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GEOIntelligence

White Paper

After assuming his second term, President Trump quickly declared a "national energy emergency" (the first one ever) that asserts "energy security is an increasingly crucial theater of global competition," and that, "an affordable and reliable domestic supply of energy is a fundamental requirement for the national and economic security of any nation." The policy further defines "energy" as "crude oil, natural gas, lease condensates, natural gas liquids, refined petroleum products, uranium, coal, biofuels, geothermal heat, the kinetic movement of flowing water, and critical minerals." Bottom line, the national urgency is driven by the vast reach of the energy eco-system as it relates to the increasing future global energy need.

The use, production, and security of energy are sometimes oversimplified, misunderstood, or taken for granted. From the seemingly simple tasks of starting vehicles, turning on lights, and checking our iPhones, to running the broadest global economic, military, and corporate enterprises — energy and its complexity is a subject well worth an in-depth understanding for any leader.

Strategically, after food and water (sources of human energy themselves), mankind's most significant resource is energy, as it impacts the functioning of every individual and collective enterprise of humanity, every second of every day. Energy impacts the global system economically, politically, socially, diplomatically, and militarily, and is becoming an increasingly major source of global competition, impacting both national and international security. Energy is strategically significant and a key to future global dominance.

As a primer, Professor Diana Gragg of Stanford University, who serves as the Managing Director for the Explore Energy program at the Precourt Institute for Energy, describes energy as power being exerted over distance, such as the flow of water through a hose or the movement of a car over distance. Energy can be accumulated and transferred as heat, work, and in matter, and it can be measured in terms of quantity, quality, and efficiency. Further, energy end-users include residential, commercial, industry, and transportation in the forms of services such as heating, cooling, and illumination. Energy essentially originates from a resource, is converted into a functional form, which is then expended by an end-user.

Energy resources are comprised of non-renewables, including fossil fuels (oil, gas, and coal) and nuclear, and renewables (including solar, thermal, ocean, hydro, wind, waves, and geothermal). The energy sources of nuclear and hydrogen can be debated, exactly where they fit, non-renewable or renewable. Most would say that nuclear is not a renewable as it uses a finite resource (uranium) as its fuel. As for hydrogen, when it is extracted from fossil fuels, it is non-renewable, but if it is produced from renewable sources such as wind or solar via electrolysis, it would be considered renewable.

Historically, from a global perspective, energy has transitioned from pre-Industrial Revolution (late 1800s) biomass-centric energy to post-Industrial Revolution non-renewable centric energy. We remain in this second phase today, as most energy used globally is generated from non-renewables. While the non-renewable energy that fuels global markets and enterprises has many advantages, there are some downsides to non-renewables. Some of these include emissions that adversely impact health and climate, production inefficiencies (it takes relatively 100 units of input to obtain 1 unit of output), and their relatively finite supply, making them contested assets leading to global competition, conflict, and security concerns.

The answer to the challenge of non-renewables appears to be renewables (a possible third phase) that provide cleaner, more efficient, and relatively infinite supplies of energy for a demand that seems insatiable. While transitioning from non-renewables to renewables might seem intuitively obvious, such a transition will be massive and slow due to the current global energy ecosystem. The global use of non-renewable fossil fuels to create energy for end users continues to increase, while efforts to transition to renewable energy sources are outpaced. Meanwhile, increased emissions contribute to air pollution and global warming, causing polar ice to melt, sea levels to rise, and people along shorelines to be displaced. The opening of polar regions is also a source of growing Great Power Competition. Surprisingly, central to energy supply and demand is not the availability of energy sources, but rather it is the harnessing of these sources for end-users. For instance, considering solar power, the Earth receives 20 times the energy in a single day than the world's population uses in an entire year, but harnessing this vast amount of energy is very difficult.

The Energy Mix:

In considering energy, it is helpful to start with what is called the energy mix, essentially the group of existing energy sources: oil, natural gas, coal, electricity, wind, solar, nuclear, and hydrogen. A more comprehensive definition is "the combination of different primary energy sources (like fossil fuels, nuclear, and renewables) that a region or country uses to meet its energy demands, and the proportion of each source contributing to the total energy supply." Nations are attempting to transiton from fossil fuels to cleaner sources of energy like nuclear, wind, solar, geothermal, and biofuels; however, current global demand for non-renewables well outpaces the trend toward renewables. Below is a recent snapshot of the energy mix of the three largest players and the world average:

Energy Mix	Gas%	Oil%	Coal%	Nuclear%	Hydro%	Wind%	Solar%	Other%
U.S.	43.1	0.4	16.2	18.6	5.7	10.2	3.9	1.9
China	3.0	0.1	62.0	4.1	15.1	6.5	4.8	4.4
Russia	45.1	0.8	16.3	19.4	17.3	0.5	0.0	0.6
World	22.5	2.7	35.5	9.1	14.3	7.8	5.5	2.6

Sources: International Energy Agency, U.S. Energy Information Agency, and Energy Institute

As shown, the U.S. energy mix is comprised predominantly of gas, nuclear, coal, nuclear power, and wind. Russia is similar with its priorities of gas, nuclear, hydro, and coal. China, in contrast, focuses predominantly on coal and hydro, while currently making deep investments in nuclear. Logically, the global energy mix follows as coal, gas, hydro, and nuclear. For Great Powers competing for hegemony across the domains of Diplomatic, Information, Military, and Economic (DIME), finite and transportable fossil fuels remain the base components of energy mixes to power all facets of societies and remain sources of tension as they relate to end users globally.

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In terms of the future, Exxon Mobil's report is very interesting with its energy predictions. Please see: ExxonMobil.com energy mix outlook to 2050. The Great Powers will almost certainly lead this transition.

Great Power Energy Mix Suppliers and Consumers:

The United States, Russia, and China are all in the top five oil and gas producers in the world. When it comes to the consumption of oil, the United States, China, and Russia rank 1, 2, and 4, respectively, as the largest consumers. The United States, Russia, and China rank 1, 2, and 3, respectively, globally as the largest consumers of natural gas. Please see interesting statistics from the U.S. Energy Information Administration: EIA.gov link for the top producers and consumers of oil and EIA.gov link on total energy production from natural gas in 2023.

When combining their demand for oil and gas, the three Great Powers (the U.S., Russia, and China) represent 40 percent of the global demand for oil and 43.5 percent of global demand for natural gas. Of the three nations, only China is a net importer of energy, which could put them in a more aggressive strategic posture for access to broader strategic, economic, and ideological goals.

There are some other interesting trends outside of the three Great Powers. India, for example, is the world's third-largest energy consumer. Its economy (and for that matter, the population) is rapidly expanding. India is also a major polluter (though improving recently) and must balance its energy ties with Russia (for oil) and the U.S. (to counter China). Looking toward the Middle East, Saudi Arabia, the largest oil exporter and the leader of OPEC, has major influence on global oil exports and pricing. Conversely, Iran has the world's second-largest natural gas reserves and fourth-largest oil reserves, yet it is not a global leader, and its regional influence is dwindling rapidly.

Risks – Supply Chains and Free Market Stability:

The United States and Russia are net exporting nations. However, oil and gas are fungible global strategic assets. Therefore, international supply chain disruptions (e.g. production limitations and policy decisions by the U.S. or OPEC, trade route disruptions in the Red Sea by Houthi Rebels, control of the Panama Canal by Chinese-owned companies, natural disasters affecting extraction and refining capacity, and sub-market pricing contracts for Russian oil circumventing sanctions) influence domestic pricing and the impact on consumer demand and behaviors. Oil is particularly vulnerable to chokepoints; see: EIA.gov link to charts showing volume of crude oil, petroleum and liquids transported through world chokepoints.

The potential scope and scale of disruptions, real or perceived, affect great power incentives, risk calculations, and reactions across all areas of political, military, economic, social, information, infrastructure, physical environment, and time. For the broader nexus of national security and economics, please see Bancroft GEOIntelligence White Paper on the Intersection of National Security and Corporate Strategies.

The U.S. and the Energy Mix:

The IEA reports that 85 percent of all U.S. energy consumption goes to transportation, industrial, and commercial sectors, while the remaining 15 percent goes to residential demand. Further, with the transportation sector, Stanford University's Precourt Energy Institute reports that oil fuels over

90 percent of U.S. and global transportation (ships, airplanes, trucks, and cars) despite recent focus on the development of vehicles that use alternative fuels (e.g., natural gas, biofuels, and electricity). Also, in terms of electricity, fossil fuels (oil, gas, and coal) are expected to remain the prominent energy source to 2050 and beyond.

Nuclear Power: Nuclear energy accounts for approximately 20 percent of the U.S. electricity that is produced. Though nuclear power is reliable and supports decarbonization, it is a high investment option. However, once a plant is functional, nuclear power has lower operational costs than fossil fuels. More recently, Small Modular Reactors (SMRs) have been emerging with the potential to significantly reduce upfront investment and timelines to open nuclear power generation facilities. But nuclear waste management is a major concern in terms of safety and efficient land use. Also, a national security risk consideration is the impact of a catastrophic nuclear power plant event.

The business case for nuclear power is strong after initial investment, contingent on public safety and uranium market conditions. Currently, Australia and Canada account for nearly 40% of the globe's known uranium reserves. Government policy and diplomacy will be important factors domestically and abroad. Nuclear power will likely remain a key and growing energy resource in global energy capacity in decades to come, comprising an increasing portion of the U.S. and global energy mix, while enhancing decarbonization and energy independence. Nuclear energy does have a synergy with hydrogen production, where excess electricity from nuclear energy can be reinvested in hydrogen.

Hydrogen Power: Hydrogen is a grid-independent energy source, which is viewed as a viable alternative in the future to reduce, or potentially to replace, fossil fuels. It has zero emissions and can be retrofitted into existing gas infrastructure; however, there are challenges in current technologies, materials science limitations, and storage. Hydrogen has opportunities for the future, but with uncertainty as it requires significant infrastructure investment, requiring leveraging multiple financial sources, including government incentives and private sector funding.

Renewable Power: While use of renewables appears to be dwarfed using non-renewables, the IEA reports that for 2024, solar, wind, and hydropower represented nearly a quarter of the U.S. energy mix for electricity. Solar and wind combined totaled 17 percent, surpassing the long-term non-renewable use of coal, which has decreased to 15 percent for the first time. Renewable energy sources are gaining traction with a business case substantiated by long-term savings following upfront investments (installing solar panels, establishing wind turbines, and modernizing infrastructure), resulting in cleaner, more efficient, less expensive, and nearly limitless supplies, enhancing energy independence. Solar, for instance, at a consumer level, reduces costs, provides optionality to sell power back to the grid, and lowers carbon emissions.

Switching to renewables does require forethought and deep consideration, as they are dependent on grid modernization, including storage capacity to provide on-demand delivery of electricity, weather and geography, technological advancements, land availability, access to rare earth minerals, and funding incentives for investment. Further, access to rare earth minerals depends on global supply chains, a risk factor in Great Power Competition. Furthermore, renewable energy delivery can be intermittent due to weather conditions and transmission disruptions. Specifically, hydropower has been impacted by droughts and low water levels in certain regions across the country during the past year. This makes storage a critical factor in the ability of renewables to deliver base loads for electricity consumption.

Renewables will play a key role in the U.S. energy future, with public and private investment required throughout the energy ecosystem, including grid modernization, domestic manufacturing, and access to rare minerals. The nation (or nations) that dominate the future of renewables will likely secure a key advantage over other nations, as the limited supply of non-renewables, as well as their adverse impact on the atmosphere from a health and climate perspective, will increasingly mandate mankind’s transition to them.

Electricity and The Power Grid:

Today, much of the world is dependent on electricity for its everyday needs, and the demand continues to increase exponentially, given the focus on electrification and digitization of our economy. The primary energy infrastructure that converts energy from raw materials into electricity to serve end-users is the Power Grid. This critical and complex network transforms natural resources in ways that generate, transmit, and distribute on-demand electricity to end-user residences and businesses, powering lives and economies globally. Today, most of the Earth’s population is connected to a power grid.

The Power Grid ecosystem is vast, complex, and comprised of many elements, including:

- Natural resources like non-renewables (oil, natural gas, coal, and uranium ore that can be enriched for nuclear power) and renewables (solar, wind, hydropower, and hydrogen) are used by power plants across the globe.
- Generation power plants (fossil fuel, nuclear, and renewable) installations that transform natural resources into electricity.
- High-voltage transmission lines that transmit power from generation power plants to substations for distribution.
- Storage networks, especially when generated through renewables, which can be an intermittent source due to weather trends.
- Distribution networks that provide power at a lower voltage to end users.
- Control centers that provide and monitor a balanced and efficient flow of electricity across the network through advanced technologies.

There are different scales and types of power grids that fall into three general categories. Wide-Area grids are interconnected grids that span countries and continents. Super grids are transmission networks that move high volumes of electricity across long distances. And Microgrids are localized and operate independently or are connected to other grids.

The current U.S. power grid was built during the 1960s and ‘70s and has proven to be remarkably resilient for the past 60 years plus. In the United States there are four major Wide Area grids including: the Eastern Grid spanning from the East Coast to the Rocky Mountains, the Western Grid spanning from the Rocky Mountains to the West Coast, the Texas Grid covering the state with the ability to connect into other grids, and the Alaska grid, which is independent covering the state.

While the U.S. has experienced blackouts and brownouts periodically, these are rare instances, with most service interruptions being in the distribution networks resulting from weather-related or accident-related destruction of lines. Due to increasing demand and complexity of risk factors that can potentially interrupt services, there is steadily growing pressure to increase grid capacity and automation. Wide Area grids will increasingly need to be invested in to meet demand.

Enterprises are implementing power purchase contracts to meet their needs. For example, in 2024, Constellation Energy announced that it was restarting its Three Mile Island Unit 1 service to support expected regional energy growth, principally driven by a 20-year power agreement with Microsoft for its data centers. These types of agreements, especially by data center companies, are becoming more common across the globe and are focused on capacity and decarbonization.

The focus on increased capacity, decarbonization, and transformation of power sources poses economic and national security risks related to the entire energy ecosystem, and central to this ecosystem is the power grid. Such risks only increase with growing reliance on an ever-expanding and interconnected power grid, which arguably touches every aspect of our nation's enterprises individually and collectively. Key risks include:

- Natural Disasters with the increasing risk of weather volatility.
- Operational risk due to potential cyber or physical attacks by VEOs, TCOs, Foreign Global Powers, and their agents.
- Power plants are potential targets for attack, especially nuclear facilities, which, if attacked, would have implications beyond electricity disruption. Aging infrastructure is increasingly at risk of failure.
- Dependence on global supply chain for natural resources, rare earth minerals, and foreign physical components for transformer equipment.
- Consideration also includes risk from Electromagnetic Pulses, which can irreversibly damage grids through events such as natural solar storms or high-altitude nuclear detonations in the Earth's atmosphere.

Sufficiently mitigating risks to today's power grid will require significant investment, estimated to be in the trillions of dollars, focused on modernization, diversifying energy sources, cybersecurity enhancements, and onshoring manufacturing of components. In October 2022, the U.S. Government Accountability Office issued a report recommending that a comprehensive plan be developed between the Department of Energy and Homeland Security for grid cyber risk on attacks in the distribution systems by threat actors remotely accessing the network, which could pose the most significant risk to the grid. Such planning will be critical to ensure our collective energy ecosystem security.

From a national security standpoint, protecting our energy infrastructure from cyber and physical threats is critical. The power grid faces numerous challenges from a security standpoint. Operationally, the grid is challenged by the demand for electricity growth, which a 2025 Deloitte study shows will be driven by the expansion of data centers for artificial intelligence (AI), machine learning, cryptocurrency mining, electric vehicle (EV) adoption, onshore manufacturing, consumer consumption growth, and decarbonization initiatives.

Data Centers are Critical:

Today, data centers are driving exponential demands for power and water, and are critical components of the global technology ecosystem and energy security, and these data centers are concentrated. The Energy Power Research Institute reports that, "15 states account for 80 percent of the national data center load: Virginia, Texas, California, Illinois, Oregon, Arizona, Iowa, Georgia, Washington, Pennsylvania, New York, New Jersey, Nebraska, North Dakota, and Nevada." In Virginia, data centers currently consume 25 percent of all electricity in the state, and Amazon estimates that about 70 percent of global internet traffic passes through the data centers in Loudoun, Fairfax, and Prince William counties in Northern Virginia.

Risks – Demand Drivers Outpacing Supply:

In summary, in addition to Great Power Competition and supply disruptions, risks to energy supplies are accelerating, ironically, due to economic and technological progress. Electricity demand is growing dramatically throughout the world, especially in free-market nations and China. Global electricity demand is expected to double by 2050. According to the International Energy Agency, much of the surge is being driven by the technology demands of data centers, industrial facilities, and artificial intelligence.

Key Economic Takeaways:

- The global dominance of energy is a key factor for global power dominance.
- Energy demand is projected to increase exponentially, driven by data centers, advanced technologies, decarbonization, and consumption across consumer and enterprise sectors.
- The technologies necessary for achieving societal advances in everything from medicine, supply chains, and defense, to managing the energy transition to lower carbon sources, are the primary drivers escalating demand for electricity, stressing the global energy ecosystem. They rely on base-load sources of power and require access to the same strategic minerals, which Great Powers compete to control.
- Economic and national security are dependent on resilient energy production, capacity, transmission, and distribution.
- Investment in physical, cyber, and natural resource security is critical in modernizing and diversifying our energy sources and distribution.
- A global and national portfolio approach to energy sources and transition to higher renewable sources over time is critical to global power positioning.
- Renewables require technological advancements to enable generation, storage, and exportability of energy.
- Businesses need to understand business-model dependence on energy sources and methods to reduce risk through diversified and distributed systems.

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