U.S. grid map).[103]

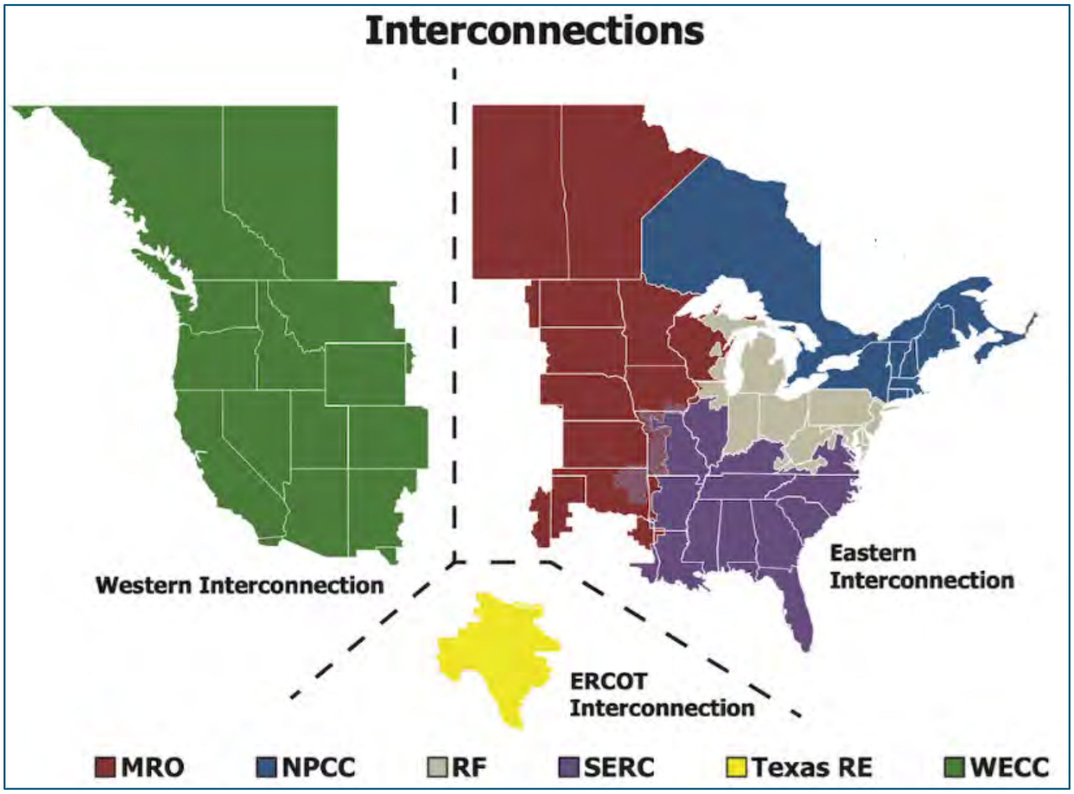

Figure 77. U.S. Grid Interconnection Map.

Inconsistent federal energy policies, shifting political priorities, and regulatory inefficiencies create uncertainty for long-term investment and infrastructure development. While the United States has advantages in innovation, demand, and private capital, weaknesses in supply chain security, shareholder-driven investment strategies, and industrial policy hinder its ability to maintain global energy leadership.

Competitive Analysis of China

China's energy competitiveness is characterized by strategic long-term planning and extensive industrialization driven by centralized government policies. China has an unparalleled industrial infrastructure, controlling the extraction of essential minerals (lithium, REEs, graphite) and investment/production of batteries, electrolyzers, and solar panels (*see* Figure 8 for global investment data from the IEA).[104]

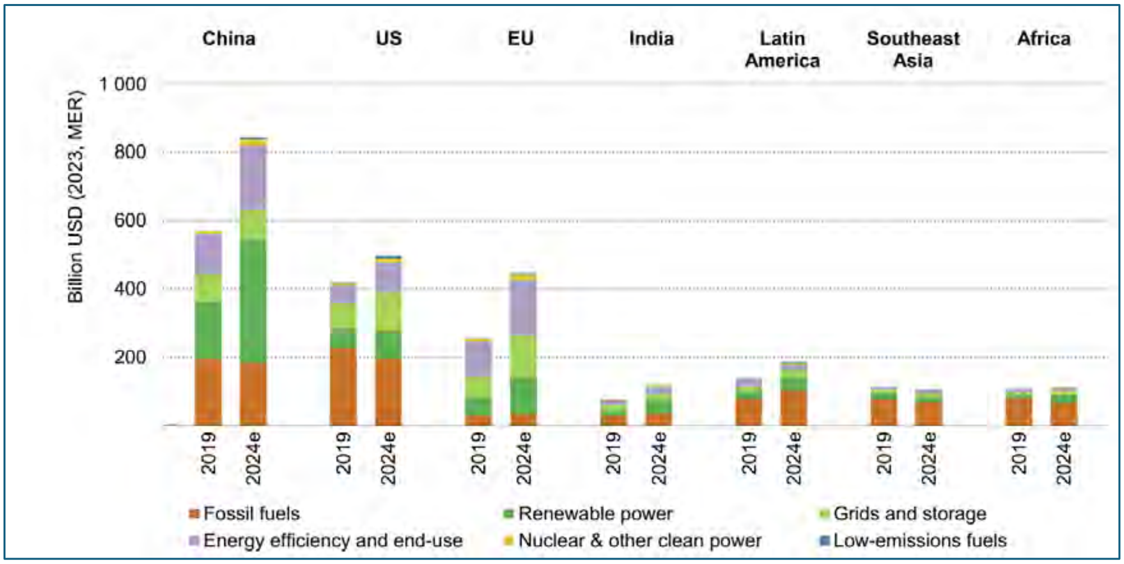

Figure 8. Annual Energy Investment by Country and Region, 2019 and 2024.

The strength of China's industrial clusters, combining manufacturing, research, and export of sustainable technologies, ensures their advantage in related sectors. However, China's CMF-driven industrial dominance faces key weaknesses, including overcapacity, inefficient SOEs[105] hindering private sector growth, and subsidies that drive production below market demand.[106]

At the same time, China's technological dominance is also reinforced by its support for R&D, which government-linked technical centers carry out. China's strong intervention has shaped the "electrification of everything" policy (adding 375 GW of zero-emission capacity by 2024), driving electricity consumption, distributed generation, and energy storage.[107] However, signs of decline in China's economic growth, structural inefficiencies, and competition from emerging economies raise concerns about long-term sustainability. China's BRI-backed export model has expanded its energy influence across Asia, Africa, and Latin America, but has led to concerns of "debt diplomacy."[108]

China's state-driven strategy coordinates long-term energy investments through SOEs, ensuring strategic control but prioritizing political directives over market responsiveness. This centralized approach faces criticism for environmental harm, forced labor, and unprofitable industries. While China holds a competitive edge in scale and vertical dominance, inefficiencies in SOEs, uncertain demand sustainability, and global resistance to its energy dominance pose growing challenges.

Competitive Analysis of Russia

Russia's advantages are rooted in vast fossil fuel reserves and nuclear expertise, but systemic weaknesses undermine Russia's competitiveness in the energy sector. Outdated infrastructure, weak coordination between research and public policy, and limited innovation incentives restrict technological advancements. Russia's centralized energy model, dominated by state-owned firms like Gazprom, enables rapid mobilization but stifles market-driven innovation and competitiveness.[109] Efforts to forge partnerships, such as blue hydrogen exports, to China and the United Arab Emirates, remain constrained by geopolitical isolation and the Ukraine conflict.[110]

Russia also lacks an integrated industrial framework to support energy innovation. Scientific excellence exists in energy efficiency, but poor collaboration between universities, research centers, and policymakers prevents the formation of a cohesive innovation ecosystem in Russia.[111] The lack of industrial clusters and the weak synergy between supporting industries hinder the development of advanced energy technologies in Russia. Coupled with limited domestic demand and excessive reliance on hydrocarbons, these factors significantly constrain Russia's capacity to adapt to the global energy transition.

Overall, (*see* summarized below in Table 1), China leads in energy and national security competitiveness through state-driven coordination and resource control, while the United States must strengthen industrial policy, reduce supply chain dependence, and align innovation with long-term strategic goals to maintain its global position, as Russia remains hindered by outdated systems and geopolitical constraints.

Model Element	United States	China	Russia
Production Factors	• World-class innovation (DOE, DARPA, Helion, NuScale) • Top oil & gas producer • *Weakness*: Dependence on imported REEs, lithium	• Dominates REE extraction, battery & solar manufacturing • Integrated industrial base • *Weakness:* Overcapacity, inefficient SOEs, reliance on subsidies	• Large reserves of oil, gas, uranium • *Weakness:* Obsolete infrastructure, low integration of science/policy
Demand Conditions	• High-tech defense & infrastructure needs • Strong policy drivers (IRA, IIJA) • *Challenge:* Private capital favors short-term gains	• "Electrification of everything" fuels domestic demand • Largest renewable rollout globally • *Concern:* Structural inefficiencies, long-term demand risks	• Weak domestic demand, fossil-heavy economy • Limited scale in hydrogen/renewables
Related & Supporting Industries	• Strong R&D and university base • *Weakness*: Fragmented grid (East, West, ERCOT), limits renewables integration	• Industrial clusters integrate R&D, production, exports • BRI supports energy export diplomacy • *Risk:* Debt diplomacy backlash in partner states	• Scientific excellence, but poor synergy with industry • Lacks innovation clusters and industrial diversification
Structure, Strategy, Rivalry	• Competitive, private-led market • *Weakness*: Regulatory instability, shareholder primacy, risk of losing edge to China coordinated policy	• State-driven, civil-military fusion ensures coordination • *International Criticism:* Overcapacity, subsidies, forced labor, lack of transparency	• Centralized SOEs (Gazprom, Rosneft) enable mobilization • Weakness: War-related sanctions, isolation, and investment decline

Table 1. Comparative Table: Porter's Diamond -- Energy Competitiveness.

Policy Recommendations (Actionable and Resource-Informed)

Streamlining Federal Regulations

Establish an expedited review process and harmonize permitting procedures to reduce project delays. As noted, this would especially help nuclear and renewable energy sectors, along with grid modernization and transmission line expansion efforts.

<u>Specific example</u>: Codifying EO 14154 to Streamline Federal Regulation

Codifying Executive Order 14154, *Unleashing American Energy*, would convert the current administration's permitting directive into binding law, embedding reforms to modernize the federal regulatory framework for energy and infrastructure projects.[112] Codification ensures legal durability and long-term regulatory consistency beyond administrative changes through Congressionally drafted legislation.

Successful execution requires cross-agency coordination. The Council on Environmental Quality (CEQ), Office of Management and Budget (OMB), and permitting bodies—including the Departments of Energy, Interior, and Transportation, the EPA, and the Army Corps of Engineers—would lead implementation, each focused on their parts of the complicated process. Oversight from the White House and the Office of Information and Regulatory Affairs (OIRA) would enforce compliance by the tasked agencies in ensuring regulation and permit streamlining are implemented in a timely manner. Key stakeholders include energy developers, infrastructure firms, and state and local governments relying on predictable, timely decisions.

Codification would institutionalize core reforms to accelerate permitting while safeguarding environmental standards. CEQ's current National Environmental Policy Act (NEPA) rules would be replaced by agency-specific NEPA procedures, enhancing flexibility and mission alignment.[113] Enforceable deadlines by OIRA—60 days for categorical exclusions (CATEXs), one year for environmental assessments, and two years for environmental impact statements—would end chronic delays.[114]

Regulatory bodies would expand CATEXs to exempt low-impact projects from detailed review, minimizing paperwork without sacrificing environmental outcomes. Agencies would be required to repeal duplicative rules under a "10-for-1" policy. Current project reviews would proceed under existing rules until transitioned to avoid disruption.

These reforms would apply nationwide, especially to federal lands and waters projects. Pipelines, transmission lines, and nuclear facilities stand to benefit. Changes would be initiated at agency headquarters and carried out in regional offices, where permitting occurs.

EO 14154 required agency implementation to begin within 30 days, with regulatory revisions due in one year. Codification should maintain these timelines. Agencies must continuously revise procedures to stay aligned with the law and evolving policy.

The case for codification is strong. Large infrastructure projects face average permitting delays of six to thirteen years.[115] that stifle investment, raise costs, and undermine energy security. Codification would reduce bureaucratic uncertainty, promote investment, and create jobs.

Critics argue that the reforms could compromise environmental oversight by forcing agencies to prioritize speed over scientific rigor.[116] Shortened timelines may increase legal risks if reviews appear rushed.[117] Reductions in discretionary climate funding could also weaken state-level innovation critical to energy resilience.[118]

EO 14154 builds on previous Trump-era directives. EO 13807 introduced "One Federal Decision," centralizing reviews under a lead agency.[119] EO 13927 used emergency powers to fast-track investments,[120] and EO 13783 eliminated climate rules seen as obstacles to energy independence.[121] Together, they laid the foundation for this comprehensive reform.

Resources should be reallocated within agencies to fund implementation. Staff from low-value review roles can shift to high-impact projects. Expanded CATEXs will reduce staffing needs and free capacity for training, digital tools, and legal defense. Funds from discretionary environmental programs should support regulatory modernization and transparency tools. Reallocating existing funds will allow legislation codifying EO 14154 to proceed without significant budgetary impact and eliminating duplicative and costly reviews will save resources.

Codifying EO 14154 would secure durable permitting reform, accelerate energy and infrastructure development, and preserve environmental integrity and national economic resilience.

Enhancing Domestic Manufacturing While Fostering International Alliances

Incentivize domestic production of critical components to mitigate reliance on unstable foreign supply chains, while building robust partnerships with key allies to diversify and secure energy underpinning critical supply chains.

<u>Specific Example:</u> Bilateral Energy Agreements and Supply Chain Assurance as Key U.S. Policy Pillars

Bilateral energy agreements—with Ukraine, Canada, Norway, and Brazil—and reinforced supply chain assurance are critical to reducing vulnerabilities, supporting defense readiness, and sustaining industrial competitiveness.

Russia's invasion of Ukraine exposed how conflict destabilizes markets. With vast metallurgical-grade silicon (MG-Si) reserves, Ukraine offers strategic potential. On April 30, 2025, the United States and Ukraine signed the Reconstruction Investment Fund, a 50/50 venture granting the United States preferential access to Ukraine's lithium, REEs, and oil and gas projects. Ukraine retains ownership, and profits will fund its reconstruction. U.S. support may include military aid, reinforcing sovereignty, and recovery.[122] The deal covers new mineral supplies that require investment and construction during an active conflict. Congress will also need to authorize and approve funding to support the new Reconstruction Investment Fund. Neither consideration is guaranteed due to domestic political divisions and competing budgetary priorities. Continued Russian attacks on potential new supply locations may delay investment and construction.

Canada is a stable ally with an integrated grid infrastructure and vast REE, lithium, nickel, cobalt, copper, and uranium reserves, though extracted at a higher cost than from other sources such as the Democratic Republic of the Congo.[123] Canada's SMR leadership also aligns with U.S. clean energy and defense resilience goals. Norway, a NATO ally with strong offshore energy assets, is ideal for hydrogen development, wind expansion, and countering Russian energy influence.[124] Brazil's clean grid and robust ports make it well-positioned for green hydrogen exports.[125]

Alongside bilateral efforts, domestic supply chain assurance must expand. The United States should accelerate the processing of its own deposits to include MG-Si, lithium, nickel, cobalt, graphite, copper, and REEs, build hydrogen manufacturing hubs, and stockpile strategic materials. Programs like DOE's Office of Manufacturing and Energy Supply Chains grants, Defense Production Act Title III, and Development Finance Corporation (DFC) financing should support these objectives. Federal procurement by contracting officers, and where applicable, the General Services Administration, should favor domestic and allied sources to mitigate risk. The Office of Federal Procurement Policy within the OMB can enforce these new policies and acquisition requirements.

Implementation requires coordinated federal action. DOE, Department of Defense (DOD), Commerce, and Department of Homeland Security (DHS)—supported by CESER, Cybersecurity and Infrastructure Security Agency (CISA), and CYBERCOM—must lead on procurement and cybersecurity. The United States Trade Representative, State Department, and DFC should drive financing and diplomacy. Congress must authorize targeted foreign assistance and update trade and industrial policies, potentially amending the IRA.

This strategic foreign assistance funding should include $1 billion for Ukraine's energy infrastructure, $750 million for Brazilian hydrogen projects, and $500 million for U.S.-Canada cost-sharing on SMRs and REE processing. Congress can reallocate funds from other recently cancelled foreign assistance projects to cover these investments. Oversight bodies like TSA and CISA must be resourced to enforce security standards.

This strategy meets the current administration's goals: securing supply, supporting defense, and advancing energy independence. It complements fossil fuel infrastructure while enabling clean energy resilience. While some warn that bilateral deals could reduce flexibility or raise costs, the long-term benefits in security, sovereignty, and industrial strength outweigh the risks. China may view increased U.S. involvement with Brazil and others as a threat to its own interests and push back on outreach efforts. This can be mitigated through targeted investment, as Brazil has remained relatively neutral between the two countries.

The United States can meet its energy emergency through targeted agreements and resilient supply chains with strategic resolve and global leadership.

Investing in Cybersecurity and Infrastructure Upgrades

Strengthening physical and digital security measures across energy assets (*i.e.*, the grid, pipelines, dams, and power plants). Ensure operational and information technology vulnerabilities are addressed.

<u>Specific Example:</u> Nationalizing Grid Cybersecurity Standards

In 2024, attacks on U.S. utilities surged, revealing vulnerabilities in a fragmented and aging grid.[126] The rapid integration of distributed energy resources (DERs), automation, and legacy systems has outpaced existing voluntary guidance. Federally mandated cybersecurity baselines are essential to protect military and civilian operations.[127]

The DOE, through CESER, should develop these standards, with the CISA and DHS supporting implementation. The Office of the National Cyber Director (ONCD) should ensure strategic coordination. TSA must transition from voluntary to mandatory cybersecurity and physical security guidelines for pipelines.

The proposal mandates uniform cybersecurity standards for all utilities and companies connected to the U.S. electric grid. These should define best practices for threat detection, response, and resilience, including compliance auditing, incident simulations, and workforce training. CISA, CYBERCOM, and TSA should update these annually to adapt to evolving threats.

Compliance must apply to all entities accessing the grid—investor-owned, municipal, and rural cooperatives, DER operators, and pipeline companies. Uniformity eliminates exploitable weak links and ensures collective security. While previous administrations have worked on baseline standards for private sector consideration, required implementation to access critical infrastructure under the declared national emergency will be necessary to ensure compliance. A lack of compliance can remove energy sources from the queue to supply the grid.

Nation-states and criminal actors are executing cyberattacks. ONCD's January 2025 risk overview highlighted these significant vulnerabilities.[128] A phased rollout over 12 to 36 months should begin with federally regulated utilities and pipelines, followed by municipal and DER actors. CISA and DOE should conduct annual reviews.

Implementing this plan will require targeted funding and resource reallocation. Agencies like CESER, CISA, DHS, and TSA will need additional capacity for development, enforcement, and auditing. Congress and OMB can reallocate these funds from eliminated climate programs. Leveraging DOD personnel, embedding fellows in utility security teams, and expanding public-private R&D are cost-effective strategies. Utilities must also invest in upgrades, monitoring, and training. Though grid modernization in total could exceed $1 trillion, cybersecurity is a focused and smaller investment.[129] Tax incentives, grants, and loan guarantees can help smaller utilities meet requirements. Federal investment should also support cybersecurity workforce development through training programs detailed in other recommendations.

While federal regulation may face ideological resistance, this initiative defends infrastructure rather than prescribing energy types. Security must transcend energy politics. Critics may warn of federal overreach or burdens on small utilities. However, without action, adversaries will continue to exploit known gaps.

Improving Public Outreach and Messaging

Increase public awareness of the need for additional energy sources to meet rising demand. Focus on outreach efforts to improve public perception of infrastructure projects and modernization efforts.

<u>Specific Example:</u> Institutionalizing a Federal Communications Strategy to Raise Public Awareness of Energy Needs and Infrastructure Modernization (2025–2030)

A significant obstacle to progress on energy security is public energy illiteracy. Despite advancements and mounting global competition, many Americans remain unaware of how energy is produced and distributed and why modernization is essential. Without public understanding and support, even the most advanced policies risk failure.[130]

The federal government should start a national communications campaign to align public sentiment with national priorities and present energy modernization as a unifying cause. This strategy should be embedded in federal energy policy, using existing programs and budgets. Agencies such as the DOE, DOD, CISA, and Federal Communications Commission (FCC) already conduct outreach that can be reoriented. Funding—estimated at $15–20 million annually—can come from DOE and FCC budgets, interagency grants, and public-private partnerships. Execution will require regional coordinators, content specialists, and public affairs officers supported by digital platforms, data dashboards, and multilingual content.

DOE will lead campaign design and policy alignment; DOD will emphasize resilience and defense infrastructure; CISA will integrate security messaging and coordinate with state emergency managers; FCC will manage media dissemination and digital accessibility. Together, they will pursue three goals: First, citizens must understand the nation's energy realities and risks. Second, the case must be made that modernization—through upgraded grids and enhanced capacity—is essential for civilian and defense needs. Third, trust must be earned through transparency, local engagement, and tangible community benefits.

The campaign will proceed in three phases between 2025 and 2030: phase one will raise awareness; phase two will deepen engagement with regional focus; phase three will maintain support. Channels will include national media, digital tools, schools, town halls, and local forums. While messaging must be locally tailored, it must remain nationally coherent. Public resistance rooted in confusion and distrust can derail critical energy projects. Messaging should also target all audiences, including unions that may oppose modernization and automation, emphasizing upskilling opportunities instead. Outreach that targets new training opportunities can be tied to the campaign.

Launching this campaign by the end of FY2025 will help mobilize public support for energy transformation. While critics may argue that federal messaging risks politicization or resource diversion, sustained civic partnership remains essential. The path forward demands public policy understanding and shared commitment to a stronger, more secure energy future.

Boosting Workforce Development

Address the shortage of skilled labor through targeted education initiatives and training programs, particularly in advanced energy technologies.

Specific Example: Strategic Initiative for Developing a Skilled Workforce in the U.S. Energy Sector (2025–2035)

Transformation in the energy sector has exposed a critical vulnerability: the shortage of skilled workers across vital energy domains—from power generation and grid operations to nuclear, hydrogen, cybersecurity, and renewables.

Demographic shifts are intensifying the challenge as retirements drive rising labor demands in technical fields like environmental compliance and industrial automation. Without immediate action, these shortages could derail infrastructure deployment, weaken industrial competitiveness, and jeopardize national security.[131]

The federal government should adopt a unified strategy to align workforce development with national energy goals.[132] The Strategic Energy Workforce Initiative will create a national framework led by the DOE, with support from the Departments of Labor (DOL) and Education

(ED). It aims to modernize technical education, align federal investments, and engage the private sector. Workforce shortages affect other industries as well, and targeting recruitment efforts to national priorities will allow energy to remain a top draw for new entrants into the labor force.

A central focus is workforce readiness for critical mineral extraction, processing, and supply chain development, essential to clean energy, advanced manufacturing, and defense. Training geochemists and environmental managers to meet regulatory standards is crucial for maintaining a stable domestic supply through expertise in mining, refining, and technological applications.

The initiative has five objectives:

1. **Labor Market Mapping:** Analyze energy workforce needs across extraction, generation, grid systems, and emerging technologies by integrating federal data, state forecasts, and industry trends.
2. **Credentialing Framework:** Develop a federally guided system supporting state-accredited programs in key fields like SMR operations and hydrogen infrastructure.
3. **Institutional Expansion:** Expand technical and vocational institutions, especially in transition regions, to meet evolving workforce demands.
4. **Inclusive Access:** Prioritize veterans, women, rural youth, and minorities through scholarships, apprenticeships, and hybrid learning linked to employers.
5. **Training on Advanced Manufacturing Technologies:** Increase reliance on robotics and automation industry to mitigate demographic concerns and train a workforce to sustain new technologies.

Implementation runs from 2025–2035 in four phases: **Planning -** Joint federal-state assessments should define workforce gaps and investment priorities; **Network Development-**

Regional centers of excellence will connect educators, agencies, and employers under a shared credentialing model; **Deployment-** Outreach will scale modular training and job placement pipelines for high-need groups; and **Modernization-** Curricula will be regularly updated to reflect changes in SMRs, hydrogen, grid systems, and battery storage.

The strategy is regionally tailored. Coal-dependent areas like Appalachia will prioritize retraining and stabilization. High-growth zones like Tennessee's nuclear corridor and the Gulf hydrogen region will scale training capacity.

No new funding stream is proposed. The initiative will align DOE's Office of Energy Jobs; DOL's Employment and Training Administration; ED's Perkins V programs; any remaining IIJA clean energy workforce funds; and Title III of the Defense Production Act. Private-sector co-financing, innovation grants, and union-supported certification programs will ensure local delivery. Federal-state coordination will maximize efficiency and reduce redundancy.

Critics argue that federal overreach may hinder local innovation or prove ineffective without new funding.[133] Others question whether regional programs will duplicate federal initiatives.[134] Without a strategic workforce development plan tailored to the energy industry, labor shortages will persist, failing to meet the growing demand for skilled workers in extraction, processing, and advanced energy technologies. Proactive recruitment, specialized training, and long-term investment in talent pipelines will be essential to bridge this gap and ensure a sustainable workforce for the sector.

Launching October 1, 2025, with a complete design by FY2026, this initiative mirrors the current administration's model of using existing tools, like EO 14154 for permitting reform, to solve structural challenges. Energy technologies require skilled labor. This plan builds the workforce needed for national energy security and resilience.

Conclusion

The United States faces an urgent energy security challenge, failure to address structural fragmentation, supply chain dependencies, and workforce shortages, leaving the country exposed to geopolitical and economic pressures from strategic competitors, like China. Without a national energy strategy and decisive policies, the United States risks falling behind in technologies like SMRs and cybersecurity, and uncoordinated investment will increase vulnerabilities during crises. The United States should enhance industrial capacity, align federal and state efforts, and promote public-private innovation to counter China's and Russia's energy market manipulation.

Policy reforms should enhance industrial competitiveness and position U.S. innovation at the forefront of emerging technologies, ensuring long-term energy independence. Priorities include streamlining federal regulations, expanding domestic manufacturing while fostering alliances, enhancing cybersecurity, improving public outreach, and investing in workforce development. These actions align with the NSS and NDS to bolster resilience and mobilization readiness. Challenges such as bureaucratic inertia, competing fiscal priorities, and shifting political landscapes require sustained investment and institutional support. The NEDC must streamline regulations and coordinate interagency efforts. Without decisive action, China will continue to dominate energy supply chains and critical materials, exacerbating U.S. vulnerabilities. Optimizing domestic energy policy is vital for U.S. strategic advantage, energy independence, and economic growth.

Appendix A: AI is an Energy Industry Threat and Opportunity

The growing use of artificial intelligence (AI) demands significant energy but also offers critical opportunities to optimize power generation, transmission, and consumption, enabling grid balancing and informed investment in energy resilience for the United States and its allies.

The primary challenge to energy security in the United States and for its allies is the growing demand for energy driven by the rising use of data and AI. By 2050, energy demand is expected to increase by over 50%, with the increased demand for AI, cryptocurrency, and data centers.[135] A second significant threat to the energy industry through AI use is cybersecurity.

AI-driven systems introduce new cyber vulnerabilities through methods such as data poisoning (manipulating training data), adversarial attacks (altering inputs to mislead models), and model inversion (reconstructing sensitive data, such as energy load profiles, from AI outputs). Addressing these risks requires a highly skilled workforce proficient in AI and engineering.[136] However, a talent gap persists, with approximately 141,000 engineering students graduating annually in the United States but only over 900,000 engineering job openings as of October 2024.[137] This shortage, combined with high demand and rising labor costs, challenges the energy industry's ability to recruit and retain talent critical to AI integration and cyber resilience.

While AI is driving increased energy demand, it offers significant opportunities to optimize energy use. AI can monitor consumption, enable dynamic pricing, predict demand, and support peer-to-peer energy trading.[138] It can also forecast outages and prioritize resource allocation, and at the individual level, smart homes, smart cities, and technologies enable AI-driven energy management.

AI is a powerful tool for energy modeling and simulation in environments that cannot be physically tested, such as nuclear fusion. It enhances engineering and design efforts across the energy sector—from nuclear reactors to solar panel materials—by leveraging vast datasets to develop integrated energy systems and strengthen grid resilience. Emerging markets and new infrastructure can adopt AI more easily than legacy systems, offering greater returns on capital investment. However, despite its potential, AI also has significant national security implications.

AI maturity in the energy industry is uneven, while applications like predictive maintenance and demand forecasting are well established, areas such as autonomous grid management remain nascent.[139] This disparity poses national security risks, as critical infrastructure may outpace the development of security standards and security implementation through a skilled, available workforce. Malicious actors may exploit the risk during natural disasters with coordinated cyberattacks, underscoring the need for the U.S. energy industry to institute resiliency-focused solutions like small modular reactor microgrids.[140] If the energy grid fails to meet AI data center demands, these centers may relocate offshore, raising data sovereignty risks and increasing reliance on transfer pipelines, causing cybersecurity vulnerabilities. This complicates diplomatic efforts for multinational AI infrastructure. Federal energy resilience initiatives must continue incentivizing expansion, recapitalization, and resilience across energy domains, considering the decentralized grid funded by investors and customer revenue.[141]

Appendix B: Wargaming Energy and Supply Chain Scenarios

Energy independence is central to U.S. national energy security, requiring a proactive approach to counter adversarial threats and supply chain vulnerabilities. Integrated wargaming should be a fundamental component of U.S. energy security through cyber threat simulations, operational energy modeling, and supply chain analyses. This approach addresses U.S. national defense priorities by ensuring energy resilience, secure logistics, and effective adversarial risk mitigation.[142] Executive Orders 14154 and 14156 aim to boost U.S. energy security by improving cybersecurity and grid resilience, thereby enhancing supply chain independence.[143] These measures must be integrated into wargaming efforts to address threats from China and Russia. Amid geopolitical tensions, U.S. stakeholders must recognize the value of strategic simulation. Insights from field visits during this energy industry study highlighted how useful it is for private-public stakeholders to partner in planning for critical risks to energy independence and national defense resilience.

Given the critical risks to the U.S. energy sector posed by cyberattacks, supply chain disruptions, and other crises, the resilience of our energy sector has become a matter of utmost importance. Wargaming has emerged as an essential tool for U.S. military and civilian government agencies, along with industry partners, to simulate 'black sky' scenarios (*i.e.*, critical mineral embargoes, cyber intrusions, and climate disasters).[144] Wargaming simulations help decision-makers identify vulnerabilities (Project Pele, microgrid adoption initiatives, and small modular reactor deployments have been integrated to test battlefield logistics)[145] and improve coordination among utilities, the DOD,[146] and regulatory agencies for a national response strategy.[147] During the industry study field visits, key stakeholders highlighted efforts to counter threats from China's People‘s Liberation Army and Russia's Main Intelligence Directorate (GRU), underscoring the need to integrate wargaming into national energy security planning. Here is a summary of the insights:

- Dominion Energy (Richmond, VA): Regularly conducts cyberattack simulations on Supervisory Control and Data Acquisition (SCADA) systems and hosts DOD fellows to ensure internal cyber protocols align with military standards, critical as energy demand surges from data centers.
- National Renewable Energy Lab (Golden, CO) simulates thermal network vulnerabilities and Electric Vehicle-grid saturation risks for DOD/FEMA and developed synthetic datasets for secure utility modeling under non-disclosure agreements for energy security quantification.[148]
- Argonne National Lab (Chicago, IL) uses contingency models like APT-E to estimate the impact of substation failures due to hurricane-induced outages for FEMA. It provides forecasts on grid infrastructure prioritization based on scenario-based climate disasters.

Energy resilience is foundational to U.S. national security, and wargaming for both defense applications and operational/supply chain vulnerabilities can be identified through simulations between various public-private partners to test responses and guide investment.[149] A National Wargaming Center focused on Energy Resilience (*see* Figure A (Threat Matrix) below to identify risks if wargaming is not institutionalized) is crucial to counter disruptions. It would combine cyber threat simulations, operational energy modeling, and red-teaming on supply chain analyses. More importantly, it would enable effective responses to challenges from China, Russia, and non-state cyber actors through the vital collaboration among DOD, DOE, and industry.[150] The potential risks of not institutionalizing wargaming and energy/supply chain risk, such as through a national framework for energy-related wargaming, are significant. U.S. energy resilience will be compromised, leaving it vulnerable to disruptions. Budget constraints pose challenges, but the failure to establish such policies could lead to severe operational risks and inefficiencies that give the advantage to U.S. strategic competitors, China, and Russia.[151]

Figure A: Strategic Threat Matrix: U.S. Wargaming Scenarios to Adversarial Disruption[152]

Threat Scenario	Adversarial Action / Situation	Targeted Sector / Capability	Real Wargaming / Simulation	Institutional Strength	Risk Level
Grid Cyberattack	Coordinated malware/ransomware on SCADA & substations	Transmission grid, substations	Dominion Red/Blue Cyber Exercises	High	High
Multi-State Power Outage from Storm	Superstorm + cascading substation failure (N-5)	Regional grid, emergency systems	FEMA/Argonne "APT-E" Hurricane Simulation	High	High
REE Supply Cutoff by China	Export restrictions on lithium, REEs	SMRs, EVs, solar, batteries	DoD/DOE Strategic Minerals Access Wargames	Medium	High
Pacific Conflict – Energy Logistics	Naval blockade, cyber denial in Indo-Pacifi	DoD base energy & logistics	DoD Indo-Pacific Wargame + Project Pele	High	High
EV Surge and Grid Overload	Mass EV load on outdated grid	Substations, transformers	NREL Grid Resilience Load Simulations	Medium	Med.-High

Institutional Strength		
High	=	Proven simulation, active mitigation capability, real-world implementation
Medium	=	Modeled or analyzed in limited exercises, needs resourcing or integration
Low	=	No significant institutional coordination or effective policy framework

Risk Level		
High	=	National-level threat; adversary has significant leverage
Med.-High	=	Active vulnerability with partial mitigation capacity
Medium	=	Strategic but manageable risk with targeted reforms

Appendix C: Glossary of Acronyms

- ADVANCE Act – The Accelerating Deployment of Versatile, Advanced Nuclear for Clean Energy Act of 2024
- AI – Artificial Intelligence
- BRI – Brick and Road Initiative
- CATEX – categorical exclusions
- CEQ – Council on Environmental Quality
- CESER - Cybersecurity, Energy Security, and Emergency Response
- CHIPS and Science Act – Creating Helpful Incentives to Produce Semiconductors and Science Act of 2022
- CISA – Cybersecurity and Infrastructure Security Agency
- CMF – Civil-Military Fusion
- CWED – Center for Energy Workforce Development
- CYBERCOM – Cyber Command
- DARPA – Defense Advanced Research Projects Agency
- DER – Distributed Energy Resources
- DFC – Development Finance Corporation
- DHS – Department of Homeland Security
- DOD – Department of Defense
- DOE – Department of Energy
- DOL - Department of Labor
- EA – Environmental Assessments

- ED – Education Department
- EIA – Energy Information Administration
- EIS – Environmental Impact Statements
- EO 13783 – Executive Order: Promoting Energy Independence and Economic Growth
- EO 13807 – Executive Order: Establishing Discipline and Accountability in the Environmental Review and Permitting Process for Infrastructure Projects
- EO 13927 – Executive Order: Accelerating the Nation's Economic Recovery from the COVID-19 Emergency by Expediting Infrastructure Investments and Other Activities
- EO 14154 – Executive Order: Unleashing American Energy
- EO 14156 – Executive Order: Declaring a National Energy Emergency
- EPA – Environmental Protection Agency
- ERCOT – Electric Reliability Council of Texas
- FCC – Federal Communication Commission
- FERC – Federal Energy Regulatory Commission
- FEMA – Federal Emergency Management Administration
- FY – Fiscal Year
- GAO – Government Accountability Office
- GRU – Russia's main intelligence directorate
- HVAC – Higher-voltage alternating current
- HVDC – Higher-voltage direct current
- IAEA – International Atomic Energy Agency
- IBEW – International Brotherhood of Electrical Workers

- IRA – Inflation Reduction Act
- LIUNA – Laborers' International Union of North America
- MESC – Manufacturing and Energy Supply Chains
- MW – Megawatt
- NDS – National Defense Strategy
- NEDC – National Energy Dominance Council
- NEPA – National Environmental Policy Act
- NRC – Nuclear Regulatory Commission
- NREL - National Renewable Energy Laboratory
- NSS – National Security Strategy
- OFPP – Office of Federal Procurement Policy
- OIRA – Office of Information and Regulatory Affairs
- OMB – Office of Management and Budget
- ONCD – Office of the National Cyber Director
- Perkins V – Strengthening Career and Technical Education for the 21st Century Act of 2018
- PLA – People's Liberation Army
- PPP – Public-Private Partnership
- R&D – Research and Development
- REEs – Rare Earth Elements
- SMR – Small Modular Reactor
- SOE – State Owned Enterprise
- TSA – Transportation Security Administration
- U.S. – United States

- USMCA – US-Mexico-Canada Agreement
- USTR – United States Trade Representative
- UWUA – Utility Workers Union of America

Appendix D: *AI Tools*

A. *Create a Threat Matrix*

develop a modern, clean threat matrix for wargaming scenarios based on a summary of the papers and notes from visits and adversarial disruption

Based on your documents, visits, and individual papers, here is a **modern, clean, and strategic threat matrix** tailored to **energy-focused wargaming scenarios**, linking **adversarial disruption** with **institutional readiness and simulation-based learning** from real exercises and research-backed vulnerabilities.

🔷 Modern Strategic Threat Matrix for Energy and Industrial Wargaming (2025)

Scenario / Threat	Adversarial Action	Targeted System	Institutional Simulation or Exercise	Institutional Strength	Risk Level
Grid Substation Cyberattack	Malware on ICS/SCADA during peak demand	Transmission nodes, control systems	Dominion Red/Blue Cyber Exercise; DOE CESER support	🟩 High	🟥 High
APT E Hurricane & Grid Collapse	Natural disaster worsened by adversarial cyber actions	FEMA Region V & VIII power grid	Argonne APT E modeling for FEMA; N-5 line scenario	🟩 High	🟥 High
Pacific SMR Fuel Blockade	Indo-Pacific naval interference, restricting uranium/nuclear logistics	SMR deployment for forward DoD bases	DoD Pacific Wargames + Project Pele simulations for microreactor resilience	🟢 High	🔴 High
REE Embargo by China	Halt in rare earth exports (electrolyzers, REEs)	Hydrogen and fusion production supply chains	DoD/DOE Hydrogen & DPA Title III wargaming; Hydrogen DIB Task Force	🟡 Medium	🔴 High
Foreign FDI in Critical Minerals (Africa/LatAm)	PRC and Russian-backed mineral control via BRI & port FDI	Lithium, cobalt, graphite supply chains	DoD–DOC Mineral Access Wargames; economic FDI scenarios	🟡 Medium	🔴 High
Mass EV Load Without Grid Readiness	Surge in EV adoption creates transformer stress without distribution upgrades	Local grid nodes, battery storage systems	NREL distributed grid simulations; DOE/NREL extreme weather & storage modeling	🟡 Medium	🟠 Medium–High
SMR & SAF Permitting Paralysis	Delays in NRC/EPA/FERC across clean energy deployments	SMRs, SAF refineries, HV lines	DOE & industry energy permitting simulation roundtables	🔴 Low	🟡 Medium
Energy Workforce Gap Under Mobilization	Surge demand for SMR, hydrogen, cyber, and microgrid technicians without training pool	All clean energy & defense innovation sectors	DoD–DOE Mobilization Tabletop Exercises for skilled labor ramp-up	🟡 Medium	🟠 Medium–High

Legend

- Institutional Strength
  - 🟩 **High**: Proven simulation & active mitigation capacity
  - 🟡 **Medium**: Modeled but needs integration or resourcing
  - 🔴 **Low**: Gaps in response capacity or coordination
- Risk Level
  - 🔴 **High**: Strategic or operational-level vulnerability
  - 🟠 **Medium–High**: Disruptive risk, growing threat
  - 🟡 **Medium**: Contained with proactive intervention

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