



U.S. ENERGY LANDSCAPE

DOMINANCE, CHALLENGES,
& OUTLOOK

Atmospherics

August 16, 2024

Bottom Line Up Front (BLUF):

The United States has achieved a position of energy independence and global dominance, leveraging its abundant natural resources, cutting-edge technologies, and exceptional human capital. This status has significantly bolstered the nation's energy security and economic competitiveness. However, this formidable position is not impervious to disruption, as the U.S. faces mounting challenges in its energy landscape.

Chief among these challenges are the escalating domestic energy demand, particularly driven by emerging technologies such as AI and data centers, the complex integration of renewable energy sources into the existing grid, and the growing cybersecurity threats to aging infrastructure. These factors collectively threaten to place unprecedented strain on the U.S. energy supply chain, potentially compromising the nation's energy supremacy if left unaddressed.

Maintaining the United States' position as a global energy leader requires a multifaceted approach. This includes the development of adaptive government policies that can keep pace with the rapidly evolving energy sector, enhanced public-private collaboration to better define problems and develop effective solutions, and a careful balancing act between fostering innovation and ensuring the reliability and security of the energy system. These efforts are not merely about maintaining economic advantages; they are crucial for national security, especially in the context of Great Power Competition, where energy resources and infrastructure play a pivotal role in geopolitical strategies.

Introduction

The United States possesses an unparalleled wealth of energy-related assets, encompassing both abundant natural resources and cutting-edge technologies for refinement and distribution. This comprehensive energy portfolio has propelled the nation to a position of "energy independence" since 2019, as evidenced by its net export status in energy products. This shift has not only established the U.S. as a dominant force in global energy markets but has also significantly bolstered its energy security.

The U.S. energy sector, including its vast natural resources, stands as a critical pillar of the nation's enduring competitive advantage on the world stage. However, this formidable position is not impervious to disruption or potential crises. Domestic energy demand has shown consistent growth over recent decades, with no signs of abatement, particularly given the burgeoning requirements of AI computation and data center proliferation.

This escalating demand trajectory threatens to place unprecedented strain on the U.S. energy supply chain. Consequently, federal and state governments may soon find themselves in a race against time to comprehend the evolving nature of this challenge and to formulate appropriate policies that will safeguard and reinforce this vital national capability.

As the energy landscape continues to evolve, the interplay between technological advancement, resource management, and public-private collaboration will be crucial in maintaining the United States' energy supremacy and ensuring its long-term economic and strategic interests.

Macro and Strategic Relevance of U.S. Energy Assets

Abundant Natural Resources: The United States is blessed with a diverse array of energy resources, ranging from conventional fossil fuels to renewable sources. The country's vast reserves of oil, natural gas, and coal have long been the backbone of its energy sector. In recent years, the shale revolution has unlocked previously inaccessible oil and gas reserves, further bolstering the nation's energy production capabilities.

For instance, the Permian Basin in Texas and New Mexico has become one of the world's most productive oil fields, with daily production exceeding 5 million barrels in 2023. This abundance has not only reduced reliance on foreign oil but has also positioned the U.S. as a major exporter of crude oil and refined petroleum products.

Cutting-edge Technologies: The U.S. leads in developing and implementing cutting-edge technologies across the energy value chain, from extraction to distribution. Innovations in hydraulic fracturing and horizontal drilling have revolutionized oil and gas production, while advancements in renewable energy technologies have dramatically reduced costs and improved efficiency.

For example, the cost of solar photovoltaic (PV) modules has plummeted by 99% since 1976, largely due to American innovations and scale efficiencies. Similarly, U.S. companies are at the forefront of developing next-generation nuclear reactors and fusion technologies, which could reshape the global energy landscape in the coming decades.

Human Capital: The United States continues to be a magnet for the world's brightest minds in energy-related fields. American universities and research institutions consistently rank among the top globally in energy studies and related disciplines. This intellectual capital drives innovation and maintains the U.S. competitive edge in the energy sector.

For instance, the National Renewable Energy Laboratory (NREL) in Colorado is home to over 2,500 researchers and scientists working on cutting-edge renewable energy and energy efficiency technologies. Such institutions, coupled with a robust private sector R&D ecosystem, ensure that the U.S. remains at the forefront of energy innovation.

Energy Independence Achieved: In 2019, the United States achieved a milestone by becoming a net energy exporter for the first time since 1952. This shift marked a significant turning point in the nation's energy narrative, transitioning from a position of energy dependence to one of self-sufficiency and global influence.

According to the U.S. Energy Information Administration (EIA), in 2023, U.S. crude oil exports reached an unprecedented level, with a daily average of 4.1 million barrels. This figure represents a 13% increase, or 482,000 barrels per day, compared to the previous record set in 2022. The trend of increasing U.S. crude oil exports has been consistent since 2015, with 2021 being the only exception.

Dominant Force in Global Energy Markets: The achievement of energy independence has catapulted the United States into a position of unprecedented influence in global energy markets. As a major producer and exporter of oil and natural gas, the U.S. now plays a crucial role in global price dynamics and supply stability.

For example, U.S. shale oil production has acted as a stabilizing force in global oil markets, helping to mitigate price volatility caused by geopolitical tensions or supply disruptions in other producing regions. This newfound influence extends beyond fossil fuels, with the U.S. also emerging as a leader in clean energy technologies and setting global standards for energy efficiency and environmental regulations.

Bolstered Energy Security: Energy independence has significantly enhanced U.S. national security by reducing vulnerability to foreign supply disruptions and price shocks. This increased security provides greater flexibility in foreign policy decisions and reduces the need to engage in conflicts or alliances solely for energy-related reasons.

For instance, the reduced dependence on Middle Eastern oil has allowed the U.S. to recalibrate its strategic priorities in the region, focusing more on broader geopolitical objectives rather than securing energy supplies. This shift has profound implications for global power dynamics and the U.S. role in international affairs.

Critical Pillar of Competitive Advantage: The energy sector, with its vast resources, advanced technologies, and skilled workforce, stands as a critical pillar of the nation's enduring competitive advantage. It not only ensures a stable and affordable energy supply for domestic industries but also positions the U.S. as a global leader in energy innovation and exports.

The sector's contribution to the U.S. economy is substantial. In 2019, the U.S. energy industry supported more than 11.5 million jobs and accounted for nearly 8% of the nation's GDP. This economic impact extends beyond direct employment, influencing everything from manufacturing competitiveness to national research priorities.

Vulnerabilities and Potential Crises

Dynamic Nature of the Energy Landscape: The U.S. energy landscape is in a constant state of flux, presenting both opportunities and risks. While this dynamism has been a key driver of the nation's energy success, it also poses challenges, particularly for legacy infrastructure.

Supervisory Control and Data Acquisition (SCADA) systems, which form the backbone of industrial control and monitoring in the energy sector, face increasing strain as the pace of technological change accelerates. These legacy systems, many of which were designed and implemented decades ago, are becoming increasingly vulnerable to cyber threats and may struggle to integrate with modern technologies.

There's a growing risk that these SCADA systems may become obsolete or inadequate to meet rapidly evolving energy needs. For instance, the integration of renewable energy sources and the

need for real-time load balancing require more sophisticated control systems than many legacy SCADA installations can provide. Moreover, the increasing connectivity of these systems to the internet, while offering improved efficiency and remote management capabilities, also exposes them to a wider range of cybersecurity threats.

Escalating Domestic Energy Demand: Domestic energy demand in the United States has shown a consistent upward trajectory over the past decades, with no signs of abating. This trend is particularly pronounced in electrical demand, driven by factors such as population growth, increasing electrification of various sectors, and the proliferation of energy-intensive technologies.

For instance, the EIA projects that U.S. electricity consumption will grow by about 1% per year from 2022 to 2050. This steady increase puts pressure on the existing energy infrastructure and necessitates continuous expansion and modernization of generation, transmission, and distribution systems.

Impact of AI and Data Centers: The recent explosion in AI computation and data center needs highlights both the potential rewards and risks that a single industry can have on the broader energy landscape. The energy consumption of data centers in the U.S. is projected to reach 139 billion kilowatt-hours annually by the end of 2024, equivalent to 14 large power plants.

This surge in demand presents challenges for grid stability and capacity planning. However, it also drives innovation in energy-efficient computing and could accelerate the adoption of renewable energy sources, as many tech companies commit to powering their operations with clean energy.

Integration of Renewable Energy Sources: The integration of renewable energy sources into the existing grid presents both tremendous opportunities and significant challenges. While renewables offer the potential for cleaner, more sustainable energy production, they also introduce complexities in terms of grid management and energy storage.

For example, the intermittent nature of solar and wind power requires sophisticated load balancing and energy storage solutions. The U.S. is making strides in this area, with utility-scale battery storage capacity expected to grow from 1.5 gigawatts in 2020 to 30 gigawatts by 2025. However, the transition to a high-renewable grid will require continued investment and innovation.

Cybersecurity Concerns: The increasing digitalization of energy resources, while bringing numerous benefits, also expands the attack surface for hackers and nation-state adversaries. This creates potentially critical vulnerabilities in the nation's energy infrastructure.

In 2021, the Colonial Pipeline cyberattack demonstrated the potential impact of such vulnerabilities, causing fuel shortages across the southeastern United States. This incident underscored the need for robust cybersecurity measures across the energy sector.

Assessing Vulnerability: While it's clear that the U.S. energy infrastructure faces various challenges, the exact degree of vulnerability remains uncertain. It's unclear whether adding significant loads of electrical demand, such as from AI computation, marginally increases this vulnerability or has an exponential effect.

This uncertainty underscores the need for comprehensive risk assessments and ongoing monitoring of the energy infrastructure's resilience. It also highlights the importance of adaptive policies and investments to address emerging vulnerabilities proactively.

Critical Role of Government Policies

Addressing Escalating Demand: The escalating energy demand trajectory threatens to put unprecedented strain on the U.S. energy supply chain. Federal and state governments, known for their relatively slow pace of policy development, may soon find themselves in a race against time to comprehend and formulate policies to address this evolving challenge.

For instance, the Biden administration's goal of achieving 100% carbon pollution-free electricity by 2035 requires rapid policy action and implementation. This includes initiatives like the Energy Act of 2020, which authorizes \$35 billion in clean energy research and development over the next decade.

Need for Adaptive Policies: While federal and state governments are involved in energy policy creation on a regular basis, the need for adaptive policies is becoming increasingly important. The rapidly evolving energy landscape requires flexible regulatory frameworks that can keep pace with technological advancements and changing market dynamics.

For example, the Federal Energy Regulatory Commission (FERC) has been working on updating its policies to accommodate the growing share of renewable energy in the grid. This includes efforts to reform capacity markets and transmission planning processes to better integrate variable renewable resources.

Balancing Innovation and Regulation: Policymakers face the challenge of fostering innovation while ensuring the reliability and security of the energy system. This requires a delicate balance between providing regulatory certainty for long-term investments and maintaining the flexibility to adapt to new technologies and market conditions.

The Department of Energy's Advanced Research Projects Agency-Energy (ARPA-E) exemplifies this balance, funding high-risk, high-reward energy research that might not otherwise receive support. Since its founding in 2009, ARPA-E has provided \$2.93 billion in R&D funding, resulting in 131 new companies and more than \$5.4 billion in private-sector follow-on funding.

The Imperative of Public-Private Collaboration

Defining Challenges and Developing Solutions: The responsibility to address U.S. energy challenges does not fall on the government alone. Public-private collaboration is crucial for better defining the problems and developing effective and timely solutions.

For instance, the National Renewable Energy Laboratory's (NREL) partnership with private companies has accelerated the development and deployment of renewable energy technologies. One such collaboration led to the development of high-efficiency solar cells that achieved a record-breaking 47.1% efficiency as far back as 2019.

Information Sharing and Co-Development: As the energy landscape continues to evolve, the interplay between technological advancements, resource management, and risk mitigation will hinge on the ability of the public and private sectors to share information and co-develop solutions.

The Electricity Subsector Coordinating Council (ESCC) serves as a model for such collaboration. This partnership between the federal government and electric power industry leaders has improved the sector's ability to prepare for and respond to national-level disasters or threats to critical infrastructure. However, while the ESCC plays a crucial role in grid security, its effectiveness can be limited in certain scenarios. For instance, during the 2021 Texas power crisis, the ESCC's coordination efforts were hampered by the state's isolated grid system and complex regulatory environment. This event highlighted how local jurisdictional issues and the increasing complexity of energy systems can sometimes outpace the ESCC's ability to respond swiftly and comprehensively. Moreover, the council's reliance on voluntary cooperation among diverse stakeholders can lead to delayed decision-making in time-sensitive situations, potentially compromising its rapid response capabilities during emergencies.

Economic and National Security Implications: The significance of public-private collaboration in maintaining energy independence and dominance is paramount, given its profound economic and national security implications, especially in the context of the evolving approach to Great Power Competition (GPC), Strategic Competition, and Strategic Deterrence.

In today's security environment, energy security has become a critical component of national security strategy. The resurgence of Great Power Competition, particularly with China and Russia, has placed energy resources and infrastructure at the forefront of geopolitical considerations. The U.S. Department of Defense (DoD) and Department of Energy (DoE) share increasingly intertwined responsibilities in this new paradigm.

The DoD, as a major energy consumer, has a vested interest in ensuring a reliable and resilient energy supply. In fiscal year 2023, the DoD's energy costs totaled approximately \$16.5 billion, underscoring the direct link between energy security and military readiness. Simultaneously, the DoE plays a crucial role in safeguarding the nation's energy infrastructure and promoting technological advancements through initiatives like the Office of Cybersecurity, Energy Security, and Emergency Response (CESER).

The race for technological supremacy in clean energy technologies has become a key battleground since the transition to GPC. China's dominance in solar panel manufacturing and its control over critical rare earth elements highlight the intricate links between energy policy, economic competitiveness, and national security.

To address these complex challenges, enhanced collaboration between government agencies, private sector entities, and research institutions is crucial. The National Defense Strategy explicitly recognizes the need for a "whole-of-government" approach to address the multifaceted challenges posed by what has now become an evolving approach to Great Power Competition, Strategic Competition, and more recently Strategic Deterrence, with energy security playing a pivotal role.

In Conclusion

The United States stands at a critical juncture in its energy journey. Its unparalleled wealth of energy assets, technological prowess, and human capital have propelled it to a position of global energy dominance. However, this position is not impervious to disruption or potential crises.

The escalating domestic energy demand, particularly driven by emerging technologies like AI and data centers, poses significant challenges to the existing energy infrastructure. The integration of renewable energy sources, while promising, introduces complexities that require careful management and innovative solutions.

As the energy landscape continues to evolve at an unprecedented pace, the role of adaptive government policies becomes increasingly crucial. These policies must strike a delicate balance between fostering innovation and ensuring the reliability and security of the energy system.

Ultimately, the key to maintaining U.S. energy supremacy lies in effective public-private collaboration. By leveraging the strengths of both sectors, the nation can better define its energy challenges, develop timely solutions, and navigate the complex interplay between technological advancements, resource management, and risk mitigation.

The stakes are high, with significant economic and national security implications hanging in the balance. However, with its rich energy resources, cutting-edge technologies, and innovative spirit, the United States is well-positioned to meet these challenges head-on and maintain its position as a global energy leader in the years to come.

INFORMATION:

1. ABC News. (2024, June 18). Energy Department awards \$2.2B to strengthen electrical grid, add clean energy. <https://abcnews.go.com/Politics/wireStory/energy-department-awards-22b-strengthen-electrical-grid-add-112602048>
2. Epp, J. (2024, June 17). Data centers offer energy peril and promise, with the Midwest increasingly in the crosshairs. Energy News Network. <https://energynews.us/2024/06/17/data-centers-offer-energy-peril-and-promise-with-the-midwest-increasingly-in-the-crosshairs/>
3. Ghosh, I. (2024, January 8). Visualizing global energy production in 2023. Visual Capitalist. <https://www.visualcapitalist.com/visualizing-global-energy-production-in-2023/>
4. Pew Research Center. (2024, August 5). Majority of Americans support more nuclear power in the country. <https://www.pewresearch.org/short-reads/2024/08/05/majority-of-americans-support-more-nuclear-power-in-the-country/>
5. Teixeira, P. (2020, July 22). United States energy consumption since independence. World Economic Forum. <https://www.weforum.org/agenda/2020/07/united-states-energy-consumption-since-independence/>
6. U.S. Department of Energy. (n.d.). Energy independence and security. Retrieved from <https://www.energy.gov/eere/energy-independence-and-security>
7. McCown, B. (2024, March 7). Effective US energy policy could strengthen international security. Hudson Institute. Retrieved from <https://www.hudson.org/energy/effective-us-energy-policy-could-strengthen-international-security-brigham-mccown>
8. U.S. Department of Energy. (2024, June 18). DOE leads effort to improve the cybersecurity of energy supply chains. Retrieved from <https://www.energy.gov/articles/doe-leads-effort-improve-cybersecurity-energy-supply-chains>
9. International Energy Agency. (2024, July 2). IEA policy review highlights leadership of United States on energy security and clean energy transitions. Retrieved from <https://www.iea.org/news/iea-policy-review-highlights-leadership-of-united-states-on-energy-security-and-clean-energy-transitions>
10. MarketWatch. (2024, May 22). AI and data centers are devouring energy resources, threatening U.S. security. Retrieved from <https://www.marketwatch.com/story/ai-and-data-centers-are-devouring-energy-resources-threatening-u-s-security-d2316452>
11. McNabb, D. (2024, May 29). Opinion: New energy sources for AI, data centers are vital to U.S. national security. Secure Energy. Retrieved from <https://secureenergy.org/opinion-new-energy-sources-for-ai-data-centers-are-vital-to-u-s-national-security/>
12. U.S. Department of Energy. (2024, August 13). Clean energy resources to meet data center electricity demand. Retrieved from <https://www.energy.gov/policy/articles/clean-energy-resources-meet-data-center-electricity-demand>

NEPTUNE