Written Testimony of David Gattie
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Disclaimer: *The opinions expressed in this testimony represent the personal and professional views of David Gattie and not necessarily those of the University of Georgia or the University System of Georgia*

U.S. Energy Resources & Technologies:
Prioritizing National Security and Comparative Advantage in 21st Century Strategic Competition

Thank you, Chair Duncan and Ranking Member Degette for the opportunity to testify this morning.

You've heard testimony that the U.S. has reduced carbon emissions for the past twenty years. I've included two papers along with figures and data that align with those conclusions. So, in my opening remarks I'd like to address what I believe to be one of the most direct and acute impacts an energy transition policy could have on our national security. It revolves around a central point. That being, the imperative that we secure an industrial base and energy resource advantage over our 21st century strategic competitors—particularly China.

America's industrial base was built on a diverse energy portfolio of fossil fuels, nuclear and renewables and that industrial base is the platform from which the US projects national power globally. America dominated the 20th century in large part because of our industrial capacity relative to other powers—specifically the Soviet Union. We were in this position because all past U.S. energy transitions were cumulative—domestic resources were added and diversity increased. With this came flexibility, resilience, and reliability all of which translated to our national security and opportunities for global partnerships with emerging economies.

We've learned that energy resources have different value propositions in an economy. Fossil fuels are stored, primary energy resources with high heating values necessary for industrial processes. They can be transported to where demand is greatest and deployed when called on. Nuclear power is a baseload, 24/7 resource with zero carbon emissions. These are intrinsically different value propositions compared with intermittent renewables, which are not transportable, callable or 24/7. Renewables should be included in a diverse energy portfolio, but not as replacement resources as they will not deliver the same value to America's industrial base as fossil fuels or nuclear.

Emerging economies and our competitors know this. This is important as the battle for hearts and minds is a core objective in great power competition, and the outcome will be affected by the decisions of weaker powers. Great powers compete, but weaker powers may ultimately determine who wins. This said, it is a matter of national security that U.S. energy policy account for the energy needs of emerging economies in need of proven, reliable energy resources. The world will consume oil and natural gas and build nuclear reactors—with us or without us. Better that it be with us than our strategic competitors who would welcome the opportunity.

I want to make a particular comment about nuclear power, which is becoming increasingly bipartisan. America once had a special relationship with nuclear power as a national security imperative—the original principle on which nuclear policy was founded. Currently, however, it's being treated as just another market commodity or technology for carbon reduction. I invite the members to read the paper I've included in my testimony on national security as a value-added proposition for nuclear power.

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In closing, America's economy, our industrial base, our military, our system of self-governance, our global network of alliances and our global security guarantees is the most sweeping success story of democracy and individual liberty in human history. It also, arguably, is the most complex system on Earth. As such, forcing this system to restructure itself with pledges to reduce carbon emissions by pre-determined dates constitutes a systemic change that will be fraught with unintended consequences.

Our National Security Strategy is clear: While Russia constitutes an immediate and acute threat, *"The PRC, by contrast, is the only competitor with both the intent to reshape the international order and, increasingly, the economic, diplomatic, military, and technological power to advance that objective"*[1]

To this end, China is expanding its industrial base with all energy resources and all energy technologies and establishing long-term partnerships with energy-rich nations. It is building a deep, diverse industrial base from which to project power and challenge the U.S. Moreover, China has openly declared its principle of building the new before discarding the old. China will not jeopardize its geopolitical objectives in order to address climate change. As such, a core national security concern for any proposed U.S. energy transition should be:

Can the U.S., with its industrial base restructured around low- and zero-carbon energy, retain its 20th century economic, military, industrial and geopolitical advantage relative to 21st century strategic competitors and outcompete China and deny the CCP of its intentions to disrupt a rules-based international order?

Our energy legacy tells us that we can rise up to this 21st century strategic challenge with all energy resources and technologies in our industrial base. To attempt otherwise will constitute a grand experiment on the most important industrialized nation in the world at a time of unprecedented challenges to freedom and liberty.

Note: To this summary, I have appended:

1. A recently published peer-reviewed journal article entitled, *"National Security as a Value-Added Proposition for Advanced Nuclear Reactors: A U.S. Focus"*
2. A white paper entitled: *"National Security Considerations for U.S. Energy Policy: Security-Centric, Globally-Engaged, Climate-Informed"*
3. A series of supporting summary figures with comments: *"America's Energy Resources & Industrial Base: Prioritizing National Security and Relative Advantage in 21st Century Strategic Competition"*.

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[1] Biden, J. (2022). National Security Strategy. *The White House*, 23.

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National Security as a Value-Added Proposition for Advanced Nuclear Reactors: A U.S. Focus

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Abstract: The U.S. has transitioned from being the 20th-century global leader in civilian nuclear power to a nation searching for ways to revive its once-dominant nuclear enterprise. The future of U.S. civilian nuclear power transcends that of a science and technology issue and, fundamentally, is a policy issue. This is a policy paper that uses a nuclear power policy framework to analyze current and historical U.S. civilian nuclear power policy and to identify weaknesses and deficiencies that need to be overcome in order for the U.S. to (1) leverage advanced nuclear reactors as a domestic technology to meet energy security and reliability objectives under carbon constraints, (2) operationalize national security as a priority objective and (3) restore the U.S. as a major global exporter of nuclear technology. The results of this analysis indicate that the national security implications of U.S. nuclear power have been marginalized in general due to the domestic market challenges of competing with less expensive and oftentimes more socially acceptable technologies, as well as the international challenges of competing with state-owned nuclear enterprises. The results are then discussed and used for making three following policy recommendations: (1) conduct a U.S. nuclear industrial base review; (2) create a demand signal using U.S. military installations; and (3) shift away from a sell-side nuclear vendor model for global exports to a buy-side model brokered by a third-party integrator that can work with multiple U.S. nuclear partners.

Keywords: advanced nuclear reactors; U.S. national security; U.S. nuclear power policy; nuclear industrial base review

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1. Introduction

The U.S. is in a sharply-divided debate as to which energy resources will power its 21st-century economy—a debate in which energy is viewed largely as a market commodity, with price and affordability as drivers, as a climate change issue, with CO_2 reduction as a driver, or some combination of both [1–6]. However, the specter of climate change has sparked intense scrutiny of the U.S. electric power sector, with the preponderance of this attention centered around urgent calls from the scientific community to reduce global carbon emissions. These calls have inspired an array of public movements and political rhetoric, as well as a variety of ad hoc policy responses and pledges at the local, state, and federal levels aimed primarily at replacing high-carbon fossil fuel energy resources with low- or zero-carbon resources. The phrase energy transition is regularly invoked to characterize these actions, with the catalyst and driving force being global climate change [7,8].

To this end, President Biden issued an executive order, putting the climate crisis at the center of foreign policy and national security [9]. Meanwhile, U.S. cities, states, corporations, and academics are proposing policies and strategies characterized as clean energy transition, sustainable transition, socially just and equitable transition, 100% renewable energy transition, zero-carbon economy, carbon neutrality, and fossil fuel divestment [10–15].

Many of these proposed transitions include target dates for implementation. Moreover, renewables are regularly promoted as the preferred alternative to fossil fuels, particularly for the U.S. electric power sector, and the growth of renewable energy is often used as a proxy indicator that the energy transition is well underway [16–19].

The proposed U.S. energy transition itself is a top–down policy decision, as is the promotion of renewable energy. However, the adequacy of renewable energy as a replacement for fossil fuels is unproven at the scale of an industrial economy the size of the U.S. While nuclear power has received renewed attention in recent U.S. discussions, arguments in support of nuclear power are predominantly motivated by concerns around carbon reduction and climate change while arguments against nuclear power largely revolve around cost, safety, and a proposed lack of necessity. Existing U.S. nuclear reactors are Generation III or older, with two Generation III+ reactors currently under construction [20]. While current U.S. reactors service the power generation sector, attention is being directed toward utilizing nuclear reactors for industrial processes [21–23]. Using offtake heat from nuclear reactors for appropriate industrial applications represents an added value proposition that can improve the current economics of nuclear power. However, light water reactors operate at temperatures that are low relative to many industrial needs. On the other hand, advanced reactors, particularly those using coolants, such as molten salts, which have much higher heat capacities than light water, have the potential for use in a broader range of industrial applications requiring higher temperatures. As will be discussed in this paper, small modular reactors (SMRs) and microreactors represent a class of advanced reactors that can lend themselves to improving the economics through industrial applications, as well as combined heat and power. For these reasons and more, nuclear reactors with more advanced operational and safety characteristics have been under development for some time and are now being elevated in renewed considerations for nuclear power [24,25].

This paper contends that the market aspects of U.S. nuclear power, in general, and advanced nuclear power, in particular, face substantial headwinds, domestically and globally. It also contends that the future of U.S. civilian nuclear power transcends that of a science and technology issue and, fundamentally, is a policy issue contingent upon not only the science and technology but also economics and societal aspects, both of which are subjective and complex. Moreover, what has been marginalized from U.S. nuclear power policy, if not dismissed, are the national security implications of nuclear power. This, then, is a policy paper that addresses these national security implications, discusses the current domestic and global challenges to U.S. nuclear power, and proposes specific policy recommendations for leveraging advanced nuclear reactors to operationalize national security as a priority objective within U.S. nuclear power policy, thereby aligning U.S. nuclear policy with 21st-century realities. As a policy paper, and due to the fact that U.S. nuclear power policy is a decades-old legacy issue of statecraft, a review of past U.S. civilian nuclear policy and technology innovations is a necessary inclusion in this analysis in order to lay the foundation for the primary point of contention in this paper. That being, U.S. civilian nuclear power is inherently a national security issue, and advanced nuclear reactors offer a national security value-added proposition for the U.S.

2. Methods

U.S. civilian nuclear policy is framed here as a hierarchy of three broad domains, innovation, markets, and politics/statecraft, thereby spanning from the purely objective laws of science and nature to highly subjective social and political norms and ideals (Figure 1). While the basic sciences and laws of nature dictate what is possible, innovation leverages those laws in the development of technology for deployment within society. Innovation is then constrained by economic feasibility and societal acceptance—if a technology is unaffordable or society rejects it, the technology will not be consumed. A final constraint prior to policy development is national security, which is characterized here as a gray area in the current U.S. civilian nuclear policy debate for reasons that will be evaluated and included in this analysis.

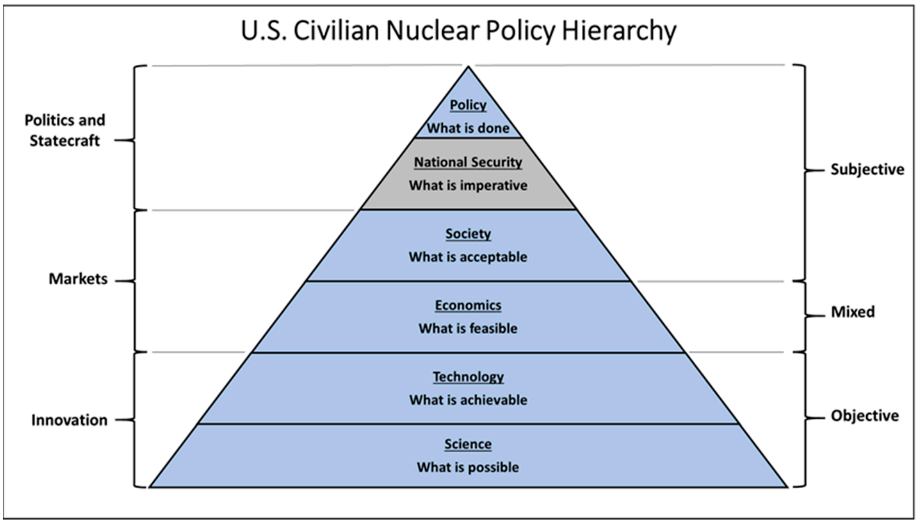


Figure 1. The proposed hierarchy illustrating the constraints on U.S. civilian nuclear policy, ranging from science to technology to economics to society to national security. National security is the gray area focused on in this paper as the dismissed constraint.

Energy policy, in general, is contingent upon this hierarchy, although national security is often a latent constraint that becomes evident during times of energy crises or shortages. However, national security is a vital concern for which the economics and societal aspects of this energy policy hierarchy may be bypassed, provided the science and technology are achievable. One example is the U.S. military and defense capabilities, which is an evident case for national security but for which there is no market or civilian demand signal. Nonetheless, there is a critical need for an industrial base and supply chain to sustain U.S. manufacturing capacity. While often referenced as the Defense Industrial Base, the overall U.S. industrial base, in civilian and defense sectors, is fundamental to ensuring this industrial capability. Similarly, policies have been deployed in the past to ensure sufficient industrial capacity for the U.S. energy sectors, particularly oil, natural gas, coal, and the electric power sector [26].

The methodology in this paper uses this nuclear policy hierarchy to analyze current U.S. civilian nuclear power policy and identify weaknesses and deficiencies that need to be overcome in order for the U.S. to leverage advanced nuclear reactors as a domestic technology to meet energy security and reliability objectives under carbon constraints and to restore the U.S. as a major global exporter of nuclear technology. To do so, a bottom-up analysis is conducted, beginning with the innovation aspects of the U.S. civilian nuclear power sector, both current and historical. This includes the U.S. definition of advanced nuclear reactors, as given by the U.S. Congress, along with a broad characterization of advanced nuclear reactor designs being proposed and developed. Next, the market aspects of civilian nuclear power are analyzed within the current context of energy resources for the U.S. electric power sector. This includes both economic and societal aspects, meaning costs and societal acceptance. Since levelized cost of electricity (LCOE) is often used in the U.S. for comparison of energy resources and technologies for power generation, a simplified version of LCOE is included in the analysis in order to highlight that national security is a non-monetized benefit of civilian nuclear power. Lastly, the political and statecraft aspects of U.S. civilian nuclear power are analyzed. This is characterized here as the gray area of national security for the U.S. civilian nuclear power policy for reasons that are discussed. The historical aspects represent a necessary review of the U.S. civilian nuclear power legacy. The overall analysis of these domains is then used for making three policy recommendations.

3. Analysis

3.1. Innovation: U.S. Civilian Nuclear Power

Nuclear power provided 18.9% of U.S. electricity generation in 2022 [27]. The current U.S. civilian nuclear fleet comprises thermal light-water reactors (LWRs), either pressurized water reactors (PWRs) or boiling water reactors (BWRs), with solid low-enriched U-235 (LEU) fuel enriched to 3–5%, and light water serving as both the moderator and coolant. Moreover, the fuel cycle is open, meaning that U.S. reactors operate as burners with no fuel recycling. The adoption of PWRs and BWRs extends back to the mid-1950s and the early stages of U.S. nuclear technology development as policymakers debated PWRs, BWRs, sodium graphite, molten salt fast breeder reactors, and other designs under development. Eventually, the decision to go with the PWR was a top–down political decision influenced by the advantages of light water as a coolant compared with that of sodium, the simplicity of the PWR design, and the decision to use PWR technology in the emerging U.S. nuclear navy [28,29]. From this, the U.S. civilian nuclear program expanded using LWR technology throughout the 20th century.

New nuclear construction in the U.S. has been largely dormant since the 1990s (Figure 2). The first new nuclear construction projects in the U.S. in over thirty years began in Georgia, USA, in 2009, with two new reactors planned at Plant Vogtle, and in South Carolina, USA, in 2013, with two new reactors planned at Plant V.C. Summer. Both projects involved Westinghouse AP1000 reactors [30–32]. Following several delays and cost overruns, the reactors in Georgia are scheduled to be online by the end of 2023 or the beginning of 2024 [33]. However, construction on the South Carolina reactors was halted in 2017 [34]. These were the first projects launched during President Obama's efforts to ensure that nuclear power remained a vibrant component of the U.S.'s clean energy strategy, motivated by concerns over climate change and the need for reliable, low-carbon power generation [35]. Prior to this activity, the most recent new nuclear construction project to start in the U.S. was the Harris-1, 980 MWe reactor in North Carolina, USA, in January 1987 [36]. The last nuclear grid connection was the Comanche Peak-2, 1250 MWe reactor in Texas, USA, in April 1993 [37]. The 1210 MWe reactor at Watts Bar-1 was connected to the grid in February 1996, but it experienced significant delays, with construction having started in July 1973 [38]. Moreover, from 1974 to 2017, forty-six reactors on which construction was started were canceled and not connected to the grid [39].

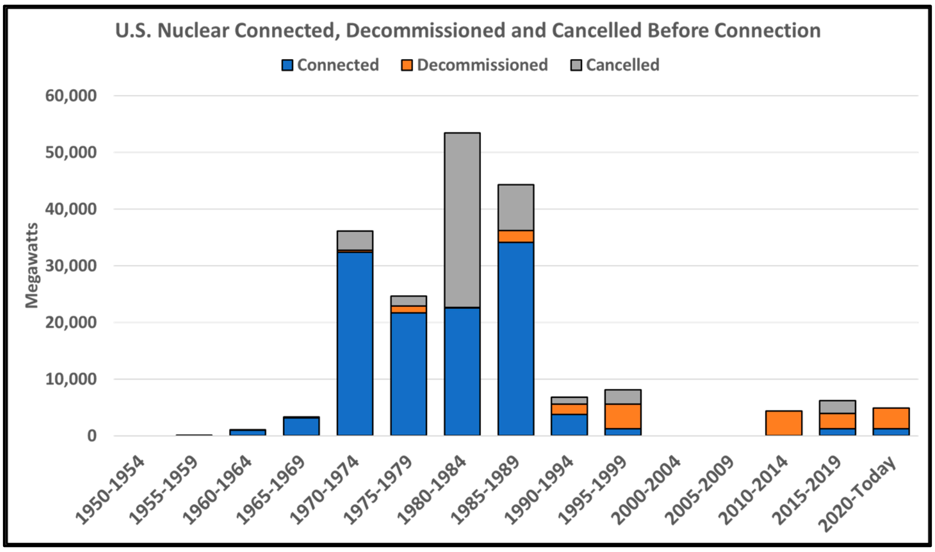


Figure 2. U.S. nuclear reactor activity since 1955. Reactors connected to grid; reactors decommissioned, and reactors canceled after construction began but before connection to the grid [39,40]. (Data Source: International Atomic Energy Agency's Power Reactor System).

The decline in U.S. nuclear construction has been attributed to high-interest rates, escalation in construction costs, structural problems in the nuclear industry, overconfidence, public perception, nuclear accidents at Three Mile Island, Chernobyl, and Fukushima, and the inability to compete with less expensive natural gas and subsidized renewable [41–44].

The Science and Technology of Advanced Nuclear Reactors

Advanced nuclear reactors are classified as fission reactors, fusion reactors, or radioisotope power systems that utilize heat from radioactive decay to generate energy. This paper focuses on fission reactors for power generation. To that end, the U.S. Congress has defined advanced fission reactors, relative to current LWR designs, as "a nuclear fission reactor, including a prototype plant (as defined in sections 50.2 and 52.1 of title 10, Code of Federal Regulations (or successor regulations)), with significant improvements compared to reactors operating on 27 December 2020, including improvements such as the following:

i. Additional inherent safety features;
ii. Lower waste yields;
iii. Improved fuel and material performance;
iv. Increased tolerance to loss of fuel cooling;
v. Enhanced reliability or improved resilience;
vi. Increased proliferation resistance;
vii. Increased thermal efficiency;
viii. Reduced consumption of cooling water and other environmental impacts;
ix. The ability to integrate into electric applications and nonelectric applications;
x. Modular sizes to allow for deployment that corresponds with the demand for electricity or process heat; and
xi. Operational flexibility to respond to changes in demand for electricity or process heat and to complement integration with intermittent renewable energy or energy storage [45].

These improvements are being pursued through various advancements in reactor design characteristics related to fuel material, fuel form, coolant, moderator, reactor type, reactor size, fuel cycle, and neutron spectrum (Table 1). Any combination of these would constitute an advanced reactor design. Although particular efforts are being directed toward fuel and coolant types, especially those of the molten salt/sodium and liquid metal type, as the heat capacities of these materials are much higher than those of light water and allow for high operating temperatures at low to near-atmospheric pressure. This translates to higher efficiencies for transferring heat from the nuclear fuel and, therefore, greater overall efficiencies and increased safety. Due to their modular design, meaning that the reactors are built offsite and transported to the site of deployment, SMRs and microreactors offer flexibility and, in the case of microreactors, transportability, both of which can be leveraged to achieve a level of decentralization by locating highly reliable generation in near proximity to high demand centers.

Table 1. Design characteristics of advanced nuclear reactors. Information is taken from International Atomic Energy Agency and Holt, 2023 [46,47].

Design Characteristics of Advanced Nuclear Reactors		
Fuel Material	• Low-enriched uranium (LEU) • High-assay low-enriched uranium (HALEU) • Plutonium • Thorium	
Coolant	• Light Water • Sodium • Lead • Molten salts	• Fluoride salts • CO_2 • Helium

Table 1. *Cont.*

Design Characteristics of Advanced Nuclear Reactors		
Moderator	• Light water • Heavy water	• Graphite • None
Fuel Form	• Molten salt • TRISO	• Oxide metal clad • Metal
Reactor Type	• Burner • Breeder	
Fuel Cycle	• Open • Closed • Fast burnup	
Reactor Size	• Conventional • Small modular • Microreactor	
Neutron Spectrum	• Thermal • Fast	

One of the world's first electricity-generating nuclear power plants was the U.S. Experimental Breeder Reactor-I (EBR-I), a research reactor developed at the Argonne National Laboratory [48]. EBR-I was the world's first breeder reactor. Beginning in 1964, Argonne National Laboratory designed, built, and demonstrated the Experimental Breeder Reactor-II (EBR-II), which served as the prototype for the Integral Fast Reactor (IFR) [49]. The IFR was tested in the 1990s and demonstrated as being technologically capable of completely shutting down in the event of a loss of coolant accident [50]. However, the program was abandoned in 1994 for non-technical reasons [51]. The U.S. has a history of research and development in advanced nuclear reactors and is currently taking the initiative to leverage that research and development for deployment within the next decade.

The NuScale SMR is a pressurized light-water small modular reactor (SMR) design with enhanced safety features and an expected deployment date of 2027 [52]. NuScale's SMR, which was certified by the U.S. Nuclear Regulatory Commission (NRC) in February 2023, represents the first-ever SMR to receive U.S. NRC certification [53]. Terrapower's Natrium technology is a sodium-cooled fast reactor with a molten salt storage system to provide flexibility and load-following capabilities [54]. The Natrium design includes features from the GEH Prism design, a fast reactor that is based on "the proven principles of the EBR-II" [55,56]. In 2021, an existing coal plant site in Wyoming, USA, was selected for construction of the first Natrium reactor. Construction was set to begin in 2023, and an original in-service date of 2028 was projected. However, the Natrium reactor uses high-assay, low-enriched uranium (HALEU) as a fuel, and, according to the U.S. Department of Energy, "Currently, there is a very limited domestic capacity to provide HALEU from either DOE or commercial sources. This presents a significant obstacle to the development and deployment of advanced reactors and increases the risk of private investment to develop an assured supply of HALEU or to support the infrastructure required to produce it" [57,58]. The only commercially available supplier is Russia. Consequently, the project has been delayed for two years since the U.S. does not have the enrichment capacity to supply HALEU fuel [59].

X-energy is partnering with Dow, Inc. to build the first Xe-100 advanced nuclear power plant on a Dow industrial site to provide the facility with process heat and power [60,61]. The Xe-100 is a small modular, pebble-bed, high-temperature gas-cooled reactor (HTGR) that uses meltdown-proof TRISO fuel technology. The Natrium and X-energy projects are receiving support through the U.S. Department of Energy's Advanced Reactor Demonstration Program (ARDP), which was launched in 2020 to help domestic private industry demonstrate advanced reactors in the U.S. [62]. It has been reported that nine out of ten ARDP-funded projects will need HALEU fuel [63]. Other advanced nuclear reactors in the early development stages include Elysium's MCSFR (Molten Chloride Salt Fast Reactor) and Flibe Energy's LFTR (Lithium Fluoride Thorium Reactor). Flibe's LFTR is unique in that it is a molten-salt reactor operating on the thorium fuel cycle [64].

Advanced nuclear science and technology is not a recent development in the U.S. There is a substantial and sound legacy from which future development and deployment can launch and is launching. Therefore, science and technology are not the only constraints to domestic deployment.

3.2. Markets: Economics and Societal Disposition of U.S. Nuclear Power

In the early stages of U.S. nuclear development, nuclear proponents contended that U.S. electricity demand would be increasing and, even though the U.S. had substantial coal reserves, nuclear power would help extend the life of these reserves and diversify the energy portfolio [65]. Other proponents projected that it was not too much to expect that nuclear-powered electricity generation would be too cheap to meter [66], a prediction that proved to be overly optimistic. Currently, the economics of nuclear power face the challenge of other power generation technologies that have lower costs, are politically favored, and are more amenable to societal preferences. Combined, the economics of nuclear power coupled with society's perceptions of nuclear power occupy a highly subjective space between nuclear reactor innovation and nuclear power policy (Figure 1). These represent formidable hurdles to the deployment of nuclear power, in general, and advanced reactors, in particular.

3.2.1. U.S. Nuclear Power Relative to Other Technologies

In 2022, U.S. electric power generation consisted of 38.8% natural gas, 20.1% coal, 18.9% nuclear, 10.6% wind, 6.4% hydroelectric, and 4.8% solar power, with nuclear power essentially being flat since about 2000 (Figure 3). A critical aspect of U.S. energy resource trends for its electric power sector is that each subsequent energy resource development added to, rather than displaced, previous resources. This provided the U.S. with improved reliability and a competitive advantage on the global stage, as well as an enhanced industrial capacity to advance the U.S. economy. America's energy legacy, then, has been one of adding energy resources and technologies to its economy, thus increasing the diversity of its resource base and its energy technology capabilities. However, this trend currently is not holding as the U.S. is moving away from baseload coal-fired power plants and backfilling, predominantly, with natural gas plants. Previous U.S. energy transitions, then, can be characterized as organic, emergent, and competitive through the exploration, development, and deployment of energy-dense resources to facilitate rapid industrialization, economic development, and greater national security through an increased level of energy self-sufficiency. Here, organic and emergent transitions refer to the growth and development of the U.S. energy and electric power sectors being driven from the bottom up through competition and innovation to not only provide greater access to energy resources but also to develop the most efficient and economically viable technologies for unlocking high-density energy resources, such as nuclear energy, and deploying those resources within the U.S. economy.

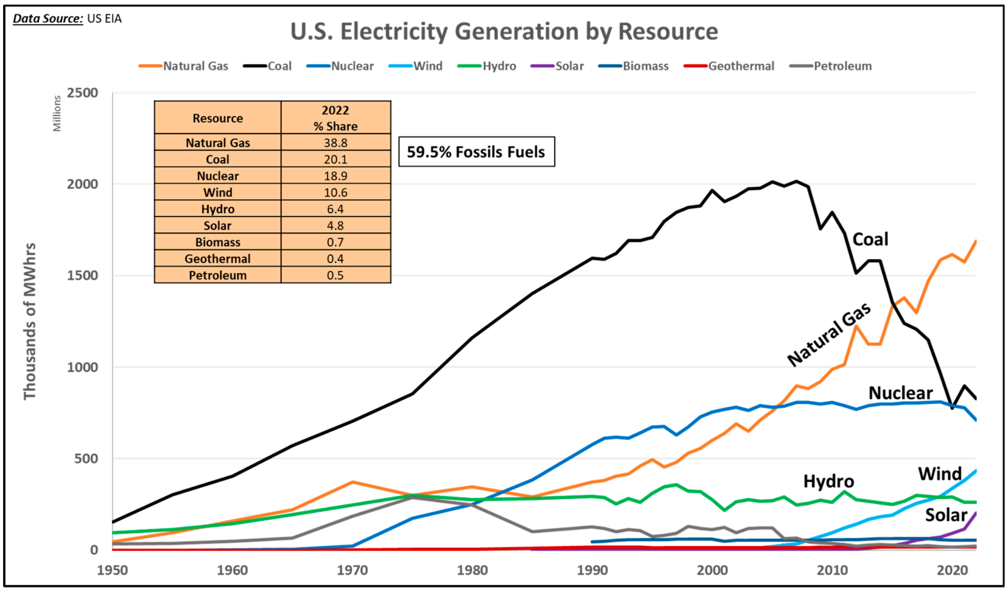


Figure 3. Trend for U.S. electricity generation, 1950–2022 [67].

Energy resource properties and power plant operation characteristics inform policy decisions within the U.S. electric power sector, with reliability, affordability, and carbon emissions being the key considerations (Table 2). Natural gas and coal are abundant domestic U.S. energy resources, and their associated power generation technologies are generally of low cost while capacity factors vary. Coal and natural gas are also transportable in primary form. Coal plants serve as baseload technologies, but the U.S. is shifting away from coal to natural gas combined-cycle plants. Consequently, capacity factors for coal-fired plants have decreased from 0.59 in 2013 to 0.48 in 2022, while capacity factors for natural gas combined-cycle plants increased from 0.49 to 0.57 over that same period [68,69]. Combined-cycle plants are being increasingly used as baseload plants. Given that coal is an onsite storable resource, and natural gas is a just-in-time flow resource subject to upstream conditions, coal can be characterized as a more reliable resource than natural gas. However, natural gas combustion turbines provide the necessary flexibility for load-following and short ramp times compared with coal, which results in low capacity factors for combustion turbines. Coal and natural gas plants are also affordable, mature technologies with generally affordable fuel costs. However, while coal prices tend to be stable, natural gas prices can be highly volatile. Coal and natural gas technologies, then, have unique reliability characteristics and are affordable but are carbon-emitters [70].

Solar and wind are also abundant domestic resources, although the actual primary resources are geographically fixed and cannot be transported in primary form. Moreover, the daily, monthly, and seasonal intermittency and variability of solar and wind combined with the lack of dispatchability for solar- and wind-generated electricity translate to lower capacity factors. In 2022, the capacity factor for utility-scale solar PV in the U.S. was 0.25, and for the wind, it was 0.36. Solar and wind are zero-cost resources, and solar PV and wind turbine construction costs continue to decrease in the U.S., making them cost-competitive, with coal and natural gas at the margins. However, their low capacity factors and intermittency are reliability concerns [71].

As is the case in most countries, U.S. nuclear power is a baseload technology with a 2022 capacity factor of 0.93. However, recent U.S. nuclear construction has proven to be a high-cost prospect for LNPPs [72]. This is creating strong societal and economic headwinds for consideration of new nuclear construction, given that natural gas combined cycle, solar PV, and wind power have lower costs with shorter construction times. While nuclear is a zero-carbon technology, the existing fleet of U.S. nuclear power plants have long ramping times and, therefore, are not dispatchable or load-following.

Table 2. Energy resource properties and operation characteristics for U.S. power plants. Capacity factor data are sourced from the U.S. Energy Information Administration [68,69].

Energy Resource, Technology	Energy Resource Properties & Power Plant Operation Characteristics	
Coal	• Abundant, domestic U.S. resource • Generally independent of weather conditions • Resource is transportable and stored onsite (1–3 month supply) • Generation is baseload • Lifespan: 30-plus years	• Fuel cost is market-based • Construction costs are low • Carbon emissions high • Capacity Factor: 0.48
Natural Gas Combined Cycle	• Abundant, domestic U.S. resource • Generally independent of local weather, subject to upstream supply • Resource is transportable, not stored onsite (just in-time delivery) • Generation is flexible and increasingly used as baseload • Lifespan: 30-plus years	• Fuel cost is market-based (can be volatile) • Construction costs are low • Carbon emissions half that of coal • Capacity Factor: 0.57
Natural Gas Turbine	• Abundant, domestic U.S. resource • Generally independent of local weather, subject to upstream supply • Resource is transportable, not stored onsite (just in-time delivery) • Generation is flexible and dispatchable for load-following • Lifespan: 25-plus years	• Fuel cost is market-based (can be volatile) • Construction costs are low • Carbon emissions lower than coal • Capacity Factor: 0.13
Nuclear	• Generally independent of weather conditions • Resource is transportable, stored onsite (~1.5 year refueling) • Generation is baseload • Lifespan: 60-plus years	• Fuel cost is low, but overly dependent on nondomestic supplies • Construction costs for LNPP are high • Zero carbon emissions • Capacity Factor: 0.93
Utility-Scale Solar and Onshore Wind	• Weather-dependent (daily, monthly, seasonally) • Resource is geographically fixed, not transportable, not storable • Generation is not dispatchable, cannot serve as baseload • Solar Lifespan: 30 years • Wind Lifespan: 30 years	• Fuel cost is zero • Construction costs are low • Zero carbon emissions • Solar: Capacity Factor: 0.25 • Wind: Capacity Factor: 0.36

In all, natural gas and coal plants offer reliability and affordability but have carbon emissions. Solar PV and wind offer affordability and zero carbon but lack 24/7 reliability. Large nuclear plants provide reliable, zero-carbon baseload power but currently are not economically competitive at the margins with inexpensive natural gas plants or with solar and wind technologies, particularly if solar and wind are subsidized. As such, each energy resource and power plant technology has unique benefits and limitations with respect to reliability, affordability, and carbon emissions (Figure 4). At question here is whether advanced nuclear reactors can occupy the intersection of all three, particularly given the cost challenges of recent U.S. nuclear projects.

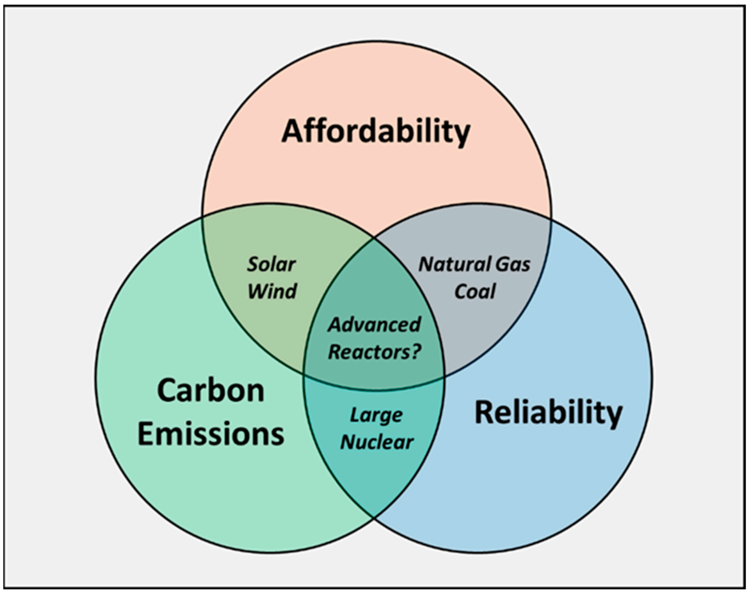


Figure 4. Venn diagram of three key objectives for power generation technologies. Carbon emission, reliability, and affordability. A key question for this paper is, "Can advanced nuclear reactors meet all three?".

3.2.2. The Insufficiency of Levelized Cost of Electricity for Nuclear Power

Levelized cost of electricity (LCOE) is a standard metric for comparing power generation technologies on an economic basis. LCOE is defined as the average revenue required per unit of electricity to recover the cost of constructing and operating a power plant. The simplified general calculation of LCOE is given by the following equation:

$$\mathrm{LCOE} = \frac{\sum_{t=0}^{n} \frac{C_t + O_t}{1+r^t}}{\sum_{t=0}^{n} \frac{E_t}{1+r^t}} \tag{1}$$

where t is the year of construction or operation, with t = 0 being the first year of construction; n is the lifetime of plant operation; C_t is capital investment costs in year t; O_t is operation and maintenance costs in year t; E_t is electricity generated in year t, and r is the discount rate [73–75]. A sale price above LCOE generates a monetary gain, and a sale price below LCOE incurs a monetary loss. The intent of LCOE is to provide a metric for comparing costs across resources and technologies. However, this simplified version of LCOE treats all kWhrs as equal and fungible even though the technologies that generate those kWhrs are operationally different. As given by this equation, LCOE is a quantitative metric, but it is also subjective in that it does not distinguish or account for qualitative operational characteristics and differences across energy resources and technologies, such as baseload, resource availability and storability, ramping time, and load-following capabilities, nor does it account for low- and zero-carbon attributes (Table 2). These constitute nonmonetized benefits, and attributes are unaccounted for in the simplified LCOE calculation of Equation (1); yet, they underpin grid reliability. Nonetheless, these benefits could be monetized through incentives that reward baseload capacity, flexibility, and load-following capabilities and penalize carbon emissions. Some markets attempt to adjust for this through capacity markets and other mechanisms [76–82]. The Lazard analysis of levelized costs for the most common power generation technologies includes an unsubsidized analysis, as well as analyses for LCOE sensitivity to federal tax subsidies, fuel prices, carbon pricing, cost of capital, and cost of firming intermittency. Ranges for unsubsidized LCOE are given in Table 3.

Table 3. Unsubsidized, levelized costs for common power generation technologies, as analyzed and reported by Lazard [83].

Technology	Unsubsidized LCOE ($/MWhr)
Solar PV--Residential Rooftop	117–282
Solar PV--Commercial & Industrial	49–185
Solar PV--Utility-Scale	24–96
Geothermal	61–102
Wind (Onshore)	24–75
Wind (Offshore)	72–140
Gas Peaking	115–221
Nuclear	141–221
Coal	68–166
Natural Gas Combined Cycle	39–101

While the simplified LCOE accounts for the amortization period, it does not explicitly account for the technical lifetime of a power plant. For a nuclear power plant, this can be 60-plus years, which is at least twice as long as for other plants [84]. This means that, in the second half of a nuclear plant's expected lifetime, recapitalization will be required to replace the generation lost from other power plants retiring after having reached their technical end of life, but prior to the nuclear plant reaching its technical end of life. The value prospect for nuclear is long-term. With LCOE as the dominant metric for determining energy resource and power plant technology portfolios, nuclear technology will have difficulty standing up to short-term marginal prices of low-cost natural gas and subsidized renewables.

3.2.3. Societal Disposition toward Advanced Nuclear Technology

While nuclear power has been a highly reliable, low-carbon power generation technology in the U.S., with capacity factors above 0.9 and zero onsite carbon emissions, it has detractors. General arguments against nuclear power often are associated with cost, safety, necessity, and the association of civilian nuclear power with nuclear weapons [85–87]. Others see nuclear power as being an ethical decision required for minimizing the impacts of climate change, but the proliferation of nuclear weapons is the most plausible candidate for overturning an ethical decision to deploy nuclear to that end [88]. Some contend that renewable energy alone is the way forward and that nuclear power is unnecessary [89–92]. Others project that without the inclusion of its carbon reduction benefits, nuclear power expansion is not expected to occur [93]. These competing interests are a fair characterization of the current U.S. nuclear power debate.

Recent Gallup polling in 2023 indicates that "Americans are more supportive of using nuclear energy as a source of electricity in the U.S. now than they have been since 2012", with 55% "strongly" or "somewhat" favoring it [94]. Gallup polls since 1994 found that Americans tend to favor nuclear power when oil prices are high and are less likely to favor it when oil prices are low. Polling by the Pew Research Center in 2022 indicated somewhat mixed views on the use of nuclear power in the U.S., with 35% saying that the federal government should encourage it and 26% saying that the government should discourage it [95]. The 2022 Pew poll, which was conducted prior to Russia's invasion of Ukraine, indicated much stronger support for the federal government to encourage solar and wind power technologies. Some studies indicate that opinions on civilian nuclear power are strongly associated with proliferation concerns over nuclear weapons, while others indicate that public opinion is impacted by past accidents at Three Mile Island, Chernobyl, and Fukushima [96–98]. In more targeted polling about advanced reactors, a 2023 survey on U.S. public awareness of small modular reactors found that only 20% of respondents had ever heard of small modular reactors, with 67% having never heard of small modular reactors [99].

Public opinion on nuclear power is influenced by social and political circumstances surrounding energy issues at the time of polling, such as high oil and natural gas prices or instability in energy-rich areas of the world [100]. Societal acceptance is also influenced by economics, which, in turn, is impacted not only by market prices of oil, natural gas, and coal but also by subsidies for renewable energy, such as solar and wind. Given that nuclear power is a reliable technology with the highest capacity factor of all generation technologies and that it emits no onsite carbon, it is understandable that the U.S.'s acceptance of nuclear power is increasing. However, nuclear power remains a long-term investment, so short-term public opinion polls on nuclear power will not necessarily contribute to a stable, principled foundation on which to develop a long-term policy.

3.3. Politics and Statecraft: The Gray Area of National Security in the U.S. Nuclear Policy

The U.S. nuclear science and technology enterprise had its beginnings in being a military application, demonstrating through the Manhattan Project that nuclear fission could be harnessed and applied to military weaponry [101]. Realizing that this science and technology could not be contained and monopolized by the U.S. long-term, concerns over the proliferation of nuclear weapons dominated early U.S. debates as to how best to control this new energy resource and technology [102]. Inherent in these concerns was the U.S. losing its advantage to the Soviet Union. Consequently, U.S. civilian nuclear policy originated as a top–down national security issue with the establishment of the Atomic Energy Commission (AEC) in 1946 and eventually led to the establishment of the International Atomic Energy Agency (IAEA) to provide stewardship over an emerging global nuclear fuel and technology ecosystem. The extension of nuclear science into the U.S. civilian sector remained a technology hurdle. President Eisenhower's Atoms for Peace program was a two-fold diplomatic framework that leveraged the potential value of nuclear power for civilian purposes while at the same time purposing to keep the U.S. engaged in the global nuclear network and on the leading technological edge of reactor development [102,103]. Anticipating increased U.S. demand for electricity, and even though coal, oil, and natural gas remained plentiful, H.D. Smyth contended that nuclear power represented the energy future for electric power generation and would bolster long-term energy security [65].

In 1955, the original principles of U.S. nuclear power policy were explicitly stated. Not only would the U.S. work to prevent the diversion of fissionable materials to non-peaceful uses, but the U.S. also would advance its domestic nuclear science, technology, and engineering to counter any efforts by its strategic competitor, at that time the Soviet Union, to establish civilian nuclear partnerships with other countries [104].

> *"In the interests of national security, U.S. programs for the development of the peaceful uses of atomic energy should be directed toward:*
>
> *a. Maintaining U.S. leadership in the field, particularly in the development and application of atomic power;*
>
> *b. Using such U.S. leadership to promote cohesion within the free world and to forestall successful Soviet exploitation of the peaceful uses of atomic energy to attract the allegiance of the uncommitted peoples of the world;*
>
> *c. Increasing progress in developing and applying the peaceful uses of atomic energy in free nations abroad;*
>
> *d. Assuring continued U.S. access to foreign uranium and thorium supplies;*
>
> *e. Preventing the diversion to non-peaceful uses of any fissionable materials provided to other countries.*
>
> *U.S. programs for the development of the peaceful uses of atomic energy should be carried forward as rapidly as the interests of the United States dictate, seeking private financing wherever possible"* [104].

The civil–military dual utility of atomic energy and the understanding that this dual utility could not be monopolized by the U.S. compelled U.S. policymakers to deal with nuclear technology as having a value proposition that transcended other energy commodities such as coal, oil, and natural gas. As such, U.S. civilian nuclear power was originally treated as a technology of special dispensation requiring a policy framework structured around novel national security principles. Early policymakers understood that they were dealing with matters of statecraft, not only technology issues [102].

Nuclear technology was deemed to have a strategic national security value proposition that was measured in terms of technological advantage relative to the Soviet Union—America's great power competitor in the second half of the 20th century. Much of the world was in economic recovery or economic development following World War II, and energy security was foundational to both. Therefore, the relative advantage in nuclear technology translated to a relative advantage in global influence—the advantage and influence both great powers at that time were competing to gain. In 1954, the U.S. enacted the Atomic Energy Act for the development, use, and control of atomic energy for the general welfare, domestically and globally, to promote world peace and to increase the standard of living [105]. Section 123 of the Atomic Energy Act, entitled "Cooperation with Other Nations", dictated the terms under which the U.S. nuclear companies exported their technologies and provided technical assistance to another country. As of 5 December 2022, the U.S. had twenty-three so-named 123 Agreements covering forty-seven countries [106]. As such, the U.S. originally dealt with nuclear power as both a science and technology issue and as a matter of statecraft and diplomacy by way of 123 Agreements. It also, early on, was a bipartisan issue as Republicans and Democrats competed for which political party would be the champion for U.S. nuclear power [107,108].

However, the national security implications of civilian nuclear power currently are a gray area for the U.S. nuclear policy. While affordability, reliability, low-carbon, flexibility, and resource storability are accepted value propositions, with efforts to monetize them, the national security value proposition of nuclear is addressed more perfunctorily by a general acknowledgment, not by formal measures to monetize that value proposition—although it is the original first principle of the U.S. nuclear policy.

4. Discussion and Policy Recommendations

It is a fair question to ask, "If the U.S. market does not select nuclear power on the basis of cost, is the absence of nuclear power from the U.S. power sector a reasonable outcome?" Similarly, "If the U.S. society does not support nuclear power, is it a reasonable outcome for nuclear power to be precluded, by policy, from the U.S. power sector?" Standard market forces of economic viability and societal acceptance might suggest that the answer to both questions is "yes". It means that if the market and society do not support nuclear power, then it is a reasonable outcome for nuclear power technologies to be excluded from the U.S. economy. However, relegating U.S. civilian nuclear power to that of a market commodity and submitting its fate to market forces alone and popular opinion circumvents and disregards the original first principles of nuclear power as a national security issue (Figure 1) [104]. Moreover, the energy market is not fundamentally a free and fair market as long as resources continue to be subsidized and favored by policymakers. Such is the case for renewables, which are beneficiaries of the recently proposed Inflation Reduction Act. Nonetheless, even if the market were free, fair, and without subsidies, the contention here is that nuclear power has such a core national security value proposition that market forces alone are insufficient signals for excluding it. Americans expect that the U.S. Government will protect and defend the United States and, in doing so, will commit resources to ensure their freedoms. This paper proposes that the national security value proposition of nuclear power should be incorporated into the 21st-century U.S. efforts to revitalize its nuclear enterprise, but to do so will require addressing several domestic and global challenges.

4.1. Domestic Challenges

The science of advanced nuclear reactors is sound and has precedent within the U.S. legacy of nuclear research and development, so advanced reactors are not fundamentally constrained by the underlying science and technology. Commercial-scale development and deployment of advanced reactor technologies within the U.S. power generation sector face several hurdles with respect to the economics and societal disposition of advanced nuclear.

Within the market space, social and political efforts are reframing the energy policy debate to focus on climate change and low carbon emissions, as amplified by President Biden's elevation of climate change to the center of U.S. foreign policy and national security [109]. To that end, current efforts to keep economically challenged large nuclear plants operating are primarily for meeting carbon emission targets and climate objectives while maintaining grid reliability [110]. Existing nuclear power, then, is not excluded altogether from this reframing, nor is advanced nuclear power, as evidenced by the Advanced Reactor Demonstration Program (ARDP) discussed previously. However, commoditizing nuclear power, particularly advanced nuclear power, as a market commodity to compete with coal, oil, natural gas, solar, and wind while continuing to use LCOE as the dominant metric for selecting across these technologies is problematic for the long-term prospects of nuclear. It dismisses the baseload and reliability value of nuclear and does not address fundamental structural issues constraining the potential deployment of advanced nuclear reactors.

Recent experience with the construction of the AP1000 reactors in Georgia and South Carolina, USA, exposed the difficulties of reviving an industry that has been dormant for over three decades. While a recent study reported that the experience with the first-of-a-kind (FOAK) AP1000 units in Georgia, USA, will be highly beneficial should a utility opt for the next AP1000 project, it remains speculative as to whether major improvements can be made for the second-of-a-kind deployment of these designs [111]. Nonetheless, a key structural issue that should be of concern is the need for a mature supply chain. This will be particularly challenging for advanced nuclear reactors without a strong demand signal and book of business for spinning up a secure and efficient supply chain. Natural gas power plants, solar PV facilities, and wind turbines already have established supply chains that afford them a significant near-term competitive advantage in cost and in meeting construction and management timelines. This will be a challenge as construction costs for advanced reactors are difficult to predict, and utilities are hesitant to assume the risk of a FOAK design [112]. Moreover, public opinion may be influenced not only by cost but also by concerns over safety and the question of necessity if there is the perception that zero-carbon solar PV and wind turbines alone can substitute for zero-carbon advanced nuclear reactors.

Currently, the demand signal for power generation technologies comes from private utilities, with the costs for those technologies paid for by ratepayers within the utility's service area. The U.S. electricity market structure plays a leading role in an energy generation mix and selection of technologies and has a particular impact on nuclear power. In traditional vertically-integrated rate-regulated markets, the utility is given a monopoly market with rates set by regulators. Utilities operating within a regulated market structure are afforded a guaranteed consumer base and a generally stable revenue stream on which it can develop integrated resource plans around a diverse portfolio of energy resources and technologies in order to optimize for cost, reliability, and low carbon over the long term. Utilities operating within a deregulated structure operate within a competitive market where rates are market-based rather than regulator-set [113]. The competitive market structure has created concerns as to whether such a market can allocate sufficient and adequate levels of competitive generation and provide for future capacity [113].

Since 2013, twelve nuclear reactors have been shut down in the U.S., with another three reactors planned for shutdown by 2025. An additional twenty reactors faced permanent shutdown but were spared by state intervention via subsidies to keep the reactors in operation. For most of these thirty-five reactors, markets and economics were an underlying issue [114]. Of the thirty-five reactors, thirty are located in states operating under nontraditional competitive market structures [115]. In the U.S., individual states determine their own market structure, and in states with a competitive market structure and aggressive renewable energy standards, nuclear reactors face particularly difficult economics.

4.2. Global Challenges: U.S. Nuclear Disposition Relative to Other Countries

The U.S. has transitioned from being the 20th-century global leader in civilian nuclear power, in terms of domestic deployment and global exports, to a nation searching for ways to revive its once-dominant nuclear enterprise [103,116–118]. This is particularly relevant given the U.S. civilian nuclear position relative to other countries and the national security implications of that position (Figures 5 and 6). Given the decline in new U.S. nuclear construction, the threat of premature closure of existing reactors, and with no new large nuclear power plant construction projects projected, it is reasonable to assume that at the completion of Vogtle Units 3 and 4 in Georgia, USA, large nuclear construction in the U.S. may conclude.

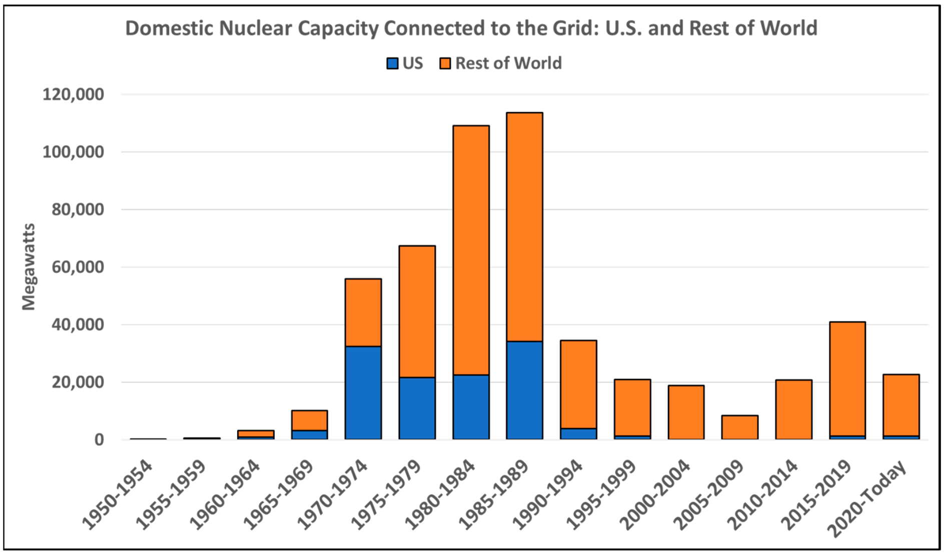


Figure 5. U.S. nuclear capacity connected to the grid relative to the rest of the world [119]. (Data Source: International Atomic Energy Agency's Power Reactor System).

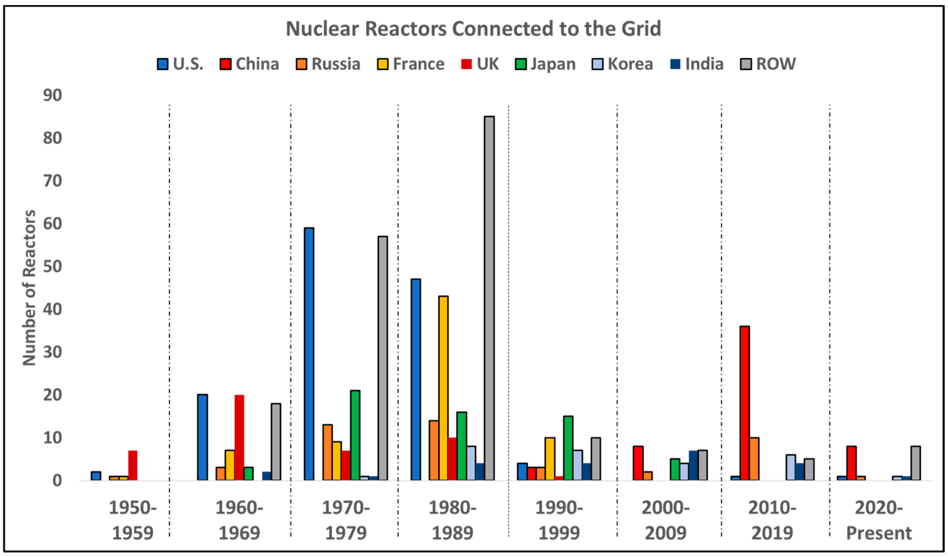
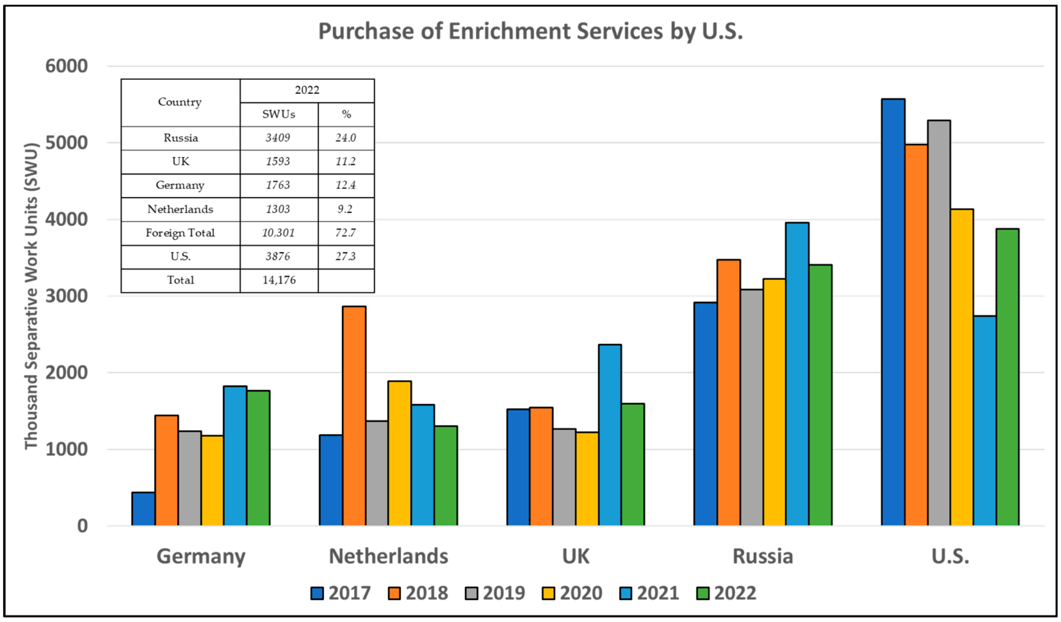


Figure 6. Comparison of nuclear reactors connected to the grid for leading civilian nuclear power countries [119]. (Data Source: International Atomic Energy Agency's Power Reactor Information System).

Currently, China leads the world in reactors under construction and, since 2000, has led the world in reactors connected to the grid (Table 4). According to the World Nuclear Association, “The USA has been overtaken in world markets by Russia and South Korea in securing export contracts, particularly for nuclear power reactors. China opted for a US design—the Westinghouse AP1000—as its standard Generation III reactor in 2007, but there has not been much else. Czech, Indian, South African, and Saudi Arabian plans open opportunities” [120]. Chinese nuclear vendors operate under what is characterized as “the government’s powerful industrial policy support”, while Russia’s state-owned nuclear corporation, Rosatom, has nearly monopolized the supply of nuclear assemblies in Eastern Europe [121,122]. Some predict that nuclear power for state-owned enterprises, such as those in China and Russia, are likely to have a bright future relative to liberalized markets, such as in the U.S., where public opinion, public opposition, political ideologies, and market competition serve as challenges to new nuclear projects [123]. Regarding nuclear fuel, the U.S. has resorted to outsourcing its uranium supply and enrichment services, reflecting the consequences of a short-sighted nuclear power policy and leading to additional structural deficiencies in the U.S. nuclear enterprise (Figure 7). Furthermore, in 2005, the U.S. Nuclear Regulatory Commission (NRC) issued a construction authorization for a Mixed Oxide Fuel Fabrication Facility, with construction starting two years later [124]. The NRC terminated the construction authorization in 2019. The project was about 70% complete and had a cost of at least $7.7 billion, which was above the original estimate of $4.9 billion [125].

Table 4. Nuclear reactors connected to the grid or under construction globally since 2000 [119]. (Data Source: International Atomic Energy Agency’s Power Reactor Information System).

	Number of Reactors Since 2000	
Country	**Connected to Grid**	**Under Construction**
China	52	21
Russia	13	3
India	12	8
South Korea	11	3
Japan	5	2
Pakistan	6	0
Czech Republic	2	0
Ukraine	2	2
Argentina	1	1
Belarus	2	0
Brazil	1	1
Iran	1	1
UAE	3	1
US	2	1
Romania	1	0
Bangladesh	0	2
Finland	1	0
France	0	1
Slovakia	1	1
Taiwan	0	0
Turkey	0	4
UK	0	2
Total	116	54



Country	2022	
	SWUs	%
Russia	*3409*	*24.0*
UK	*1593*	*11.2*
Germany	*1763*	*12.4*
Netherlands	*1303*	*9.2*
Foreign Total	*10,301*	*72.7*
U.S.	*3876*	*27.3*
Total	14,176	

Figure 7. Purchase of enrichment services by U.S. civilian reactor owners from 2017 to 2022 [126] (Data Source: U.S. Energy Information Administration.

China and Russia are U.S. competitors—economically, militarily, geopolitically, and strategically [127–130]. Currently, the U.S. is lagging behind both countries in civilian nuclear deployment. If nuclear power was solely a carbon emissions and global climate issue, lagging behind Russia and China in nuclear deployment may not necessarily be a priority concern for the U.S. as deploying more zero-carbon nuclear power would forego future carbon emissions. However, as anticipated by early U.S. civilian nuclear power policymakers, a relative advantage in nuclear technology translates to a relative advantage in global influence—an advantage and influence that Russia and China are competing to gain through civilian nuclear collaboration with other countries [103,131–135]. Such competition between great powers is inherent throughout history, and it should not be met with panic. Rather, it should be met with building the institutional and industrial capacity to compete and win. In the case of nuclear power, the world is at a critical moment when energy security, climate change, and the threat of disruptions to the global energy network are merging into a perfect storm of security-related concerns. Within this perfect storm, a relative advantage in civilian nuclear science is the national security proposition for civilian nuclear power, as articulated by early U.S. civilian nuclear policymakers.

As previously discussed, the U.S. is facing challenges in the domestic deployment of advanced nuclear power. At the same time, the U.S. perhaps faces complex challenges to ramp up global exports. At the center of these challenges are the U.S. nuclear industrial base and supply chain. For the past three-plus decades, the very time span during which U.S. nuclear construction was dormant, China and Russia established mature, reliable, and, increasingly, domestically-sourced supply chains for efficient construction and deployment of nuclear reactors [122]. China and Russia were able to accomplish this in a fairly short period of time because their top–down state-owned structure not only gives them an advantage in decision-making but also in operating off of state treasuries while U.S. nuclear vendors operate from a private sector, profit-driven position. Part of the challenge, then, is to reestablish the national security proposition for U.S. nuclear while keeping it as a private endeavor.

4.3. Operationalizing the National Security Value of U.S. Advanced Nuclear Power: A Focus on the Industrial Base

This paper contends that the national security value proposition for civilian nuclear power, as proposed by early U.S. policymakers, is a gray area in current U.S. nuclear power policy and is not incorporated into the traditional model for selecting energy resources and technologies for the electric power sector. Advanced nuclear reactors offer a renewed opportunity for the U.S. to reestablish itself as a global civilian nuclear competitor while restoring national security as the overarching priority based on the first principles of the U.S. nuclear policy (Figure 8). To that end, three recommendations are offered here.

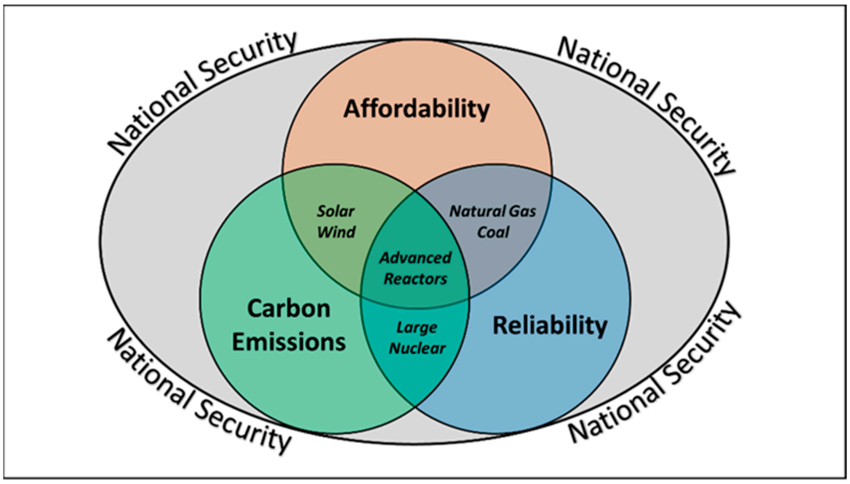


Figure 8. An augmented Venn diagram of the three key objectives for power generation technologies. Advanced nuclear reactors offer a renewed opportunity for the U.S. to reestablish itself as a global civilian nuclear competitor while restoring national security as the overarching priority based on first principles of U.S. nuclear power policy.

First, the nuclear industrial base and supply chain deficiencies should be prioritized and developed utilizing the defense industrial base model. Currently, the U.S. nuclear industry is relying on demand signals from utilities to build up a book of business to establish the supply chain. However, this places the burden on the individual ratepayers within markets where utilities have opted for advanced nuclear reactors. As previously discussed, this will be a particular challenge for competitive electricity markets. Moreover, while operational characteristics such as reliability, flexibility, and baseload could be monetized, the national security value of nuclear power is a different prospect as, by definition, it is a national-level proposition that will benefit all U.S. citizens. Therefore, it should be paid for by U.S. taxpayers, not only the ratepayers within a utility's electricity market. This being the case, the recommendation here is for the U.S. Congress to appropriate funds for the nuclear industrial base to ensure that the capacity of that industrial base can be sustained even when market signals cannot sustain it. This is not an unprecedented approach. The defense industrial base is congressionally appropriated, is bipartisan, and is built on the principles of ensuring that the U.S. has the industries to support vital national interests and national security, but it is executed by private industry. Similarly, funding to stand up and sustain the industrial base for advanced nuclear reactors can be appropriated by Congress while being executed by private U.S. vendors.

While efforts such as the Advance Reactor Development Program incentivize advanced reactor development and deployment in select locations, the private utility sector alone may not create sufficient demand signals in these early stages of ANR development. An option is to leverage U.S. military bases and installations to create a demand signal [136]. Grid security is a priority for the military; therefore, isolating these installations from the national grid has a national security value proposition of its own. Deploying advanced nuclear reactors, particularly SMRs and microreactors, at these installations can provide grid security while also creating a consistent demand signal [137]. SMRs, which range from 20 MW to 300 MW in capacity, are appropriate for large, permanent military bases, primarily for power generation. For military installations, such as forward-operating sites, microreactors offer operating characteristics not only for power generation but also for desalination if forward-operating sites call for and allow it. Moreover, microreactors are sufficiently small in size, and they can be mobilized and deployed at remote locations, thereby reducing the time required for fuel resupply. A promising design is the heat pipe-cooled microreactor, which is essentially a solid-state design that offers advantages such as strong negative feedback, long life, robustness, an independent emergency rod shutdown system, and passive heat removal [138]. Mobility and site flexibility are novel and key benefits of microreactors. As military applications of SMRs and microreactors develop into state-of-the-art, the U.S. industry will be looking for economically feasible state-of-the-shelf technologies for deployment within the U.S. economy. Beyond their utility for commercial power generation, the smaller-sized SMR and microreactor units hold promise for remote industrial applications such as hard rock mining and oil and gas development, as well as for energy-intensive facilities such as data centers. Additionally, SMRs that use high heat capacity molten salts have increased utility for industrial processing requiring high temperatures.

Second, in conjunction with leveraging military installations to create a demand signal for advanced reactors, the U.S. Department of Defense (USDoD) should be charged with conducting a nuclear industrial base review similar to that required by Executive Order 13,806 for the Defense Industrial Base [139]. Market analysis has been performed for microreactors, and supply chain analyses have been conducted for U.S. nuclear power in general [140,141]. However, an industrial base analysis will look not only at supply chains but also at domestic manufacturing capacity and opportunities for mutual collaboration with allied global partners in order to increase economic and industrial efficiencies. The National Technology and Industrial Base (NTIB) could be leveraged for exploring and shaping potential allied partnerships around nuclear manufacturing, global export agreements, and the nuclear fuel cycle [142]. The U.S. DoD, alongside Congress and the Defense Industry, have developed a cohesive, competitive, and well-understood requirement-based approach to resourcing U.S. defense. It has successfully maintained a competitive defense industry that supports not only US National Security needs but those of its allies. Maintaining strategic and technological advantage in military capability is understood, which includes private industries as well as a diverse supply chain and installations, shipyards, and geographically dispersed military bases.

Last, for the U.S. to reassert itself as a competitor in global nuclear exports, it needs to restructure its 20th-century approach, which operated from a position of relative dominance in nuclear expertise. There was a time when the U.S. was not only the preferred nuclear partner but it was the dominant nuclear partner in terms of nuclear technology. Leveraging 123 Agreements, the U.S. could strike deals with other countries and dictate conditions on U.S. terms. These terms generally aligned with original U.S. nuclear policy principles to prevent the diversion to non-peaceful uses of any fissionable materials provided to other countries [104]. U.S. nuclear vendors benefitted from this position of dominance and operated from a sell-side position where they sold nuclear reactors to countries that had limited alternatives. The 21st century has unfolded much differently. As U.S. nuclear construction went dormant, Russian and Chinese state-owned nuclear enterprises occupied the space vacated by the U.S. and now hold a strong position in domestic deployment and global exports. Russian and Chinese state-owned enterprises are in a position to function as vertically-integrated corporations offering a range of services, including construction, operation, maintenance, security, finance, education, and decommissioning. U.S. nuclear vendors accustomed to operating from a sell-side posture as per the 20th-century model do not necessarily have sufficient institutional capacity to function as a vertically-integrated entity offering a range of services competitive with those of a state-owned enterprise.

It is recommended here that the U.S. shift away from its 20th-century sell-side U.S. vendor model to a buy-side model focused on a country's broader energy and security needs. This could be brokered by a third-party integrator that can work with multiple U.S. nuclear partners, as identified in DoD's nuclear industrial base review and included in the National Technology and Industrial Base. The third-party integrator would leverage U.S. advanced nuclear offerings with advanced nuclear offerings of allied partners in a best-of-business approach that includes reactor technology, construction, operation, maintenance, security, finance, education, and decommissioning. This would serve as a multi-partner vertically-integrated entity that could compete with state-owned nuclear enterprises. Building off of the nuclear industrial base review and a goal of having at least two Small Modular Reactor vendors fully productionized for domestic and international deployment and national security requirements, the DoD could lead a requirement-based competition to obtain 10 SMRs built and operating within 10 years. This aligns with how other strategic acquisitions are developed where there is a need for a fully funded system design and development effort, considered non-recurring engineering, that would progress two vendors into full-rate production. This is also consistent with the recent U.S. Department of Energy's liftoff strategy, except that it follows a DoD acquisition model, not one of piecing together first-of-a-kind risk and asking the ratepayers to assume that risk [143].

5. Conclusions

This paper argues that the future of U.S. advanced nuclear reactors is fundamentally a policy issue contingent upon not only the science and technology of advanced nuclear reactors but also economics and societal aspects, both of which are subjective and complex. However, the commoditization of U.S. nuclear power as another market commodity has rendered numerous existing U.S. nuclear reactors uncompetitive against less-expensive natural gas and subsidized renewables and is limiting U.S. participation in the global export market. This is creating headwinds for the development and deployment of advanced nuclear reactors in the U.S. on the grounds of economics and societal acceptance.

This paper further contends that the national security value proposition of nuclear power, as proposed by early U.S. policymakers, has been marginalized, if not dismissed, from U.S. nuclear power policy and is not incorporated into the traditional model for selecting energy resources and technologies for the electric power sector and, therefore, is a gray area in current U.S. nuclear power policy. As such, advanced nuclear reactors offer a renewed opportunity for the U.S. to reestablish itself as a global civilian nuclear competitor while restoring national security as the overarching priority based on the first principles of U.S. nuclear policy. To that end, this paper makes three following recommendations:

- The fledgling status of the U.S. advanced nuclear reactors and the U.S. nuclear industrial base and supply chain represent a structural deficiency that should be prioritized. The recommendation here is for the U.S. Congress to engage in ensuring that the capacity of that industrial base can be sustained even when market signals cannot sustain it. While the private utility sector alone may not create sufficient demand signals in these early stages of advanced nuclear reactor development, an option is to leverage the U.S. military bases and installations to create an early and consistent demand signal;
- Charge the U.S. Department of Defense with conducting a nuclear industrial base review to evaluate not only supply chains but also domestic manufacturing capacity and opportunities for mutual collaboration with allied global partners in order to increase economic and industrial efficiencies;
- Shift from a sell-side nuclear vendor model for global exports to a buy-side model brokered by a third-party integrator that can work with multiple U.S. nuclear partners, as identified in the proposed DoD nuclear industrial base review.

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White Paper Submitted in Support of David Gattie's Testimony
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National Security Considerations for U.S. Energy Policy: Security-Centric, Globally-Engaged, Climate-Informed

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Keywords: Energy transition, security-centric, energy diversity, energy technologies, great power competition

ABSTRACT: America is debating an energy transition for what has been the world's largest economy and, arguably, most important industrial and military power since WWII. This paper contends that this transition should not be anchored to political pledges for reaching a carbon emission reduction level by a pre-specified target date as the unintended consequences of a top-down forcing function such as this have not been sufficiently evaluated for their impact on America's industrial base. Instead, the U.S. energy transition debate should be reframed within the context of global realities and great power competition where energy is not merely a market commodity or a climate change issue—rather, it's a deeply entrenched economic and national security issue and a systemic geopolitical issue with domestic and global implications. This paper raises critical questions and offers recommendations to consider and address in the U.S. energy transition debate.

1. Introduction

The U.S. is in a sharply-divided debate as to which energy resources will power its 21st century economy—a debate in which energy is viewed largely as a market commodity, with price and affordability as drivers, as a climate change issue, with CO_2 reduction as a driver, or some combination of both (Tice, 2014; Bade, 2018; Hartman, 2018; United States Climate Alliance, 2021; Gattie, 2022; Wilson, 2022). However, the specter of climate change has sparked intense scrutiny of the U.S. electric power sector with the preponderance of this attention centered around urgent calls from the scientific community to reduce global carbon emissions. These calls have inspired an array of public movements and political rhetoric as well as a variety of ad hoc policy responses and pledges at the local, state, and federal levels aimed primarily at replacing high-carbon fossil fuel energy resources with low- or zero-carbon resources. The phrase *energy transition* is often invoked to characterize these actions, with the catalyst and driving force being climate change (U.S. Department of State, 2021; Tollefson, 2022).

The energy transition challenge is more complex than the issue of domestic carbon reduction as the benefits of affordable and reliable electricity are broadly distributed across American society and are difficult to overstate. Electricity animates local economies and is vital to the function of critical infrastructure such as water, telecommunications, and emergency medical services. Recent events in Texas and California offer a glimpse of the devastating effects of power disruption for even brief periods of time (University of Texas at Austin, 2021; Denning, 2021; Hawkins, 2021). Moreover, a myopic U.S. energy transition defined solely by domestic carbon reduction risks undermining America's domestic and international economic stature and putting its industrial base at a disadvantage relative to great power competitors, ultimately diminishing its ability to shape both the rules-based global order and a global climate response. In short, policymakers must face the challenge of reducing carbon emissions without being blinded to, or marginalizing, broader national security implications. Constraining America's energy transition to carbon reduction pledges, despite noble intentions, is a shortsighted approach that potentially places America and the international community on a perilous path. More accurately, the real challenge for policymakers is to devise, articulate and implement a comprehensive energy policy that prioritizes energy security under carbon constraints without jeopardizing the well-being of American citizens and communities, the electric power grid or the nation's national security and its influence abroad. The magnitude and scope of a comprehensive energy strategy demands a formal vision to guide the nation's energy policy but not impose unrealistic conditions that jeopardize reliability.

This paper:

- Proposes that the U.S. energy transition debate should focus on the actual transition phase, itself, rather than being driven by pledges to reduce carbon emissions by pre-determined dates that aren't inherently anchored to national security or geopolitical and global energy realities, and
- Frames the U.S. energy transition as a fundamental security issue that accounts for the energy needs of emerging economies while being informed by climate considerations: a security-centric, globally-engaged and climate-informed framework.

Moreover, this paper recommends that the U.S. should:

- Prioritize energy resource and energy technology diversity in its energy policy,
- Establish a fossil fuel baseline (lower threshold) below which the U.S. industrial economy will not drop,
- Facilitate global energy engagement with emerging economies around all energy resources and technologies,
- Elevate nuclear power as a national security priority (Gattie and Hewitt, 2023), and
- Ensure that the time span for any level of U.S. energy transition be flexible, adaptable and resilient to global conditions and disturbances.

2. U.S. energy transitions: A legacy of resource and technology diversity

Broadly defined, an energy transition is *"the changing composition (structure) of primary energy supply"*, and for the U.S. this has included wood, coal, petroleum, natural gas, nuclear and renewables (U.S. EIA, 2011; Smil, 2016). At the center of the contemporary energy transition debate is fossil fuels—the dominant energy resources on which America's 20th century industrial economy was built and rose to become the world's strongest economic and military power in the world. If the energy transition is defined as 100% renewables, as proposed by some, then both fossil fuels and nuclear power will be targeted for omission from the U.S. economy.

A critical aspect of all U.S. energy transitions is that each subsequent energy resource development added to, rather than displaced, previous resources (Figure 1). This provided the U.S. with improved energy reliability and a competitive advantage on the global stage, as well as an enhanced industrial capacity to advance the U.S. economy, provide a higher quality of life and maintain the world's most advanced and best prepared military. America's energy transition legacy, then, has been one of adding energy resources and technologies to its economy, thus increasing the diversity of its resource base and its energy technology capabilities.

Previous U.S. energy transitions can be characterized as organic, emergent and competitive through the exploration, development and deployment of energy-dense resources to facilitate rapid industrialization, economic development and greater national security. Here, organic and emergent refer to the growth and development of the U.S. energy and electric power sectors being driven from the bottom-up through competition and innovation to not only provide greater access to energy resources but also to develop the most efficient and economically viable technologies for unlocking high-density energy resources and deploying those resources within the U.S. economy.

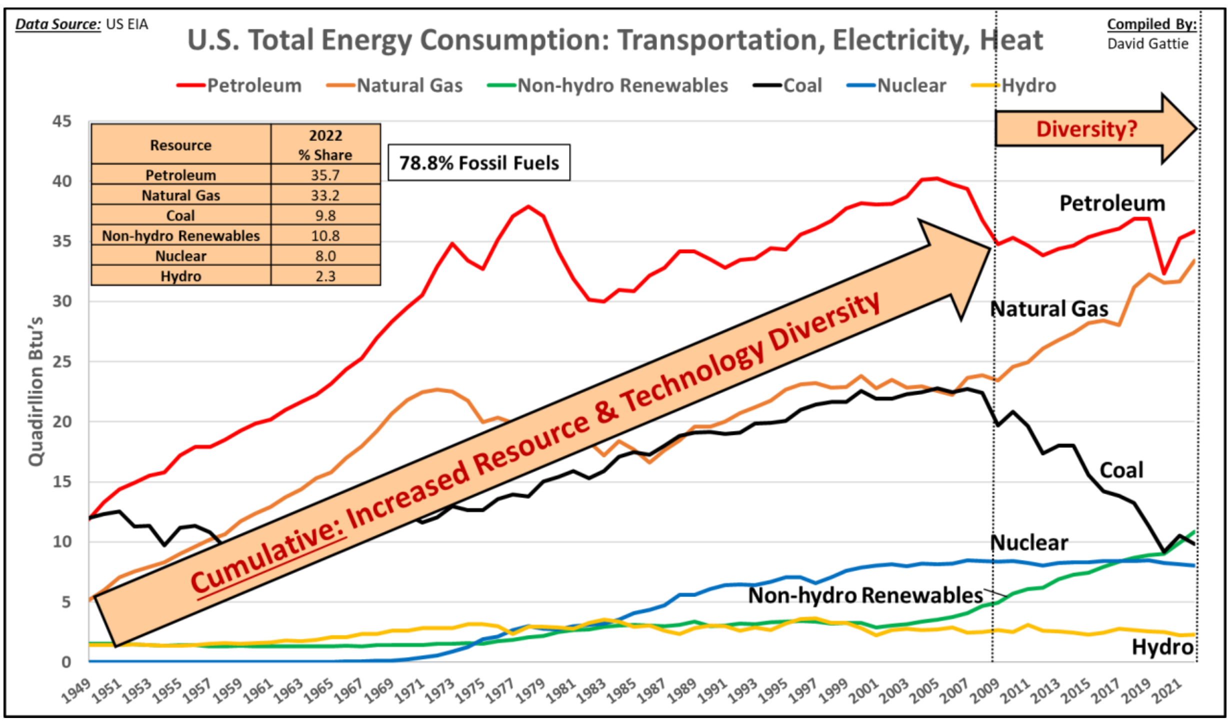

Figure 1. U.S total energy consumption trajectory. Data source: U.S. EIA, 2023a.

For security reasons, America's organic, bottom-up energy transition approach was at times punctuated by top-down energy and national security policies crafted to ensure access to the high-density energy resources that underpinned America's economic and industrial might. One example, particular to the U.S. electric power sector, is the Power Plant and Industrial Fuel Use Act of 1978 (U.S. Congress, 1978), which was based on the findings of the U.S. Congress that:

1) *"the protection of public health and welfare, the preservation of national security, and the regulation of interstate commerce require the establishment of a program for the expended use, consistent with applicable environmental requirements, of coal and other alternate fuels as primary energy sources for existing and new electric powerplants and major fuel-burning installations; and*
2) *the purposes of this Act are furthered in cases in which coal or other alternate fuels are used by electric powerplants and major fuel-burning installations, consistent with applicable environmental requirements, as primary resources in lieu of natural gas or petroleum".*

Additional purposes stated in this Act include *"increase the Nation's capability to use indigenous energy resources of the United States to the extent such reduction and use further the goal of national energy self-sufficiency and otherwise are in the best interests of the United States"*, *"to conserve natural gas and petroleum for uses, other than electric utility…for which there are not feasible alternative fuels or raw material substitutes"*, and *"to encourage and foster the greater use of coal and other alternate fuels, in lieu of natural gas and petroleum as a primary energy source"*.

By law of the U.S. Congress, the U.S. electric power sector was mandated to shift from natural gas to coal or other alternate resources for national security reasons, while ensuring that environmental requirements were met. This was a critical energy resource supply problem stemming from issues associated with the Arab oil embargo and U.S. dependency on oil and natural gas supplies from a politically unstable Middle East (Myre, 2013). So critical, that legislators and policymakers deemed it a national security threat requiring top-down legislative intervention.

For almost forty years America experienced a decline in domestic oil and natural gas production accompanied by an increasing dependence on oil and natural gas from foreign suppliers (Figure 2). This eventually was overcome by the development of fracking technology, which unlocked vast domestic oil and natural gas resources and allowed the U.S. to shift from a state of global dependency to one of domestic sufficiency. America's bottom-up, innovative and competitive energy transition structure translated to national security for the country. In this case, the U.S. energy transition was not defined by the composition of primary energy resources—it was defined by the origins, accessibility and reliability of those primary energy resources. This also initiated a shift in the U.S. electric power sector as natural-gas fired electricity became competitive with coal-fired power.

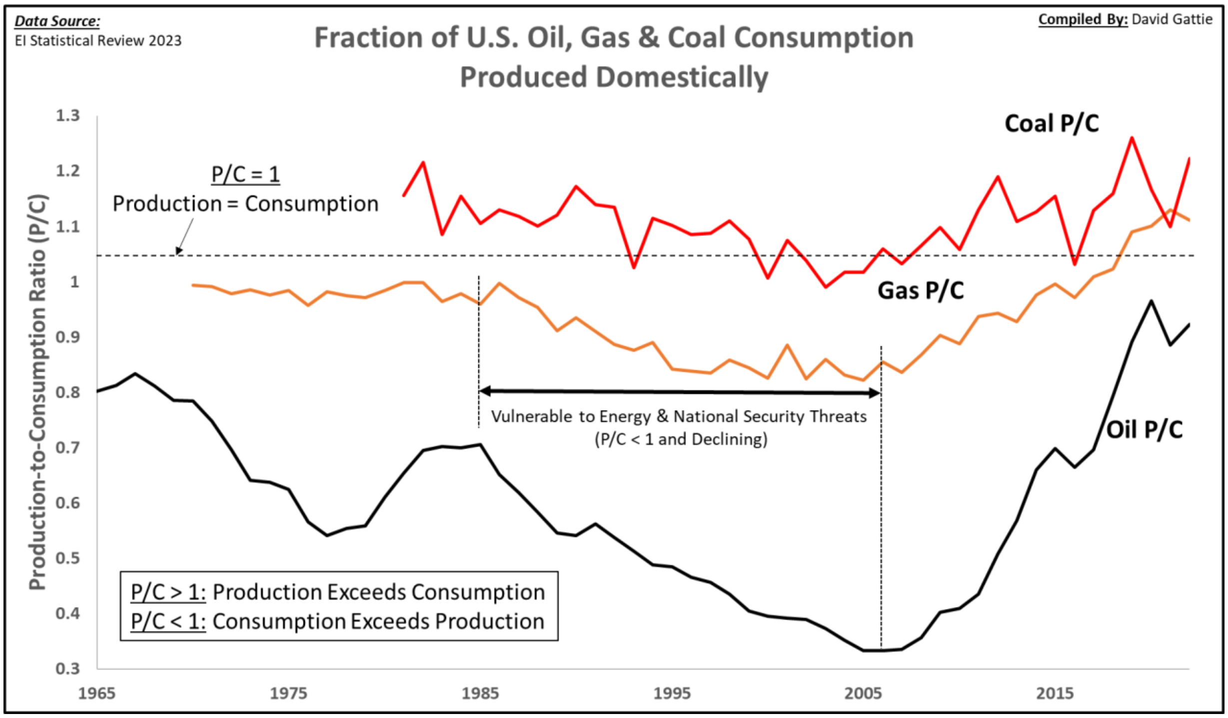

Figure 2. U.S. oil, natural gas and coal production-to-consumption ratio. Data source: Energy Institute 2023 Statistical Review of World Energy.

In general, resiliency and security were core objectives of past U.S. energy transitions, with resiliency defined as the capacity of the U.S. energy sector to respond to disturbances and perturbations and recover to a preferred economic and industrial posture for ensuring U.S. national security and protecting U.S. interests abroad. These perturbations and disturbances have been domestic, exemplified by energy resource inaccessibility, or global, exemplified by past energy crises in the Middle East and the current energy crisis stemming from Russia's invasion of Ukraine (Shaffer, 2022). And, throughout America's energy transitions, reliable access to energy-dense resources and diversity of those resources have been foundational to ensuring resiliency and security in the energy sector.

3. Orienting America's energy transition: A security-centric framework

Currently, the U.S. has no comprehensive, long-term energy strategy, which, arguably, can be attributed to ideological and political differences. It also reflects America's basic commitment to bottom-up competitiveness and free markets in the private sector as drivers of innovation in energy resources and technologies as opposed to top-down nationalism of its energy sector, as is the model in authoritarian countries such as China and Russia. The convergence of climate, economic, and national security challenges demand a global and geostrategic approach to formulating America's 21st century energy policy. An analytic framework that unifies the challenges presented across each of these domains will serve as a vital asset for navigating America's energy transition. However, the trajectory for the 21st

century U.S. energy transition is increasingly being oriented relative to global climate change and domestic carbon emissions. At the national level, President Biden issued an executive order putting the climate crisis at the center of foreign policy and national security (White House Briefing Room, 2021a). Meanwhile, cities, states, corporations and academics are proposing policies and strategies characterized as clean energy transition, sustainable transition, socially just and equitable transition, 100% renewable energy transition, zero-carbon economy, carbon-neutrality, and fossil fuel divestment (Solomon and Krishna, 2011; Carley and Konisky 2020; Jacobson, 2020; O'Shaughnessy, et al., 2021; Bruggers, 2022; Tyson, et al., 2022). Many of these proposed transitions include target dates for implementation. Moreover, renewables are regularly promoted as the preferred alternative to fossil fuels, particularly for the U.S. electric power sector, and the growth of renewable energy often is used as a proxy indicator that the energy transition is well underway (Bloomberg News Editors, 2019; Kemp, 2020; Richard, 2020; S&P Global, 2020; Alvarez, 2021).

If domestic carbon reduction frames the U.S. debate and drives the energy transition strategy, America's energy transition then could be characterized as climate-centric with fossil fuels as a target for exclusion from the U.S. energy portfolio. If clean energy is defined as renewables only, then fossil fuels and nuclear power are excluded. Such a transition toward increased dependency, if not complete dependency, on renewable energy would represent a fundamental departure from prior U.S. transitions on at least two accounts. First, it would represent a transition away from higher-density energy resources (fossil fuels and nuclear) and toward lower-density energy resources (renewables). Second, it would not be a cumulative transition if renewables are pursued in an effort to displace fossil fuels or nuclear. Thus, in contrast with previous transitions, this would constitute a reduction in energy resource diversity rather than an increase.

As such, the question should be asked: "Will a climate-centric U.S. energy transition that's focused on domestic carbon reduction also afford the U.S. with the capacity to stand up its economy with the energy security and national security it expects and to which it is accustomed"? Moreover, "Will the proposed transition increase resiliency and security within the U.S. energy and electric power sectors"?

3.1. Decarbonization: Prioritizing resource and technology diversity

A singular focus on domestic decarbonization can be misleading. It has been argued that U.S. carbon reductions alone will have limited impact on global climate change and will not insulate the U.S. economy from the impacts of global climate change as the upward trajectory of global carbon emissions is projected to increase with or without U.S. emissions (Gattie, 2019; Gattie, 2020). Therefore, it's important to keep in context that the climate change issues being debated can't be confined to U.S. borders as climate change is a global phenomenon with global impacts stemming from global causes. Furthermore, a singular focus on domestic decarbonization risks obscuring important economic and geopolitical objectives that are instrumental to American efforts to lead a global energy transition.

In 2022, CO_2 emissions from the U.S. electric power sector constituted about 4.2% of total global CO_2 emissions from energy consumption. Of this, coal-fired power accounted for 2.21% and natural gas-fired power accounted for 1.89% (Table 1). It's noted here that these are direct emissions from the power plant, which does not include methane leaks in the natural gas infrastructure. It can be argued that the impact of direct U.S. power sector carbon emissions on global climate change is limited, if not inconsequential, and that a unilateral elimination of carbon from the U.S. power sector will not reorient the upward trend of global CO_2 emissions (Figure 3). While such an argument lacks sufficient strategic rationale on which to contend that coal and natural gas should remain in the U.S. electric power portfolio, framing the contribution of U.S. electric power sector CO_2 emissions within the global context does raise security and resiliency concerns. Since reducing emissions on the input side means reducing baseload coal and dispatchable natural gas, both being abundant domestic resources, is there a critical point at which the gains from carbon reduction create diminishing returns for, and come at the expense of, reliability, resiliency, diversity and security? Even the shift from coal to natural gas creates reliability concerns as an onsite, storable resource is displaced by a resource that's subject to upstream interruptions. Here, the diversity value of retaining both coal and natural gas is in their diverse operational characteristics, not merely the fact that they are different resources (Figure 4).

CO_2 Emissions From Energy Consumption			
Region and Sector	**2022 (mtons CO_2)**	**% Share of Global**	**% Share of U.S.**
Global	*39,315,500,000*		
U.S.	*4,825,800,000*	*12.27*	
U.S. Power Sector	*1,650,366,513*	*4.20*	*34.20*
U.S. Coal-Fired Power Sector	*868,201,231*	*2.21*	*17.99*
U.S. Gas-Fired Power Sector	*742,560,206*	*1.89*	*15.39*

Table 1. Percent share of U.S. power sector CO_2 emissions to global total. Data Source: U.S. EIA, 2023a; Energy Institute 2023 Statistical Review of World Energy.

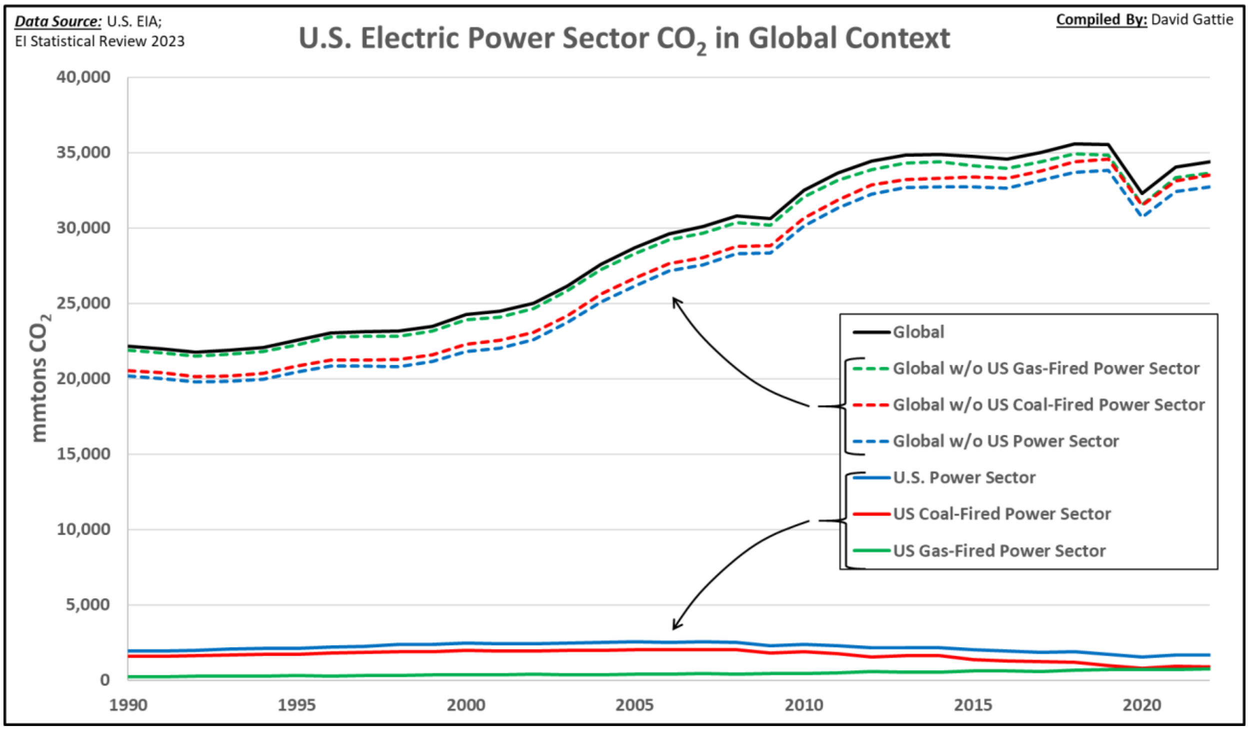

Figure 3. U.S. Power sector CO_2 emissions. Data Source: U.S. EIA, 2023c; Energy Institute 2023 Statistical Review of World Energy.

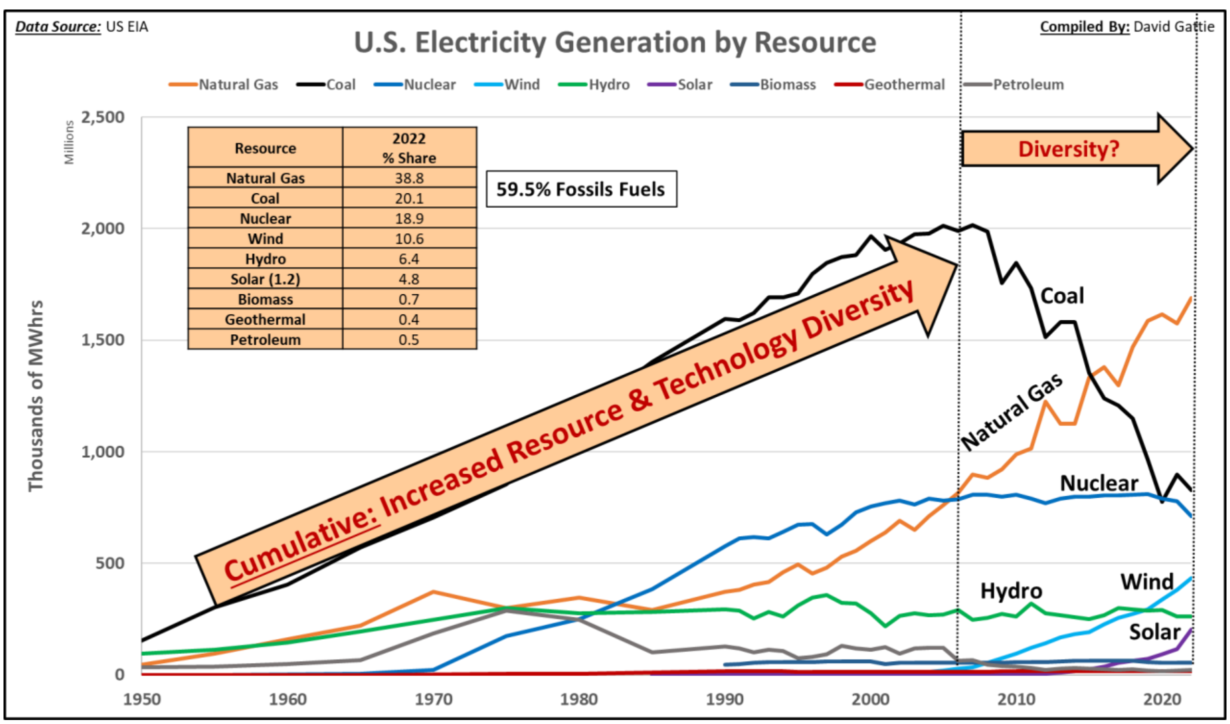

Figure 4. U.S. electric power sector energy resource portfolio trajectory. Data Source: U.S. EIA, 2023c.

Reducing domestic U.S. carbon emissions will be achieved on the input side of the economy, the output side of the economy, or both. Decreasing emissions on the input side translates to reducing fossil fuel consumption through greater efficiency and conservation measures or divesting from fossil fuels altogether. Decreasing emissions on the output side translates to direct air capture technology or carbon capture from emissions, followed by utilization and storage of the captured CO_2. Reforestation and reducing deforestation are also high value prospects for increasing CO_2 uptake. The pathways and mechanisms the U.S. chooses for carbon reduction are critical as they will determine the extent to which the input side and output side are emphasized. In a climate-centric energy transition framework, with the governing objective being to reduce domestic CO_2 emissions by whatever means is technologically possible and economically feasible, it may be inconsequential as to whether the U.S. focuses on the resource side or the emission side. However, it isn't inconsequential as decarbonization of the resource base reduces diversity, thus impacts the U.S. energy sector's resiliency by limiting its options and capacity to respond to perturbations and disturbances—domestic and foreign. Therefore, energy resource diversity should be prioritized as an anchor for national security.

Given the importance of resource diversity in the power sector and the limited impact of the U.S. electric power sector on global carbon emissions, efforts to reduce carbon emissions by way of reducing or eliminating fossil fuels from the power sector should be evaluated within the context of the security benefits of resource diversity. As such, in deliberating an energy transition, U.S. legislators and policymakers should give serious policy consideration to establishing a fossil fuel resource baseline (a lower threshold), below which the U.S. will not allow its power sector or its overall energy sector to drop as the loss of diversity will create risks and vulnerabilities. Moreover, diversity of energy resources and energy technologies within the U.S. economy also affords opportunities for the U.S. to remain engaged with developing economies as a trusted and reliable energy partner, thus allowing the U.S. to serve in a key leadership role in carbon-constrained economic development.

In general, U.S. policymakers should be asking a couple of key questions: "Does the energy transition lead to greater resource diversity, thus greater flexibility to respond to disturbances"? And, "would a diluted, less-diverse energy resource base constitute a more secure U.S. economy, an increased capacity to respond to disturbances and greater national security"?

3.2. Defining U.S. climate leadership: Global engagement

America has played an outsized leadership role in the rules-based international order it led the establishment of following World War II—economically, diplomatically, technologically and militarily—with the priority always being to provide domestic security and enhance global conditions for international peace and security. Particularly for U.S. allies and other democratic nations seeking to live and abide by the rule of law, respect for human rights and free and open trade. Given the domestic and global implications of climate change, many are looking to America to continue that outsized leadership role.

Climate leadership is being defined based on setting and meeting various goals and objectives as well as various carbon reduction tactics such as establishing a price on carbon, deploying renewables, shifting from internal combustion engines to electric vehicles (EVs), divesting from fossil fuels and raising climate ambition by way of climate pledges and encouraging other countries to make pledges. (U.S. EPA, 2013; White House Briefing Room, 2021d; Della-Rocca, 2022). The announcement in 2019 that the U.S. would withdraw from the Paris Agreement, was sharply criticized as an abandonment of climate leadership, prompting some U.S. states and local governments and some within the private sector to develop their own carbon-reducing plans (Allen, 2018; Wemer, 2019; Ricketts, et al, 2020). Following the election of President Biden, the acts of rejoining the Paris Agreement, appointing a Special Presidential Envoy for Climate and reengaging in international climate change summits have been characterized as the U.S. resuming a global leadership role in climate change (Beitsch, 2020; Chemnick, 2021; Friedman, 2021). Climate leadership, then, is somewhat subjective as it comes from various perspectives. So much so that China has been looked at as providing global leadership in climate action, based largely on having become a world leader in solar PV and wind, and China's pledge to be carbon neutral by 2060. (Savage, 2019; Macmillan-Fox, 2020; Rudd, 2020; Ritter, 2021; You, 2021). However, China leads the world in fossil fuel consumption and carbon emissions, and recently announced it would be adding 300 million tons of coal production capacity because coal remains China's top priority for energy security (Bloomberg News, 2022). Meanwhile, from 2000-2020, the U.S. led the world in reducing carbon emissions with total U.S. CO_2 emissions in 2022 being at 1987-88 levels and CO_2 emissions from the U.S. electric power sector at 1983-84 levels (Figures 5 & 6).

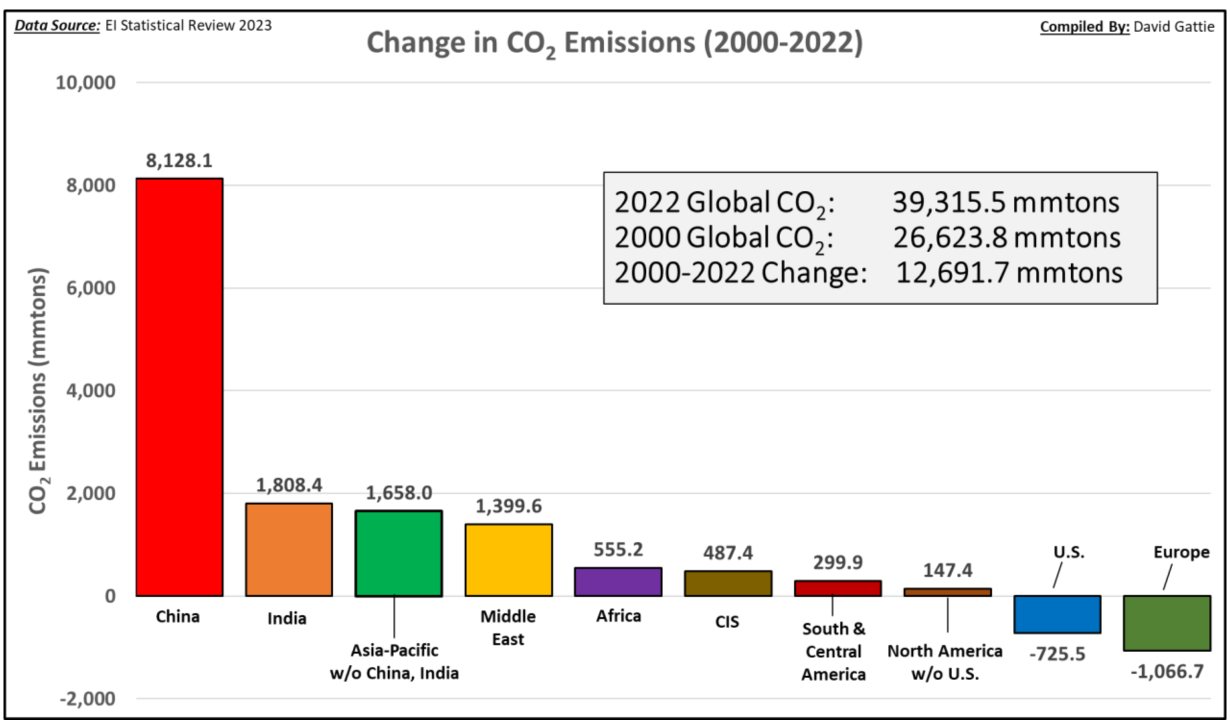

Figure 5. Global CO_2 emissions, by region, from 2000-2022. Data Source: (Energy Institute 2023 Statistical Review of World Energy).

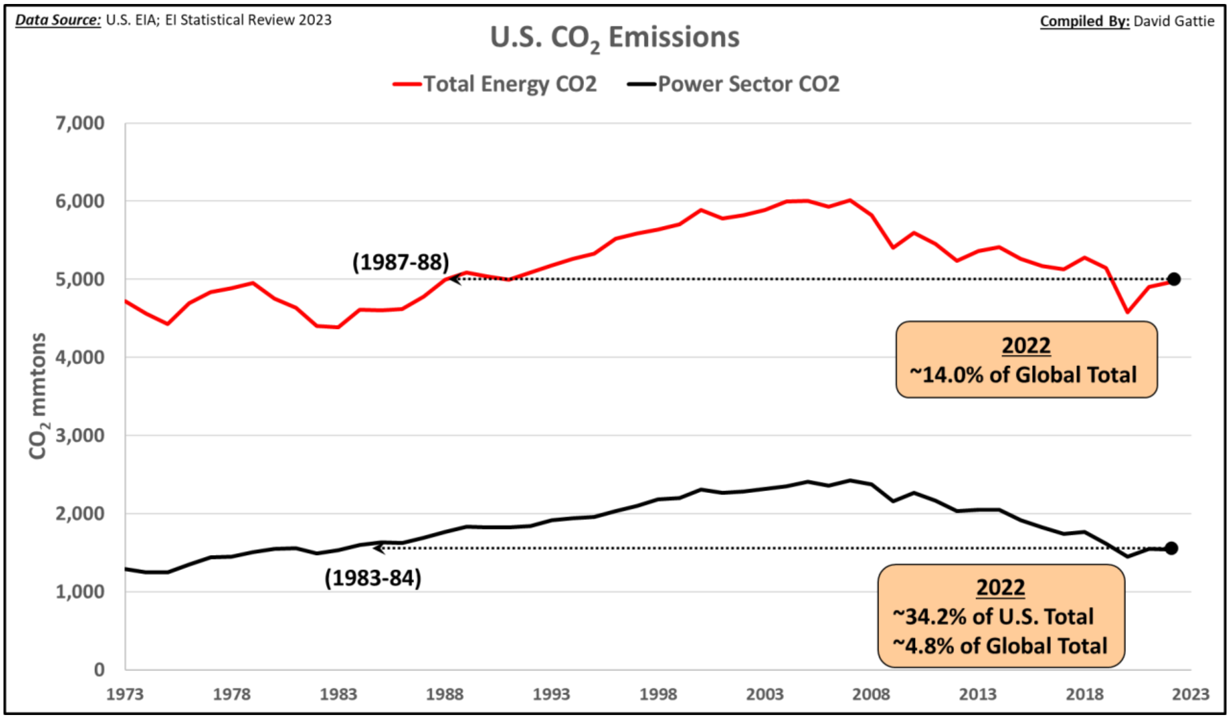

Figure 6. U.S. CO_2 emissions trends for total energy and the electric power sector. Data Source: U.S. EIA, 2023a, 2023c.

Even though U.S. CO_2 emissions are trending downward, the U.S. energy debate is often framed in reference to cumulative emissions, dating back to the Industrial Age, with the U.S. pointed at as having emitted more CO_2 than any other country in history. (Gillis and Popovich, 2017). This is a fact, and it's used as the basis for arguing that the U.S. should demonstrate climate leadership by transitioning away from fossil fuels and toward renewable energy, with some even proposing climate reparations. (Táíwò and Cibralic, 2020; Chaudhary and Rathi, 2021; Detrixhe, 2021; Evans, 2021; Sengupta, 2021). However, viewing America's energy legacy since the late 18th century through the lens of late 20th century and early 21st century climate science dismisses historical context and realities. Carbon emissions aside, fossil fuels have been central to lifting hundreds of millions out of poverty, particularly since WWII. Moreover, fossil fuels and fossil fuel technologies have underpinned America's own energy security and national security, as well as its capabilities to help ensure a more secure international environment for other countries to pursue energy security and economic development. Criticizing historical U.S. fossil fuel consumption based solely on carbon emissions overlooks the economic and national security value that has been extracted from those energy resources.

As such, without thoroughly evaluating the national security implications of reorienting the world's largest economy away from the resources on which it was established, America's carbon emission legacy is insufficient rationale for contending that the U.S. should demonstrate climate leadership by unilaterally divesting from fossil fuels. At the same time, the fact that the U.S. has led the world in reducing carbon emissions since 2000, is insufficient grounds for contending that the U.S. shouldn't play an outsized leadership role in addressing climate change in the 21st century. The U.S. should provide leadership on climate, but not because of a self-imposed guilt from legacy CO_2 emissions. Instead, the U.S. should provide climate leadership on the same grounds it has provided leadership in other global matters for the past seventy-five years. That being, for the overall purpose of security—energy security, national security and international security of allies, democratic nations and emerging economies. This then raises the question of how to define or characterize America's climate leadership role.

3.2.1. Leadership through engagement: energy resources and technologies

Though the prices of solar PV, wind turbines and battery storage have declined over the past twenty years, fossil fuel consumption continues to grow. So much so, it has been likened to an addiction from which countries have a difficult time withdrawing. (Tollefson, 2018; Hood, 2022; Idzelis, 2021; Millard, 2021; Piggot and Erickson, 2022). This has been attributed to, among other factors, fossil fuel subsidies, carbon lock-in from the existing inertia of fossil fuel energy systems and high levels of economic growth that outpace the capacity for renewable energy penetration. However, to characterize developing regions of the world as being addicted to fossil fuels is a simplification that misses some of the underlying rationale. It's not the fossil fuels these countries are addicted to—it's the reliability, accessibility and affordability of fossil fuels and the near-term economic development that these resources support. While fossil fuels will remain as targets for exclusion within a climate-centric, carbon-constrained framework, they are projected to retain a central role in the drive for economic security and energy security unless an alternative energy resource technology with similar reliability characteristics is available (UN News, 2021). And currently there is only one such technology—nuclear power.

Developing economies understand that reliable energy resources are the foundation on which the world's most advanced economies were industrialized, and they're sending signals they need access to these resources to advance their own economic development. At the 2021 Conference of Parties in Glasgow (COP26), initial drafts of the Glasgow Climate Pact referred to a "phase-out" of coal-fired power. India and China, however, intervened and demanded that it be rephrased as a "phase-down" of coal—and it was rephrased (Hook, et al., 2021; Mathiesen, 2021). At the 2022 CERAWeek, leaders from some of the least-developed regions of the world conveyed that they prefer to be left out of the world's push to transition to renewable energy (Tigue, 2022). This is due to not only the reliability mismatch between fossil fuels and renewable energy, but also because some of these countries are looking to leverage revenue streams from oil and natural gas production. On a more complex geopolitical level, India, as of the date of this writing, has resisted diplomatic pressure from the U.S. and the West to impose sanctions as a response to Russia's invasion of Ukraine, opting instead to continue purchasing cheap Russian oil and natural gas. (Martinez and Frayer, 2022; Sharma, 2022). As for China, Russia is China's number three supplier of natural gas and number two supplier of oil (Reuters, 2022).

The clearest signal being sent by emerging economies is the trend of fossil fuel consumption relative to renewable energy. Growth in renewable energy is often referenced as a key indicator that the global energy transition is well underway, particularly growth in solar and wind. However, for twenty-one of the world's top emerging economies[1] fossil fuel consumption is outpacing the growth of non-hydro renewables (Figure 7). This does not include China. While there was a downturn in fossil fuel consumption during the pandemic year of 2020, the International Energy Agency (IEA) projected in its Global Energy Review 2021 that almost 70% of the global increase in energy demand would be in emerging markets and developing economies (IEA, 2021).

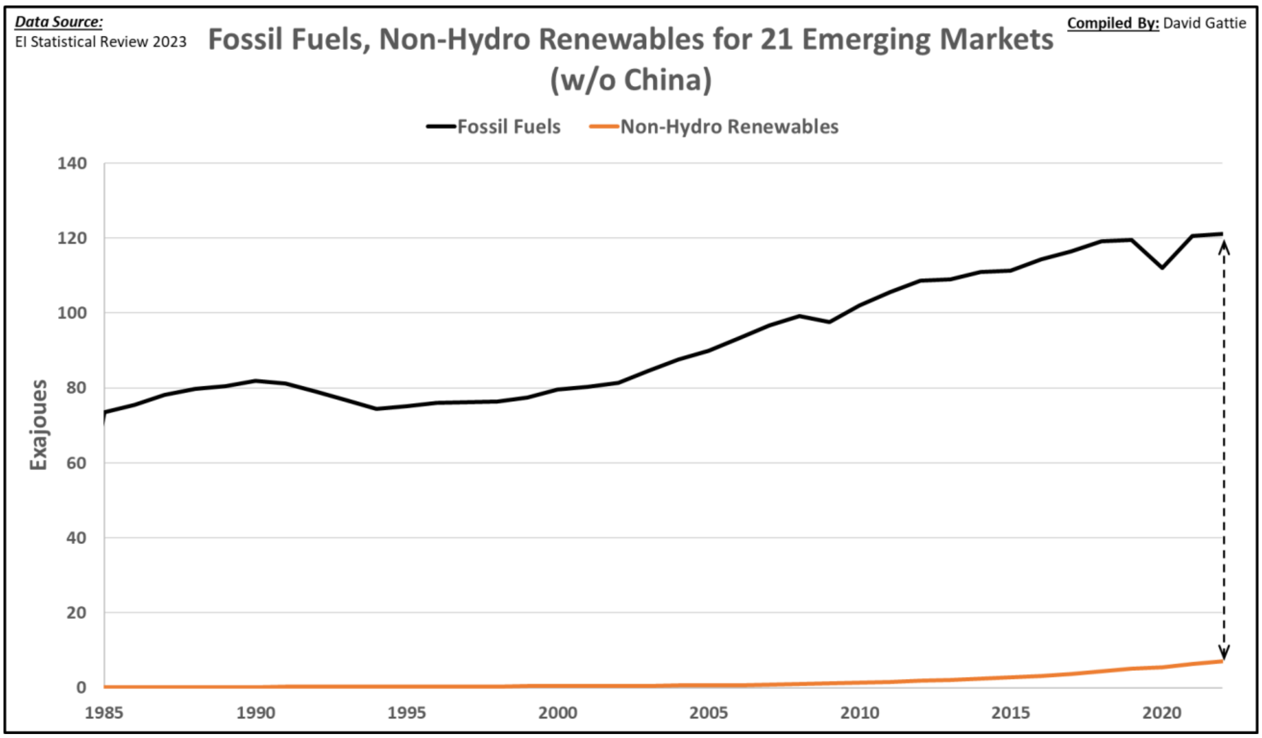

Figure 7. Fossil fuel and non-hydro renewable energy trends for emerging markets. Data Source: (EI Statistical Review of World Energy, 2023).

As for the global distribution of countries with the highest penetration of renewables, solar and wind power accounted for 4.5% and 7.2%, respectively, of global power generation in 2022 (EI Statistical Review, 2023). Of this, ten countries accounted for 80.1% of total global solar generation and ten countries accounted for 79.3% of total global wind generation (Tables 2 & 3). A more detailed analysis shows that the countries currently dominating solar and wind generation represent over 60% of global gross domestic product, meaning a level of wealth and economic capacity not necessarily shared by lesser-developed nations. More to the point of the value of a diverse and reliable energy resource base, each

[1] These twenty-one emerging economies are recognized as such by the International Monetary Fund. https://www.imf.org/en/Publications/WP/Issues/2022/02/18/Emerging-Markets-Prospects-and-Challenges-513389

of these countries has an electric power energy portfolio foundation of fossil fuels, nuclear and hydro on which to stand and deploy intermittent solar and wind. The precedent being that growth in renewables follows the establishment of an energy portfolio on which an economy can develop and that eventually can support intermittent energy resources. As of yet, there is no precedent for industrializing an economy with renewables as the foundation—something emerging economies recognize.

Country	Solar Generation	Total Generation (2022)	
	2022 Share of World Total (%)	Fossil Fuels & Nuclear (%)	Fossil Fuels, Nuclear & Hydro (%)
China	32.3	69.1	83.9
US	15.6	78.2	83.9
Japan	7.7	69.8	77.0
India	7.2	79.4	88.8
Germany	4.6	51.9	54.9
Australia	2.9	66.6	72.9
Spain	2.6	57.0	63.2
Brazil	2.3	12.3	75.4
Italy	2.1	63.9	73.7
South Korea	2.0	91.1	91.6
Subtotal	**79.3**		

Table 2. Global leaders in solar generation. Data Sources: (EI Statistical Review of World Energy, 2023).

Country	Wind Generation	Total Generation (2022)	
	2022 Share of World Total (%)	Fossil Fuels & Nuclear (%)	Fossil Fuels, Nuclear & Hydro (%)
China	36.2	69.1	83.9
US	20.9	78.2	83.9
Germany	6.0	51.9	54.9
Brazil	3.9	12.3	75.4
India	3.3	79.4	88.8
Spain	3.0	57.0	63.2
France	1.8	74.2	83.7
Canada	1.8	31.0	91.4
Turkey	1.7	57.5	78.1
Australia	1.5	66.6	72.9
Subtotal	**80.1**		

Table 3. Global leaders in wind generation. Data Sources: (EI Statistical Review of World Energy, 2023).

Regarding America's climate leadership role, the U.S. is the world's largest and most highly industrialized economy. But, what the U.S. can do to reduce carbon emissions doesn't necessarily translate to emerging economies as they aren't looking for an energy transition—they're looking for energy traction. Therefore, unilateral reduction in U.S. carbon emissions isn't inherently synonymous with global leadership on climate change if other countries can't follow, or won't follow. While America debates the energy resources that will power its 21st century economy and discusses a transition away from fossil fuels for climate reasons, emerging economies are increasing their dependence on fossil fuels and moving in the opposite direction for energy security and economic security reasons. This is the same direction as that of authoritarian powers such as China and Russia, both of which are leveraging energy resources and energy technologies as instruments of national power. There are geopolitical implications associated with emerging economies moving in the same energy direction as authoritarian countries whose intentions for engaging with the developing economies of the world are fundamentally different than those of the U.S. and its democratic allies. As such, any U.S. energy transition should take these geopolitical implications into account, with U.S. climate leadership serving to facilitate energy partnerships in these regions.

It isn't the contention here to dismiss or minimize the impact of carbon emissions on climate change, nor is it the contention here that the U.S. shouldn't play an outsized role in climate leadership. It is the contention, however, that leadership, by definition, is not unilateral—it is a bilateral or multilateral endeavor to achieve common goals. As such, America's outsized role in climate leadership should align with its national security priorities as well as with America's responsibility to help cultivate a more secure global environment for other countries to freely pursue economic development without fear of entanglement with authoritarian powers (Gattie and Hewitt, 2022a). This is particularly challenging as fossil fuel consumption continues to increase in developing economies. Therefore, defining climate leadership and America's role in providing that leadership is no trivial matter as it will have an impact on the trajectory of any U.S. energy transition, thus, implications for the resiliency and security of America's energy sector and America's capacity to engage in global energy collaborations. As such, America's climate leadership should not be decoupled from America's energy security leadership responsibilities. Rather, climate leadership should be embedded within a security-centric, globally-engaged, climate-informed framework focused on partnering with emerging economies, not merely a unilateral divestment from fossil fuels as the near-term objective. There are strategic, geopolitical benefits from the U.S. remaining a trusted energy partner for developing economies, and those benefits should be incorporated into any U.S. energy transition.

As such, a critical energy transition question for the U.S. is: "How will a unilateral U.S. disengagement from fossil fuels impact U.S. capacity to engage with developing economies, and will such a disengagement create energy security risks and vulnerabilities for authoritarian powers to exploit"?

3.2.2. Nuclear power: America's unique security and leadership responsibility

While a U.S. energy transition should ensure resource diversity and include the geopolitical calculus to remain engaged with developing regions of the world in all energy resources and technologies, U.S. leaders must revisit America's security and leadership responsibilities for civilian nuclear power. With the exception of the current construction of two new reactors at Plant Vogtle, in Georgia, USA, new nuclear power construction has been dormant in the U.S. for over thirty years (Figure 8). And it is doubtful that the U.S. or the rest of the world can realistically entertain any notion of a secure low-carbon or carbon-neutral energy future without nuclear power. Consequently, nuclear power is receiving renewed attention due to the realization that it's the only resource and technology capable of providing the reliability of fossil fuels, yet without the carbon emissions. However, the value of America's nuclear enterprise extends beyond climate benefits as the original principles of U.S. civilian nuclear power policy were security-centric (Gattie and Hewitt, 2023; Foreign Relations, 1955).

Following America's development of the atomic bomb during WWII, the U.S. advanced its military and civilian nuclear science, engineering and technology enterprise as a dual-purpose technology to counter America's Cold War great power competitor, the Soviet Union, with the promise of nuclear-powered electricity being leveraged as a means of building partnerships with emerging economies (Gattie, 2018; Gattie, 2020; Gattie and Massey, 2020). While nuclear power's zero-carbon characteristics align with a climate-centric approach to a U.S. energy transition, the security benefits of civilian nuclear should have primacy in America's national security policy and energy policy strategy. Meaning, the U.S. should aggressively pursue a civilian nuclear power strategy that is security-centric and aligned with 21st century geopolitical realities, while being inherently inclusive of climate benefits. This also should accommodate strategic arrangements for allied nuclear partnerships by leveraging existing security alliances such as NATO, Five Eyes and The Quadrilateral Security Dialogue (Gattie and Massey, 2020; McFarlane and Gattie, 2021; Gattie and Hewitt, 2022b).

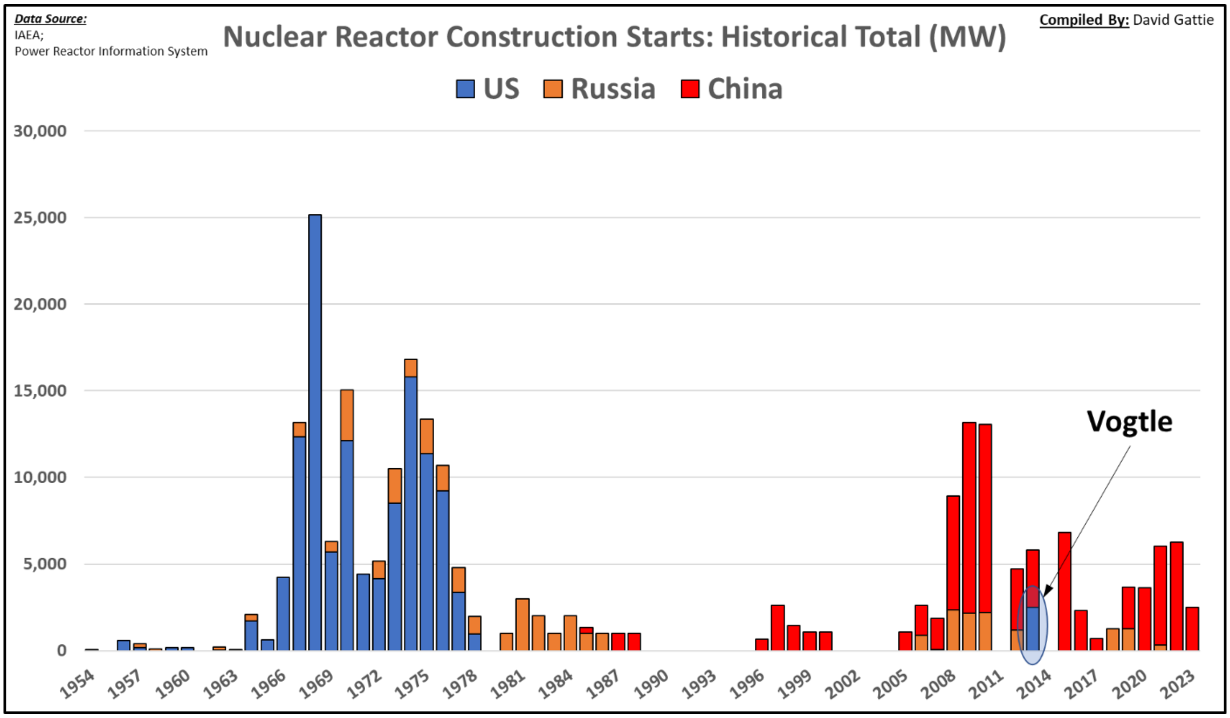

Figure 8. Nuclear reactor construction starts for the U.S., China and Russia. Data Source: International Atomic Energy Agency, 2023b.

Because nuclear power is the stand-alone carbon-free baseload energy resource and technology, it will be a leading candidate for emerging economies seeking low-carbon options—particularly as small modular reactors and microreactors are developed and deployed at economically feasible scales. Since the turn of the 21st century, Russia and China have dominated nuclear construction and have been seen as viable partners for nuclear collaboration. Since nuclear collaborations represent an 80-plus year relationship, the national security implications of the global civilian nuclear power sector being led by an authoritarian nation with geopolitical intentions that do not align with U.S. interests or the liberal international order are sufficient rationale for the U.S. to take an aggressive approach to advanced nuclear technologies (Gattie, et al., 2018; Graham and Mies, 2019; Gattie, 2020; Gattie and Massey, 2020; McFarlane and Gattie, 2021; Joint Statement, 2022). Again, if nuclear is pursued only for its carbon-free characteristics, this falls short of the national security rationale for which nuclear was originally established in the U.S.—a rationale that was agreed upon by U.S. allies and culminated in international standards for civilian nuclear power (IAEA, 2022a). As such, U.S. leaders not only should revisit America's security and leadership responsibilities for civilian nuclear power, they should ensure that any U.S. energy transition shifts nuclear power to the national security lane and restores America's security and leadership responsibilities in nuclear science, engineering and technology. The principled reason being that nuclear power is not simply a market commodity nor is it merely a carbon reduction technology.

This raises key questions: "Is the current disposition of global nuclear deployment, which is dominated by China and Russia, consistent with U.S. national security principles, and does the U.S. have the political will or desire to restore its leadership responsibilities in civilian nuclear technologies"? In addition, "Is America's current disposition in civilian nuclear development and deployment consistent with, and sufficient for, ensuring resilience and security within a carbon-constrained energy transition"?

4. The energy transition time span: Pragmatism over populism

The term "transition", by definition, means a process or period of time when a system is changing from one state to another. An energy transition, then, translates to a process over a period of time when an existing energy system is restructured or reorganized into a new energy system. In the U.S., this has generally been a bottom-up transition driven by innovation and free markets. However, given the current tendency to prioritize climate change and carbon reduction, top-down political forces are having considerable influence. Nonetheless, since this transition phase constitutes a period of reorganization, system properties will be transitional and mixed. Meaning, the transition phase, itself, is at risk of creating conditions of vulnerability that must be accounted for and guarded against (Figure 9).

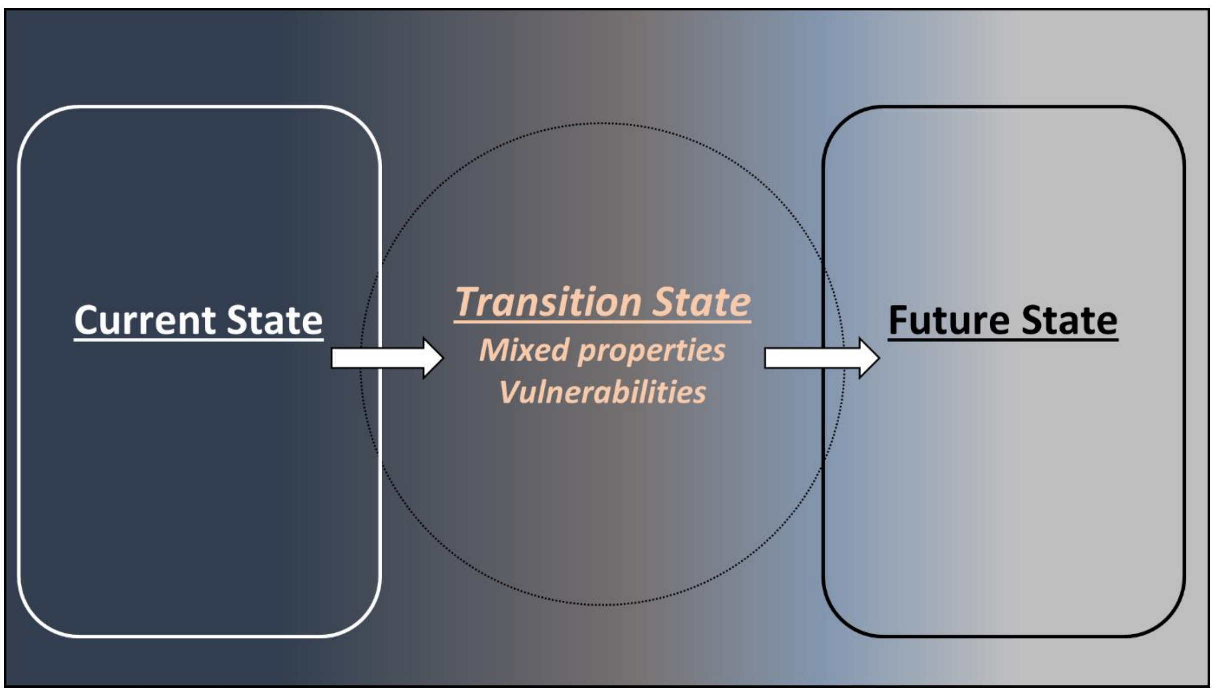

Figure 9. In transitioning from a current state to a future state, the transition state has mixed system properties that create conditions for vulnerabilities.

As discussed previously, America's energy infrastructure emerged over a long period of time through bottom-up competition, innovation and, oftentimes, trial-and-error, with a critical aspect being diversity of energy resources and energy technologies. This has afforded the U.S. with unmatched economic security, energy security and national security, all of which have positioned the U.S. as the leader of the liberal international order for the past seventy-five years. As such, any U.S. energy transition time span, then, should be based on ensuring that the security benefits of the current state are maintained while the carbon reduction objectives for the future state are included. Meaning, security-centric, climate-informed.

However, the U.S. energy transition debate is increasingly being oriented toward domestic carbon reduction at the city, state, federal and corporate levels with climate pledges and target dates proposed for a transition away from fossil fuels to low- and zero-carbon resources. Examples being, carbon-free electricity and 50% reduction in U.S. greenhouse gas emissions by 2030, 100% zero-emission vehicle acquisitions by 2035 and carbon-neutrality by 2050 (Jaglom, et al., 2020; BP Statistical Review of World Energy, 2021; White House Briefing Room, 2021b; White House Briefing Room, 2021c; ExxonMobil, 2022;). Outside the U.S., countries are making similar pledges, with target dates ranging from 2030 to 2070 (McGrath, 2021; Baiyu, 2022). COP26 provided the most recent platform for nations around the world to convene and elevate climate ambition with climate pledges touted as a key outcome (Maizland, 2021; White House Briefing Room, 2021d). The diversity of target dates is relevant, as near-term dates reflect not only a nation's sense of urgency about climate change but also the industrial capacity and economic wherewithal to attempt to reduce emissions sooner than later, as is the case with the U.S. and other advanced economies. The setting of long-term dates for developing countries such as India, South Africa, Brazil, and Indonesia, reflects the reality of emerging regions in need of proven and reliable energy resources for the foreseeable future as these countries industrialize and develop their economies (Enerdata, 2021).

While the U.S. has no legally-binding dates for an energy transition, legislators and policymakers at the city, state and federal levels are debating energy and climate policies that will constitute an energy transition. Therefore, they should exercise caution and critically evaluate two implications of allowing the pace and trajectory of a climate-centric U.S. energy transition to be dictated by a predetermined carbon reduction target date.

First, to impose an artificial transition period over too short of a time span could force step-function changes that render the system brittle, inflexible and vulnerable to disturbances rather than facilitating an emergent transition that allows flexibility and adaptability to unanticipated disturbances. If the transition period time line is populist or politically-motivated, these step-function impacts likely will be exacerbated as top-down energy pledges don't inherently comport, and may very well conflict, with on-the-ground energy realities. As such, domestic energy and climate politics and populism are poor substitutes for an energy transition as they lack strategic rationale and do not necessarily align with the geopolitical realities of energy security—domestic or global. This is not to marginalize the existential threat of climate change. It is, rather, to put the threat of climate change into the broader and more primary context of security.

California may serve as a U.S. example of optimizing a state's power generation energy portfolio for carbon reduction without sufficient consideration of the transition period. Currently, California has a single 60 MW coal-fired plant and, in 2013, the San Onofre nuclear plant ceased operation (U.S. EIA, 2022d). This leaves the state with one nuclear facility, Diablo Canyon, which is scheduled to cease operation in 2025. Meanwhile, in 2018, California set an ambitious renewable portfolio standard to procure 60% of retail electricity sales from renewables by 2030 (California Legislative Information, 2018). Consequently, California is orienting its energy sector toward low density resources and an energy technology portfolio with reduced diversity in operational characteristics—specifically, reduced baseload. While carbon reduction objectives are worthwhile, California has experienced grid resiliency issues due to insufficient capacity during periods of high electricity demand and extreme weather and has some of the highest residential electricity rates in the country (Denning, 2021; Hawkins, 2021).

On the global level, Germany's commitment to wean itself off of fossil fuels, shut down its nuclear plants and transition its electric power sector to 100% renewable energy has been accompanied by a dependency on Russian natural gas and the construction of Nord Stream 2, which was eventually abandoned in the wake of the Ukraine invasion (Eckert and Abnett, 2022; Gehrke, 2022; Tan, 2022). Here, top-down political pressure to force Germany's power sector to meet end goals did not account for the security consequences of an energy transition that depended on an authoritarian power for energy supplies.

Second, in setting a climate-centric timeline, the U.S. is announcing to the world, including great power competitors China and Russia, that the world's largest economy and military superpower is restructuring its energy infrastructure to meet the primary objective of reducing carbon emissions. If that translates to a shift towards greater dependency on renewable energy and divestment from fossil fuels, U.S. policymakers should assess the security risks of an unprecedented U.S. retreat from a global energy network dominated by fossil fuels—a global network in which the U.S. currently has substantial leverage and influence in oil and natural gas, but little to show for civilian nuclear power collaborations. The invasion of Ukraine has brought into sharp relief the tenuous nature of global energy interdependencies and the risks and vulnerabilities of being dependent on an authoritarian power for energy supplies (Gattie and Hewitt, 2022a; Gattie and Hewitt, 2022b). It also has highlighted the geopolitical implications of energy security as Russia's weaponization of oil and natural gas is hindering the European Union from sanctioning Russian energy (Casert, et al., 2022). Fortunately, the U.S. is in a position of fossil fuel self-sufficiency to not only sanction Russian oil, but also work towards increasing U.S. supplies of natural gas to Europe. This has highlighted the global nature of energy interdependencies and it can only be speculated as to what the U.S. response would be, or even could be, if it had already unilaterally reduced, if not eliminated, its fossil fuel production to the extent it had no international leverage or influence. As stated previously, unilateral divestment from fossil fuels isn't inherently climate leadership if other nations can't follow. Moreover, if the U.S. retreats from fossil fuels without an aggressive effort to reclaim global leadership in civilian nuclear power, the geopolitical risks and vulnerabilities escalate.

5. Conclusion

The time span for transitioning what has been the world's largest economy and, arguably, most important industrial and military power since WWII, should not be anchored to political pledges for reaching a carbon emission reduction level by a pre-specified target date. The unintended consequences of a top-down forcing function such as this are incalculable. Rather, the U.S. energy transition debate should be reframed within the context of global realities and great power competition where energy is not merely a market commodity or a climate change issue—rather, it's a deeply entrenched economic and national security issue and a systemic geopolitical issue with domestic and global implications. To this end, this paper has proposed several questions that should be addressed in any discussion of a U.S. energy transition:

- Will a climate-centric U.S. energy transition that's focused on domestic carbon reduction also afford the U.S. with the capacity to stand up its economy with the energy security and national security it expects and to which it is accustomed?
- Will the proposed transition increase resiliency and security within the U.S. energy and electric power sectors?
- Does the energy transition lead to greater resource diversity, thus greater flexibility to respond to disturbances (domestic and global), and is the transition time span conditioned upon geopolitical realities and broader international security responsibilities?
- Would a diluted, less-diverse energy resource base with high penetrations of renewable energy constitute a more secure U.S. economy and greater national security?
- Given America's marginal global engagement in civilian nuclear power, will a unilateral U.S. disengagement from fossil fuels impact U.S. capacity to engage with developing economies, and will such a disengagement create energy security risks and vulnerabilities for authoritarian powers to exploit?
- Is the current disposition of global nuclear deployments, which is dominated by China and Russia, consistent with original U.S. national security principles, and does the U.S. have the political will or desire to reestablish its leadership responsibilities in civilian nuclear technologies?
- Is America's current disposition in civilian nuclear development and deployment consistent with, and sufficient for, ensuring resilience and security within a carbon-constrained energy transition?

Carbon reduction goals are important, but ensuring that America's energy transition phase is security-centric should dictate how and when those goals are achieved. Therefore, to optimize for a reliable and secure U.S. energy infrastructure under low-carbon constraints and maintain America's relevance, influence and leverage in the global energy and energy technology network, it is recommended, here, that the U.S energy transition be:

1. Organized for maximum energy resource and technology diversity, thereby ensuring resilience during times of disturbances (global and domestic) and the flexibility to respond to disruptions in the domestic and international supply chains that support those resources and technologies,
2. Empathetic to, and capable of engaging with, emerging economies in need of partnerships for developing and deploying reliable, low- and zero-carbon energy resources and technologies to meet their economic objectives, and
3. Adaptable to shifting geopolitical conditions that require an immediate U.S. response of engagement or intervention in the event that authoritarian powers leverage energy or energy technologies as an instrument of national power.

Fundamental to this will be the diversity of America's energy resource portfolio and energy technology capabilities throughout the transition phase. On the energy resource side this should include all fossil fuels, nuclear power and renewable energy. On the technology side this should include combined-cycle natural gas plants, carbon capture utilization and storage, particularly for existing coal plants, supercritical and ultra-supercritical coal plants, advanced nuclear power, solar PV, wind turbines, EVs and battery technologies. Therefore, it is recommended here that any U.S. energy transition include a fossil fuel baseline (a lower threshold) below which America will not allow its energy and electric power sectors to drop. Moreover, America's approach to its civilian nuclear enterprise should be reorganized to meet 21st century geopolitical conditions (Bhambhani, 2020a; Bhambhani, 2020b; Gattie, 2020; Gattie and Massey, 2020). And the objective of this reorganization should be nothing short of restoring U.S. leadership in its civilian nuclear science, engineering and technology enterprise and building out the capacity to compete with authoritarian powers in nuclear partnerships and deployment of advanced nuclear technology abroad—particularly in emerging economies and particularly in partnership with U.S. allies.

In summary, throughout U.S. history, diverse energy resources and energy technologies have been foundational to U.S. economic security, energy security and national security and have underpinned America's rise as the world's largest industrialized economy, greatest military power and leader of the liberal international order. These are the minimal properties that should be maintained through any U.S. energy transition. As such, America's energy transition to a lower-carbon energy economy should be security-centric, globally-engaged and climate-informed while sustaining the preferred system properties of the current state (Figure 10).

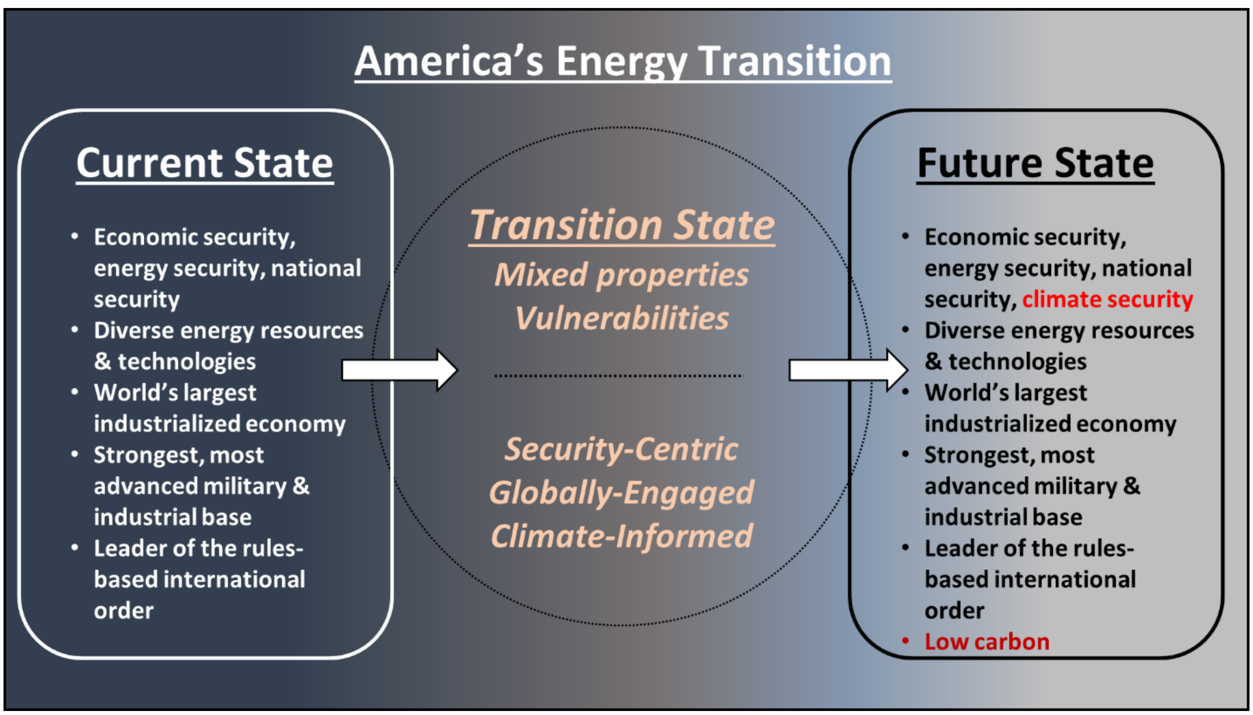

Figure 10. A security-centric, globally-engaged, climate-informed framework for America's energy transition to ensure that existing properties of economic security, national security, resource diversity, military might and global leadership are maintained.

At some future date America's energy infrastructure may be zero-carbon, it may be completely weaned off of fossil fuels and it may even be 100% renewable energy. However, on principles of national security and America's global responsibilities, this should not be pursued unilaterally. Moreover, it may constitute hubris for America to use top-down carbon reduction pledges to force on the U.S. economy a climate-centric transition that's anchored to a pre-determined date and cannot account for future global conditions and geopolitical realities. Such an approach may reflect what America can do to reduce carbon emissions by a certain date under narrow constraints and conditions. However, what America can do with its energy and electric power sectors to reduce carbon emissions is not necessarily what America should do with its energy and electric power sectors to ensure energy security, economic security and national security.

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America's Energy Resources & Industrial Base
Prioritizing National Security and Relative Advantage in 21st Century Strategic Competition

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TESTIMONY BEFORE THE U.S. HOUSE OF REPRESENTATIVES ENERGY AND COMMERCE COMMITTEE

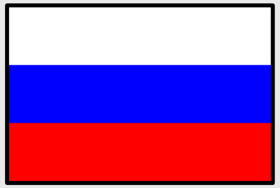
DECEMBER 5, 2023

Relative, Strategic, Competitive Advantage

The capacity and ability of one actor to achieve their objectives compared to a competitor or competitors

Economic, Military, Technological, Geopolitical

Photo NDU



"The United States has entered an era of long-term competition with revisionist powers. A key aspect of this competition will revolve around a contest for technological superiority waged between the national innovation bases of the respective competitors. The outcome of this competition will determine not just American national security but also how the nations of the world interact—and whether a free and open political and economic system will remain the foundation of those interactions."

(The Contest for Innovation: Strengthening America's National Security Innovation Base in An Era of Strategic Competition, *Ronald Reagan Institute*, 2019)

ENERGY AND THE U.S. INDUSTRIAL BASE

America's industrial base is the platform on which US economic security and national security stand and from which the US projects national power globally. It was built, and currently stands, on a diverse energy resource base of fossil fuels, nuclear power and renewables along with the diverse technologies that extract work from these resources. America has leveraged these resources and technologies to establish an industrial base advantage relative to its geostrategic competitors.

The PRC as America’s Pacing Challenge

*While Russia constitutes an immediate and acute threat…”the PRC, by contrast, is the only competitor with both the intent to reshape the international order and, increasingly, the economic, diplomatic, military, and technological power to advance that objective”**

*“The PRC presents the most consequential and systemic challenge, while Russia poses acute threats—both to vital U.S. national interests abroad and to the homeland. PRC efforts and activities to contest the rules-based international order make it the pacing challenge…”***

*Biden, J. (2022). National Security Strategy. *The White House*, 23.

**National Defense Strategy of the United States of America. (2022). *U.S. DoD*.

AMERICA’S RELATIVE ADVANTAGE IS BEING CHALLENGED

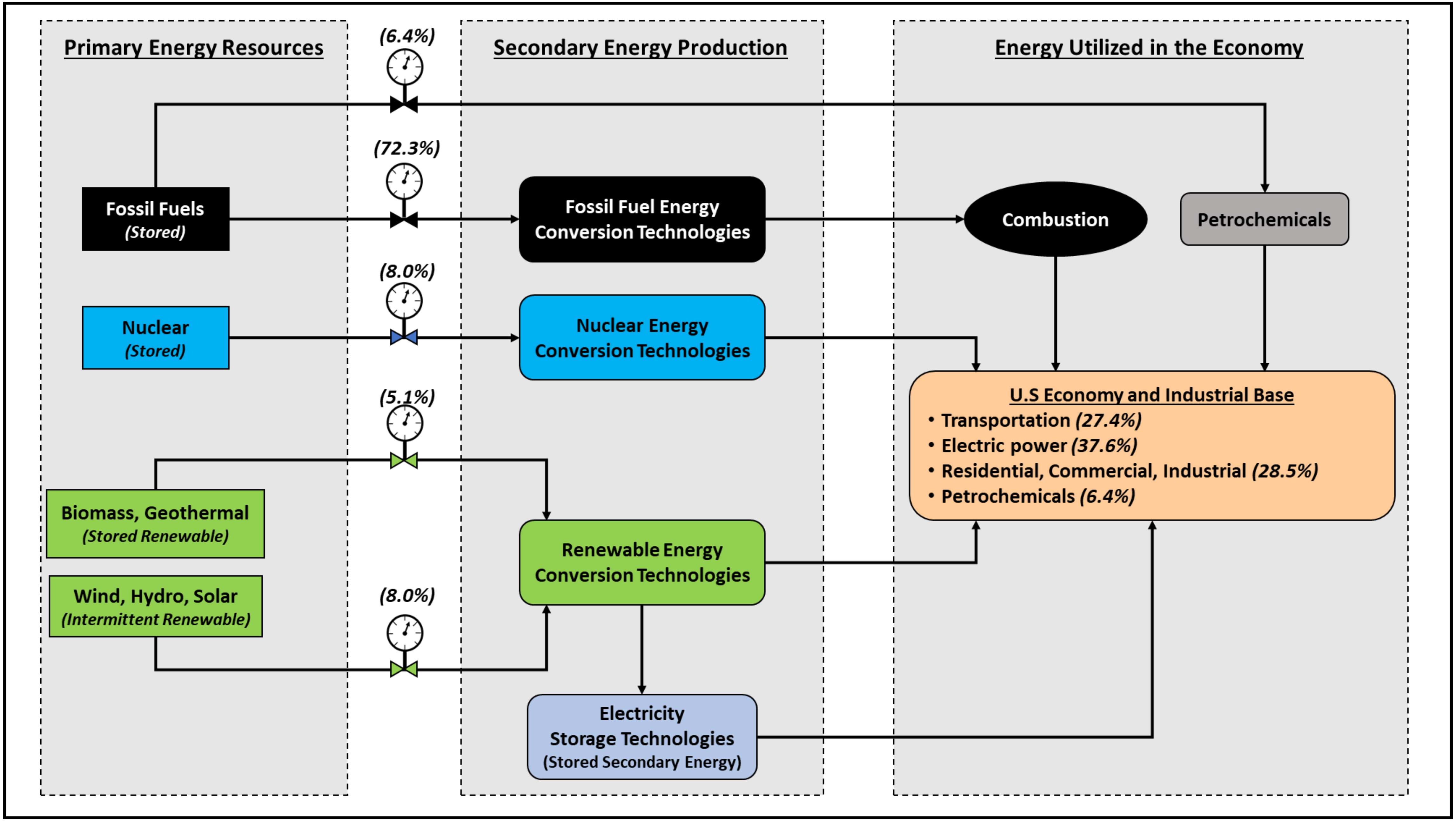
“Both nations [China and Russia] seek military and technological superiority over the U.S. and will continue attempts to overcome competitive disadvantages by fusing their national capabilities to destabilize the international order. We will be fully engaged in great power competition with China and Russia…” “PRC efforts and activities to contest the rules-based international order make it the pacing challenge…”

(*US DoD, 2020. Preserving Our Competitive Advantage, Personnel and Readiness Strategy for 2030; 2022 National Defense Strategy*)

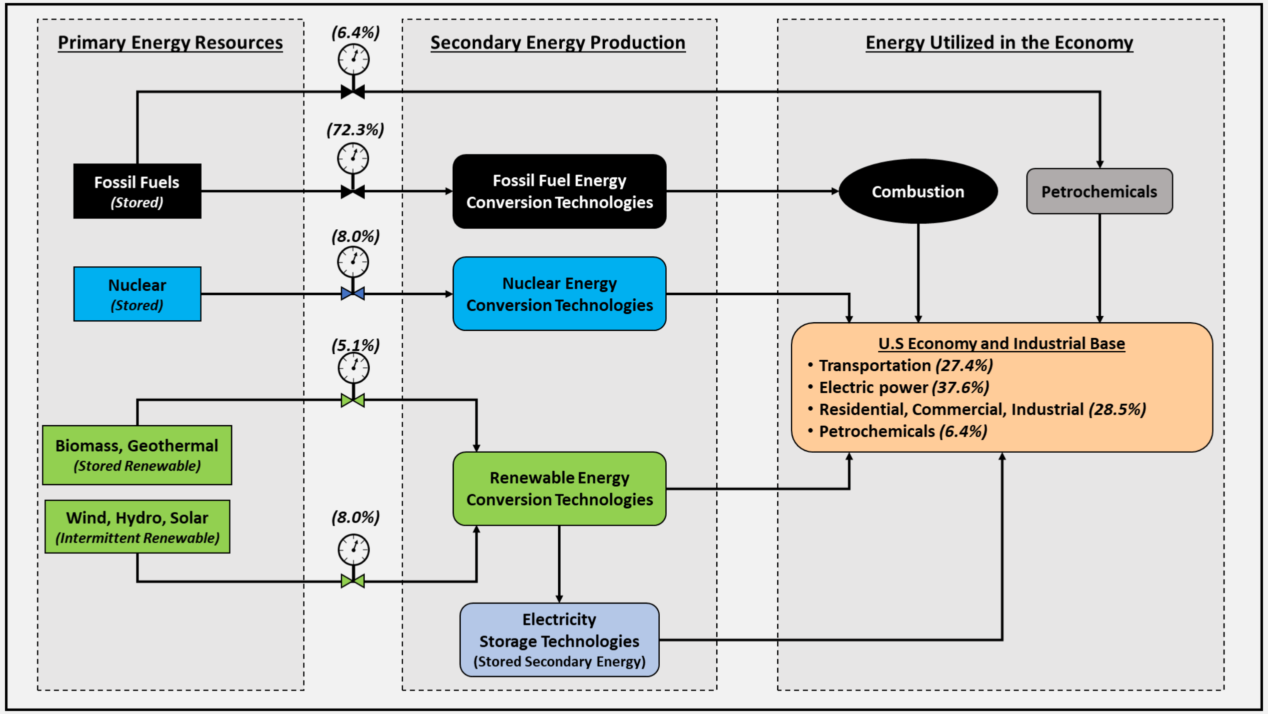
A Driving Question That Should Be Answered

If, in an effort to battle global climate change, the U.S. decarbonizes its economy by transitioning away from fossil fuels to an increased dependency on renewables and does so without an aggressive effort to expand nuclear power:

- Will the U.S. be in a stronger industrial and geopolitical position to counter 21st-century geopolitical competitors intent on displacing the U.S. as the world's greatest superpower—particularly, its pacing challenge, the PRC?

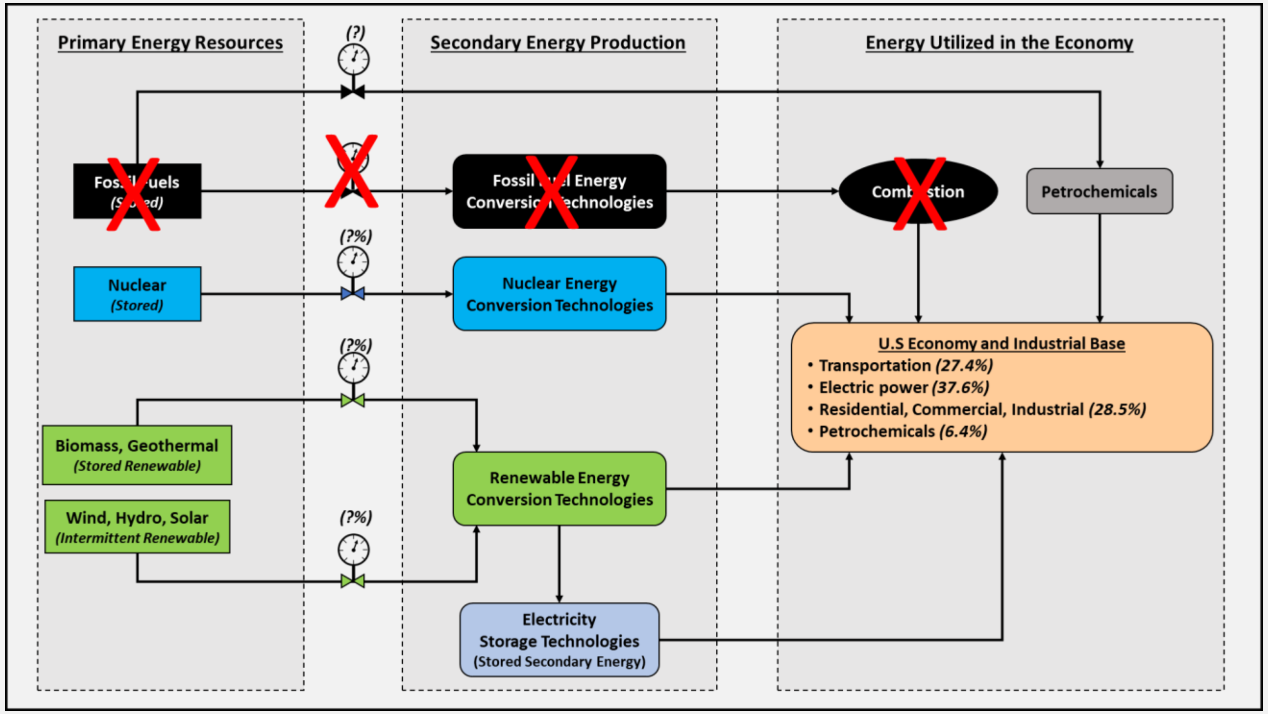


Primary Energy Resources
Secondary Energy Production
Energy Utilized in the Economy
(6.4%)
(72.3%)
(8.0%)
(5.1%)
(8.0%)
Fossil Fuels
(Stored)
Nuclear
(Stored)
Biomass, Geothermal
(Stored Renewable)
Wind, Hydro, Solar
(Intermittent Renewable)
Fossil Fuel Energy
Conversion Technologies
Nuclear Energy
Conversion Technologies
Renewable Energy
Conversion Technologies
Electricity
Storage Technologies
(Stored Secondary Energy)
Combustion
Petrochemicals
U.S Economy and Industrial Base
• Transportation (27.4%)
• Electric power (37.6%)
• Residential, Commercial, Industrial (28.5%)
• Petrochemicals (6.4%)



This transcends fuel-switching. This is a divestment of stored, domestic primary energy resources with high heating values that cannot be replaced by intermittent, weather-dependent renewables. It also shifts stored energy from that of a natural resource to a manufactured product dependent on access to, and processing of, minerals and metals.

A fundamental transition, restructuring and reorganization of America's industrial base and electric power sector.



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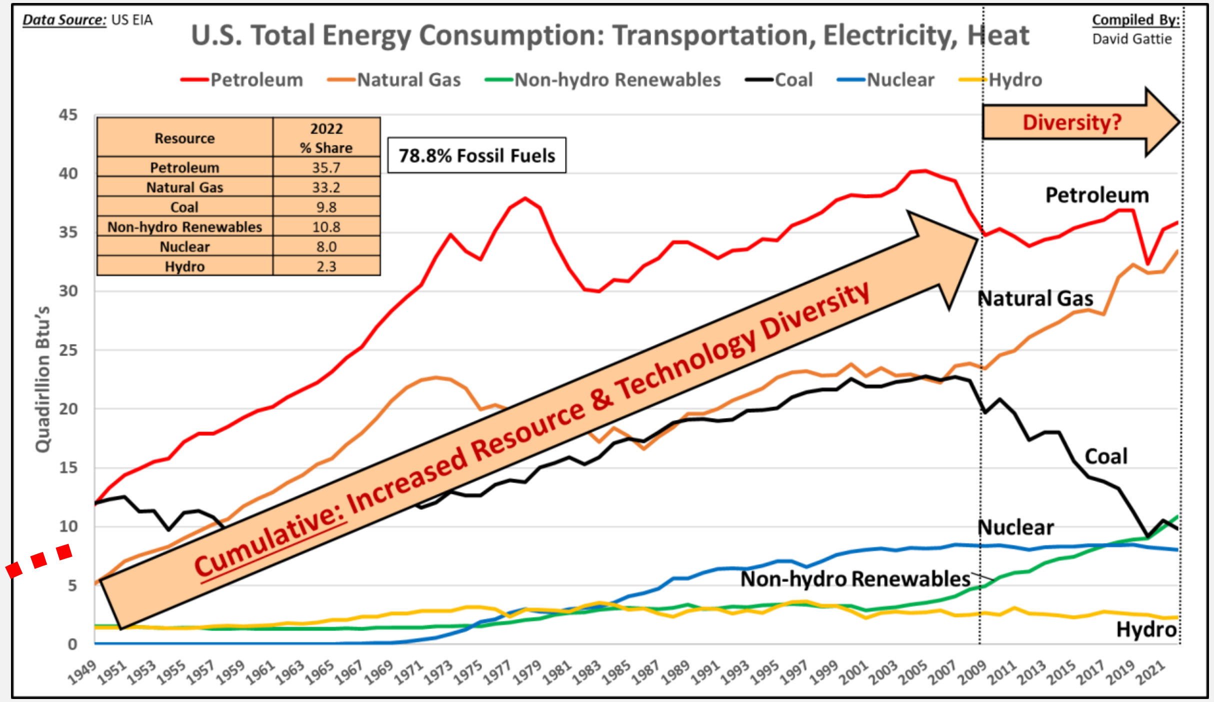
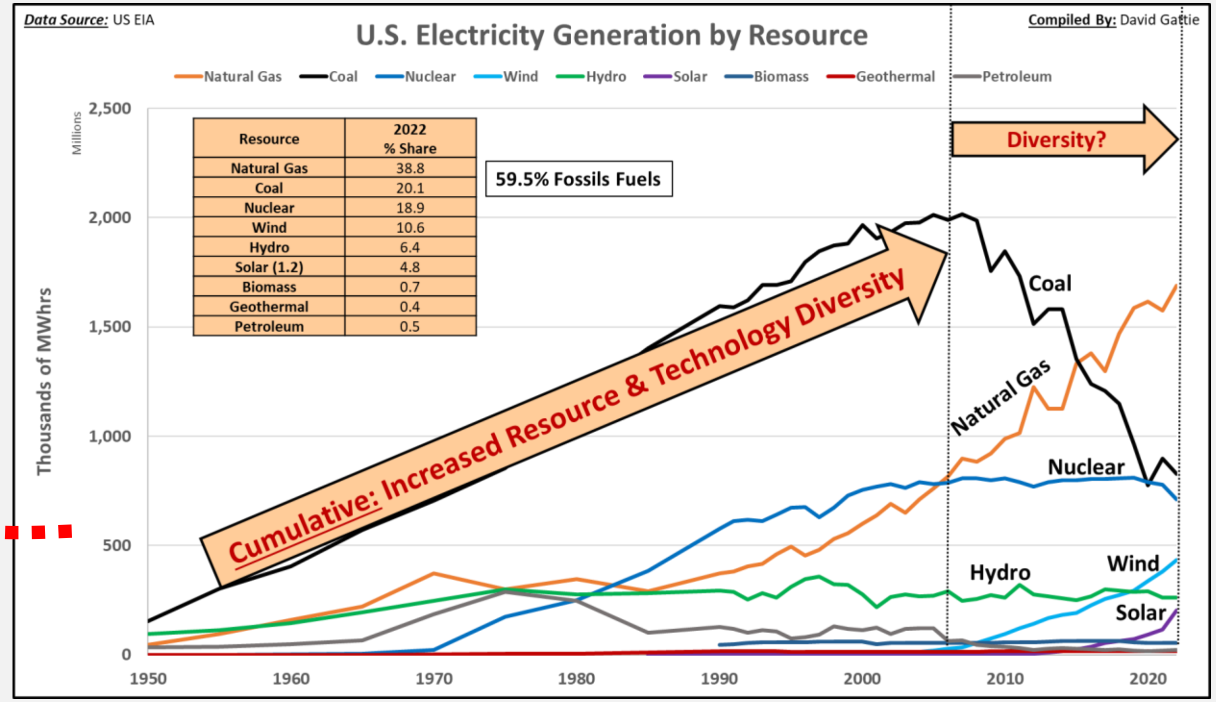
America's Energy Legacy

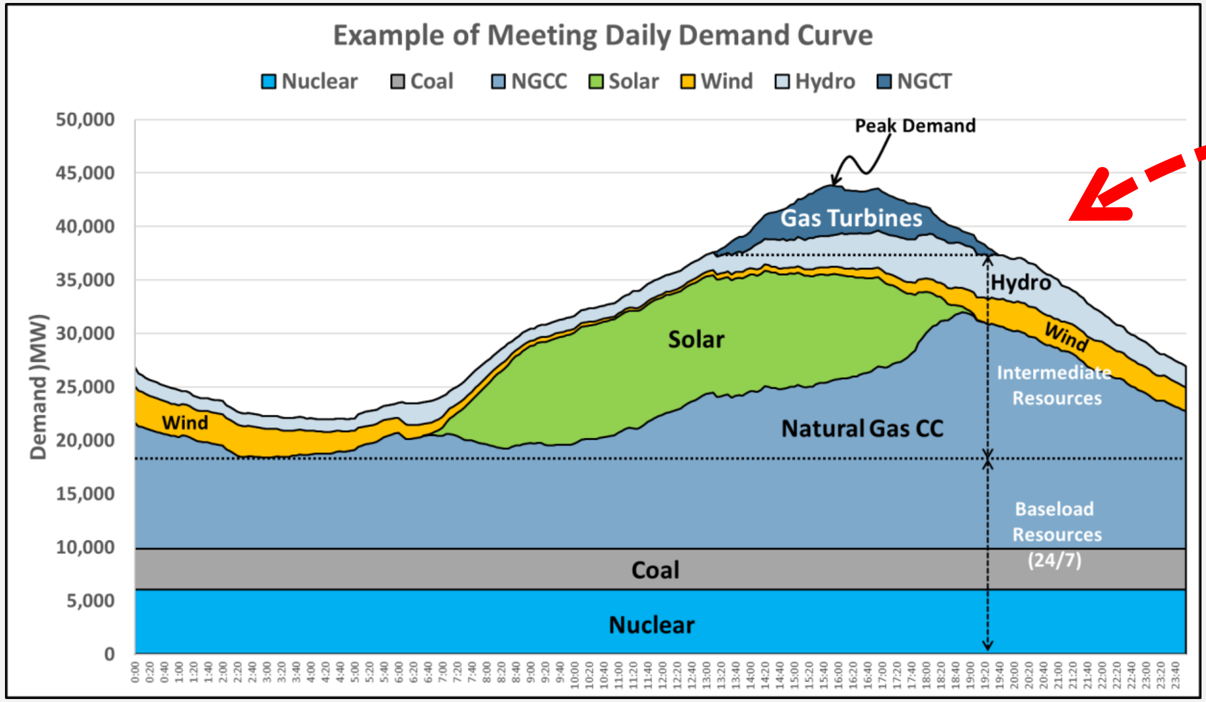
Domestic energy resource diversity and energy technology diversity have underpinned America's rise as the world's greatest industrial, military and economic superpower in all of history.

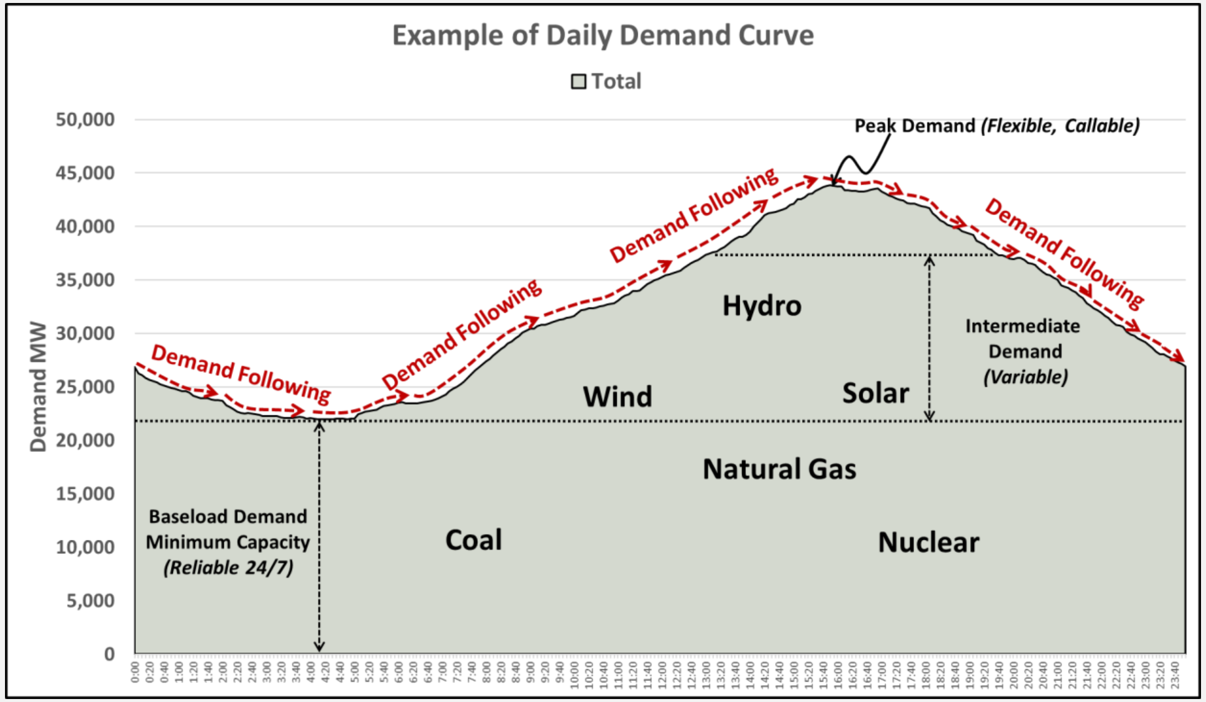




Value of Energy Resource and Energy Technology Diversity

THE POWER SECTOR





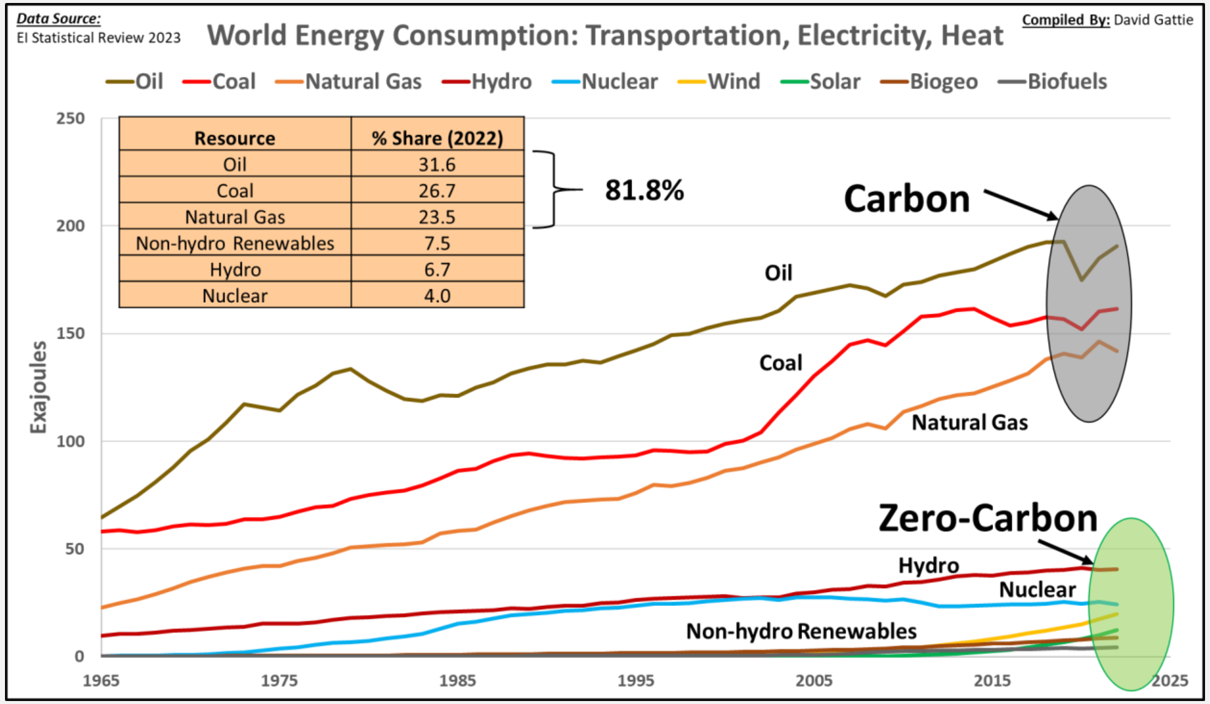
Source: *Gattie D, Hewitt M. National Security as a Value-Added Proposition for Advanced Nuclear Reactors: A U.S. Focus. Energies. 2023; 16(17):6162. https://doi.org/10.3390/en16176162*

Energy Resource, Technology	Energy Resource Properties & Power Plant Operation Characteristics	
Coal	• Abundant, domestic U.S. resource • Generally independent of weather conditions • Resource is transportable and stored onsite (1–3 month supply) • Generation is baseload • Lifespan: 30-plus years	• Fuel cost is market-based • Construction costs are low • Carbon emissions high • Capacity Factor: 0.48
Natural Gas Combined Cycle	• Abundant, domestic U.S. resource • Generally independent of local weather, subject to upstream supply • Resource is transportable, not stored onsite (just in-time delivery) • Generation is flexible and increasingly used as baseload • Lifespan: 30-plus years	• Fuel cost is market-based (can be volatile) • Construction costs are low • Carbon emissions half that of coal • Capacity Factor: 0.57
Natural Gas Turbine	• Abundant, domestic U.S. resource • Generally independent of local weather, subject to upstream supply • Resource is transportable, not stored onsite (just in-time delivery) • Generation is flexible and dispatchable for load-following • Lifespan: 25-plus years	• Fuel cost is market-based (can be volatile) • Construction costs are low • Carbon emissions lower than coal • Capacity Factor: 0.13
Nuclear	• Generally independent of weather conditions • Resource is transportable, stored onsite (~1.5 year refueling) • Generation is baseload • Lifespan: 60-plus years	• Fuel cost is low, but overly dependent on nondomestic supplies • Construction costs for LNPP are high • Zero carbon emissions • Capacity Factor: 0.93
Utility-Scale Solar and Onshore Wind	• Weather-dependent (daily, monthly, seasonally) • Resource is geographically fixed, not transportable, not storable • Generation is not dispatchable, cannot serve as baseload • Solar Lifespan: 30 years • Wind Lifespan: 30 years	• Fuel cost is zero • Construction costs are low • Zero carbon emissions • Solar: Capacity Factor: 0.25 • Wind: Capacity Factor: 0.36

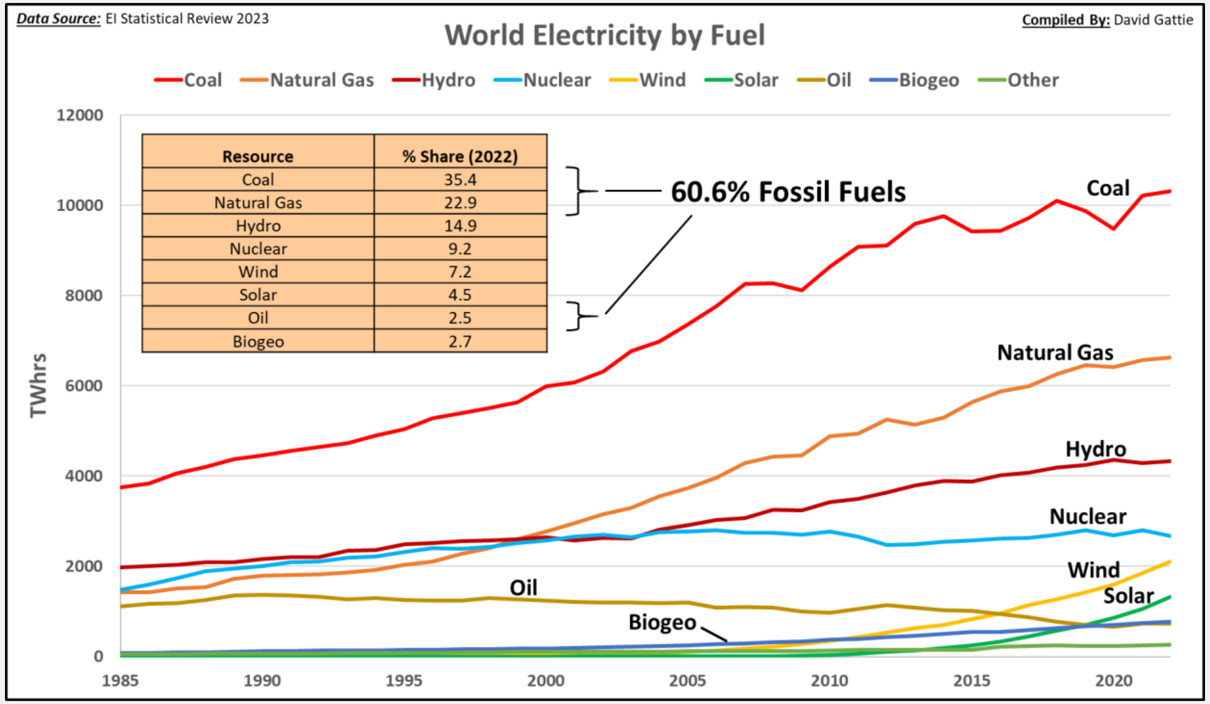
Diversity in energy resources and power plant technologies underpins *grid reliability, flexibility and security*.

ENERGY & CO_2

GLOBAL CONTEXT & REALITIES

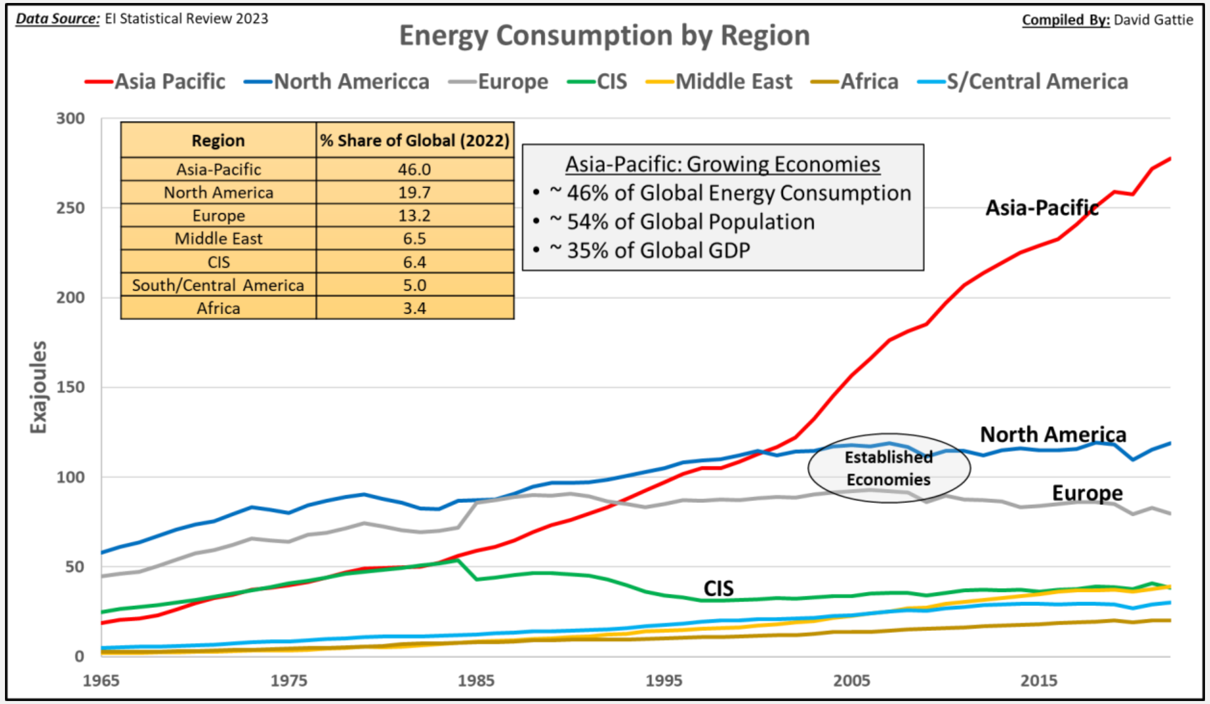


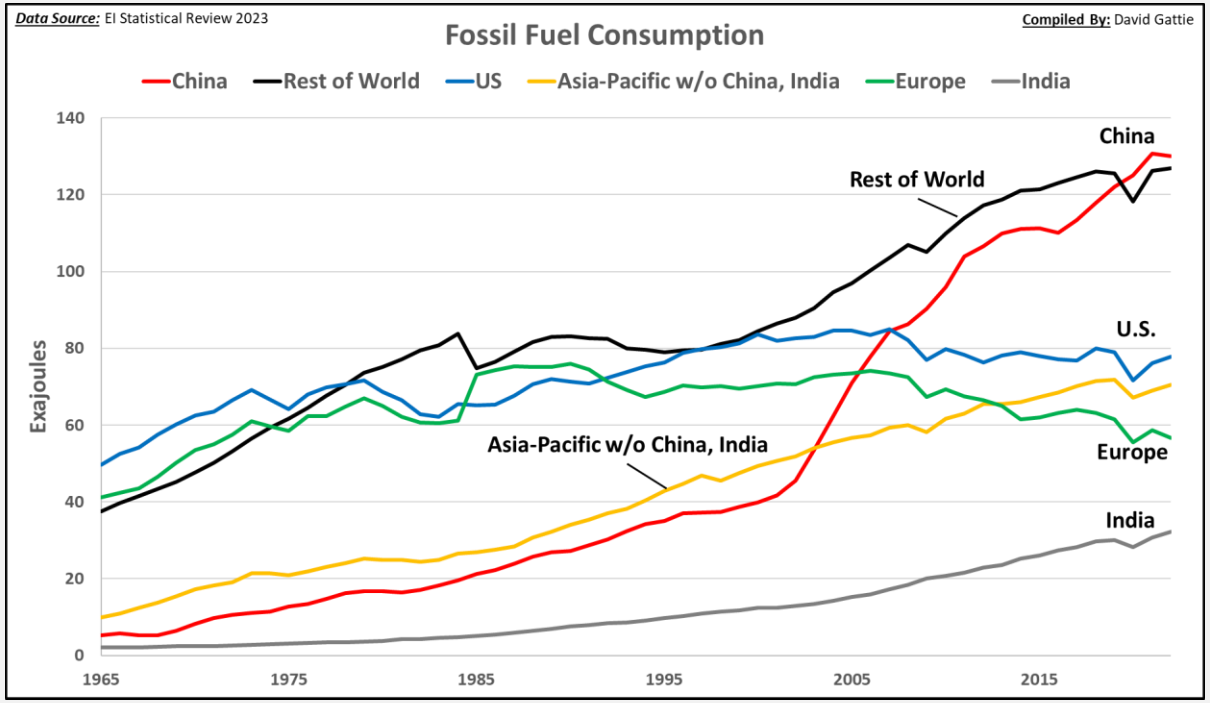
Resource	% Share (2022)
Oil	31.6
Coal	26.7
Natural Gas	23.5
Non-hydro Renewables	7.5
Hydro	6.7
Nuclear	4.0



Resource	% Share (2022)
Coal	35.4
Natural Gas	22.9
Hydro	14.9
Nuclear	9.2
Wind	7.2
Solar	4.5
Oil	2.5
Biogeo	2.7

Global energy consumption, including fossil fuels, is increasing for all sectors—transportation, electricity and heat.





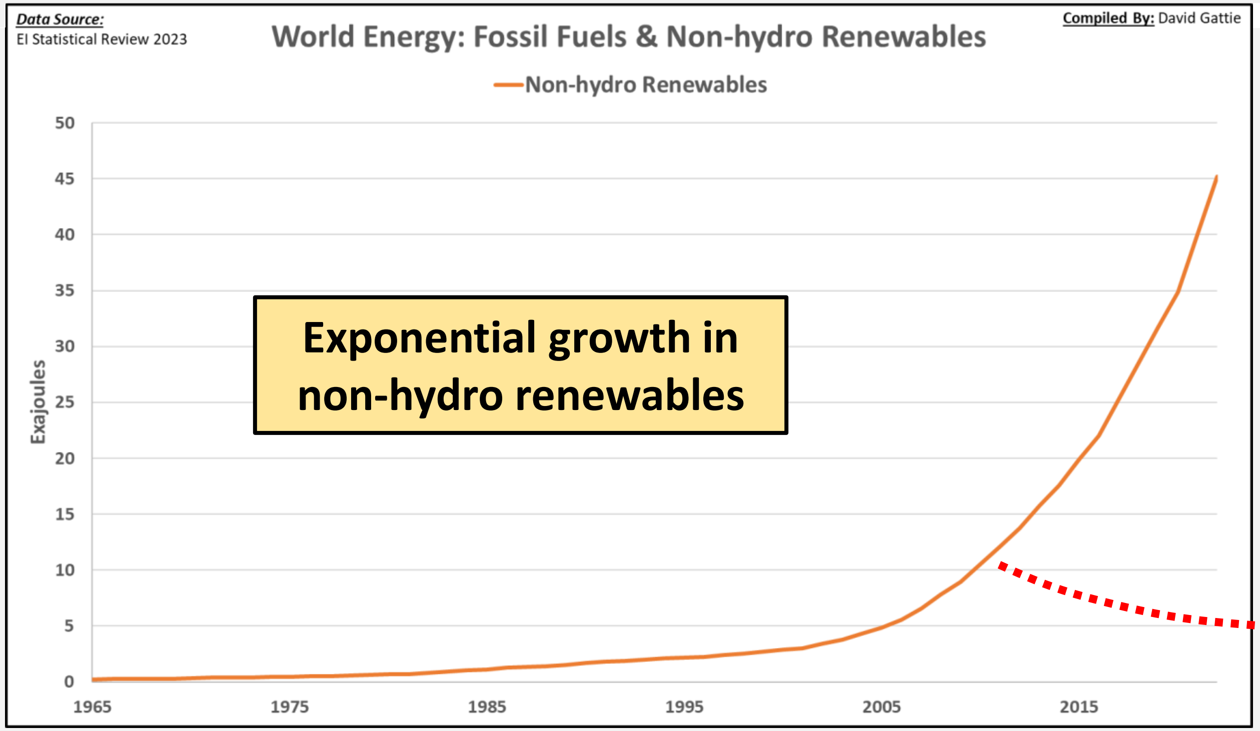
The greatest increase in energy consumption and fossil fuel consumption is in the Asia-Pacific region, which is highly populated and growing in population, and is home to many emerging economies trying to both industrialize and escape energy poverty.

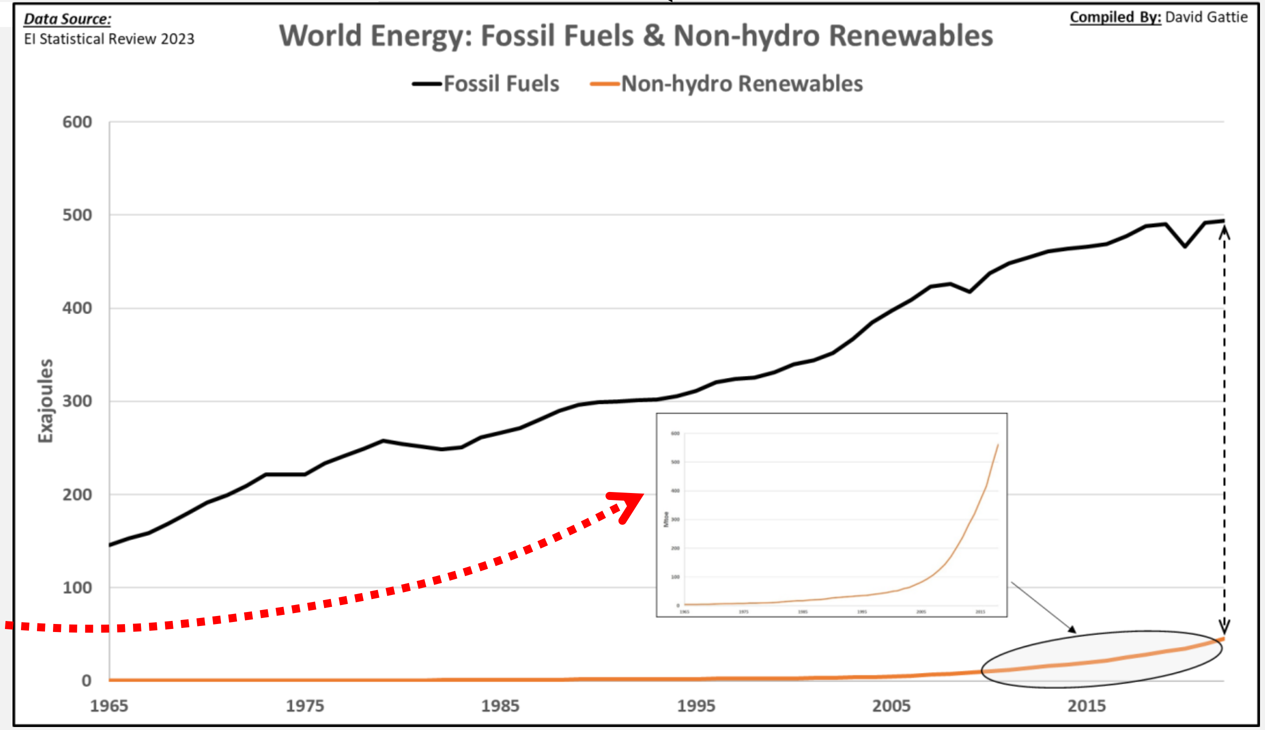
Country	Wind Generation	Total Generation (2022)	
	2022 Share of World Total (%)	Fossil Fuels & Nuclear (%)	Fossil Fuels, Nuclear & Hydro (%)
China	36.2	69.1	83.9
US	20.9	78.2	83.9
Germany	6.0	51.9	54.9
Brazil	3.9	12.3	75.4
India	3.3	79.4	88.8
Spain	3.0	57.0	63.2
France	1.8	74.2	83.7
Canada	1.8	31.0	91.4
Turkey	1.7	57.5	78.1
Australia	1.5	66.6	72.9
Subtotal	80.1		

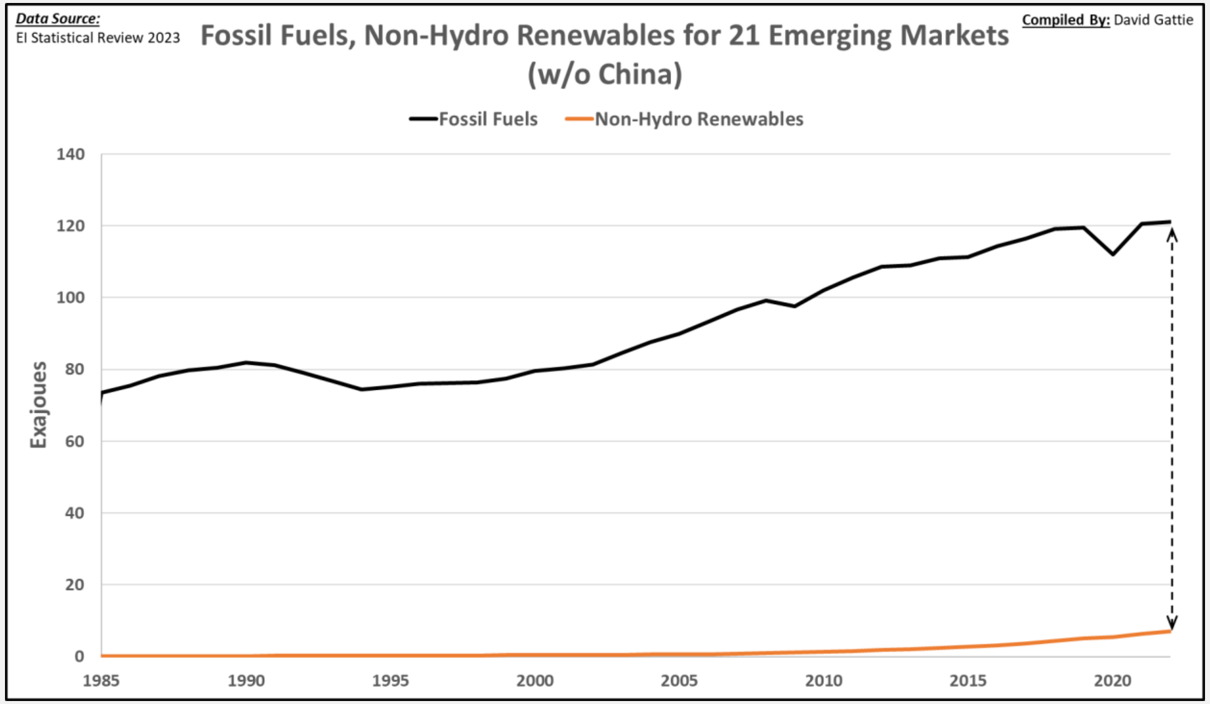
Country	Solar Generation	Total Generation (2022)	
	2022 Share of World Total (%)	Fossil Fuels & Nuclear (%)	Fossil Fuels, Nuclear & Hydro (%)
China	32.3	69.1	83.9
US	15.6	78.2	83.9
Japan	7.7	69.8	77.0
India	7.2	79.4	88.8
Germany	4.6	51.9	54.9
Australia	2.9	66.6	72.9
Spain	2.6	57.0	63.2
Brazil	2.3	12.3	75.4
Italy	2.1	63.9	73.7
South Korea	2.0	91.1	91.6
Subtotal	79.3		

Non-hydro renewables (predominantly solar and wind) are growing exponentially. However:

1) **It is predominantly in countries with an established baseline of conventional energy—fossil fuels, nuclear and hydro;**
2) **Renewables are not displacing fossil fuels**

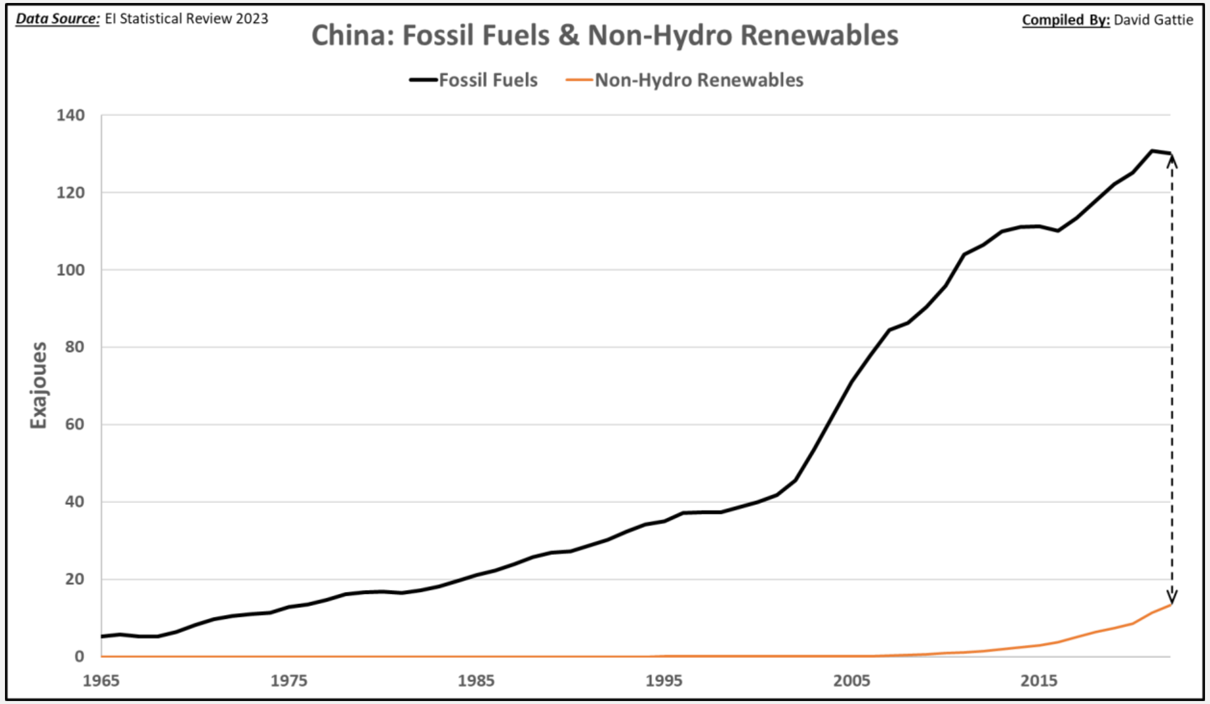


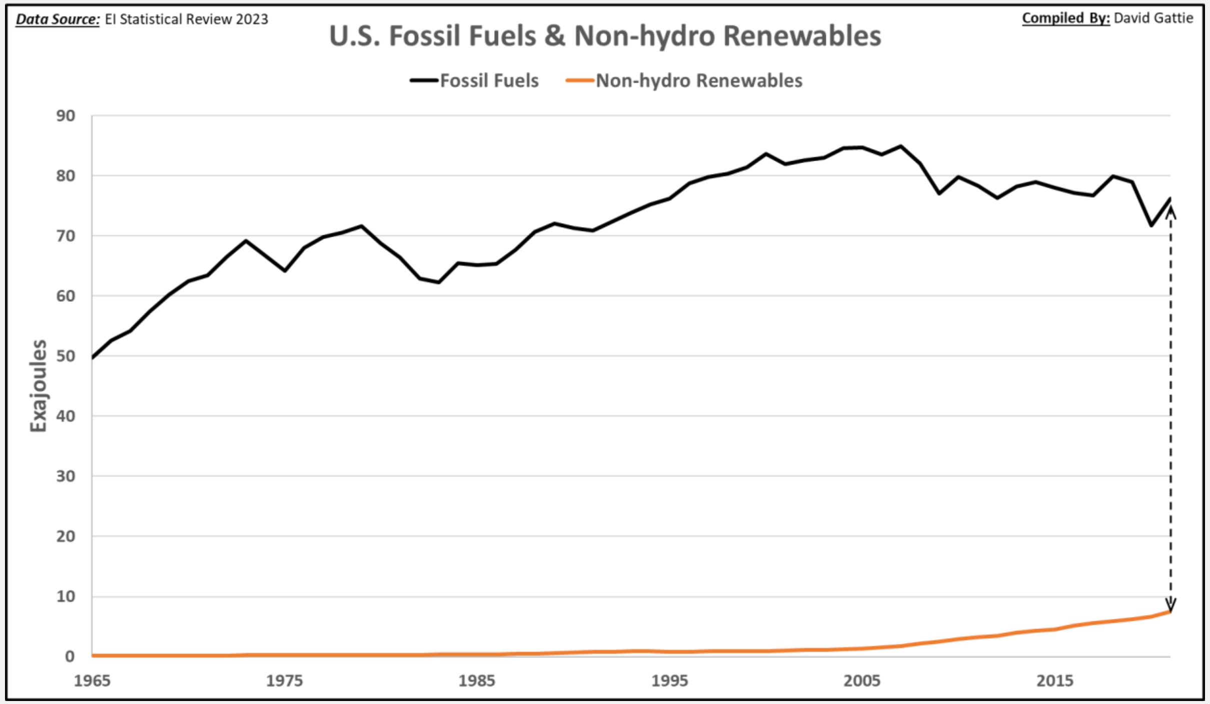




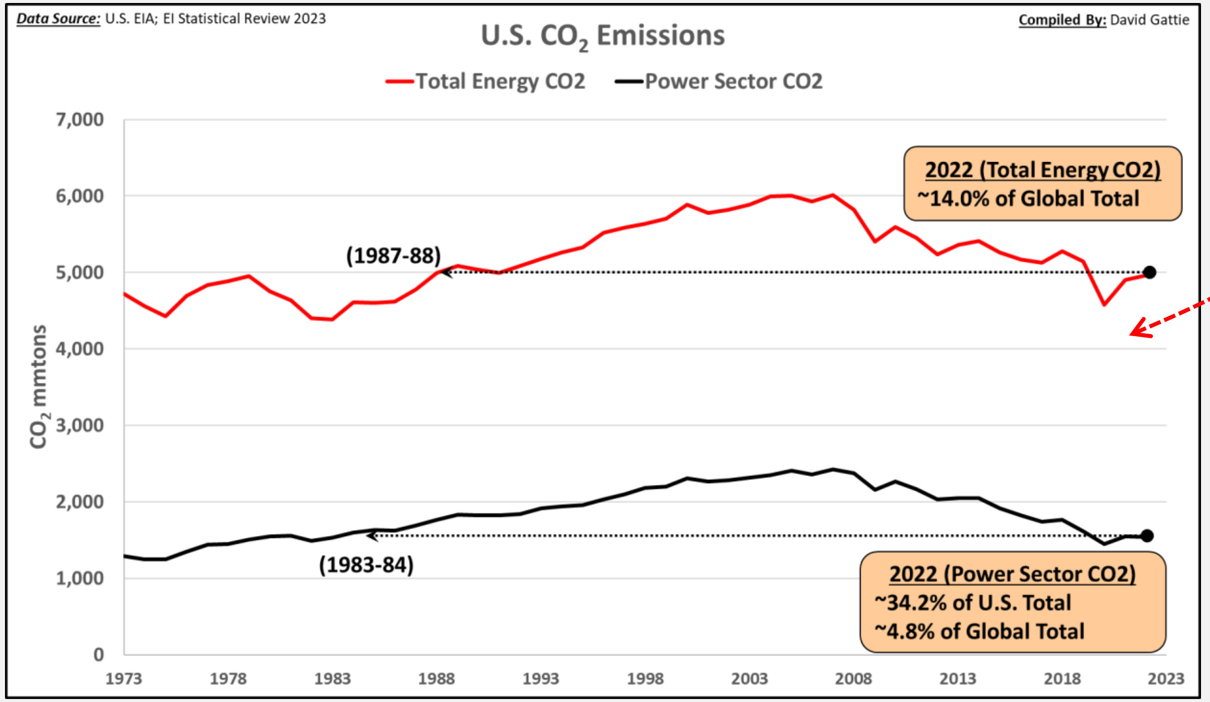
Emerging economies, which are looking for energy resource and energy technology partnerships for industrializing their economies, are moving in the same direction as China with respect to fossil fuels.

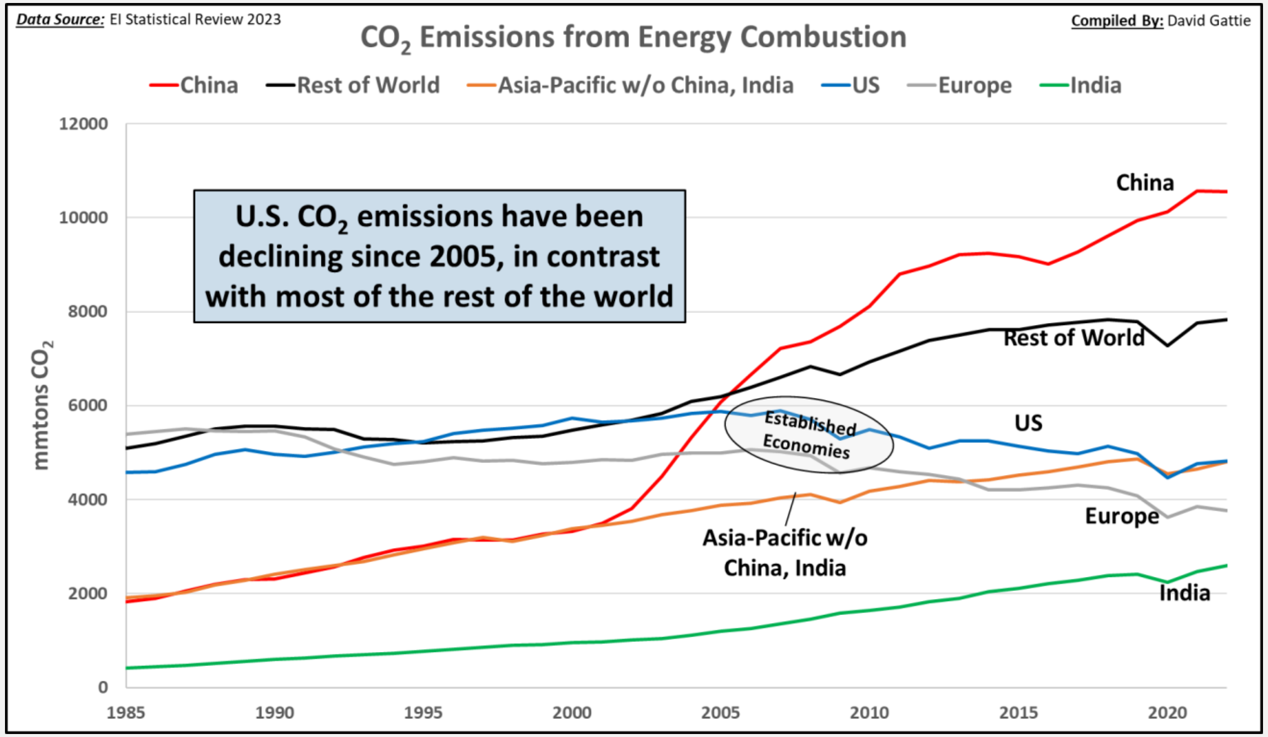
Meanwhile, the U.S. is reducing fossil fuel consumption while integrating renewable energy.

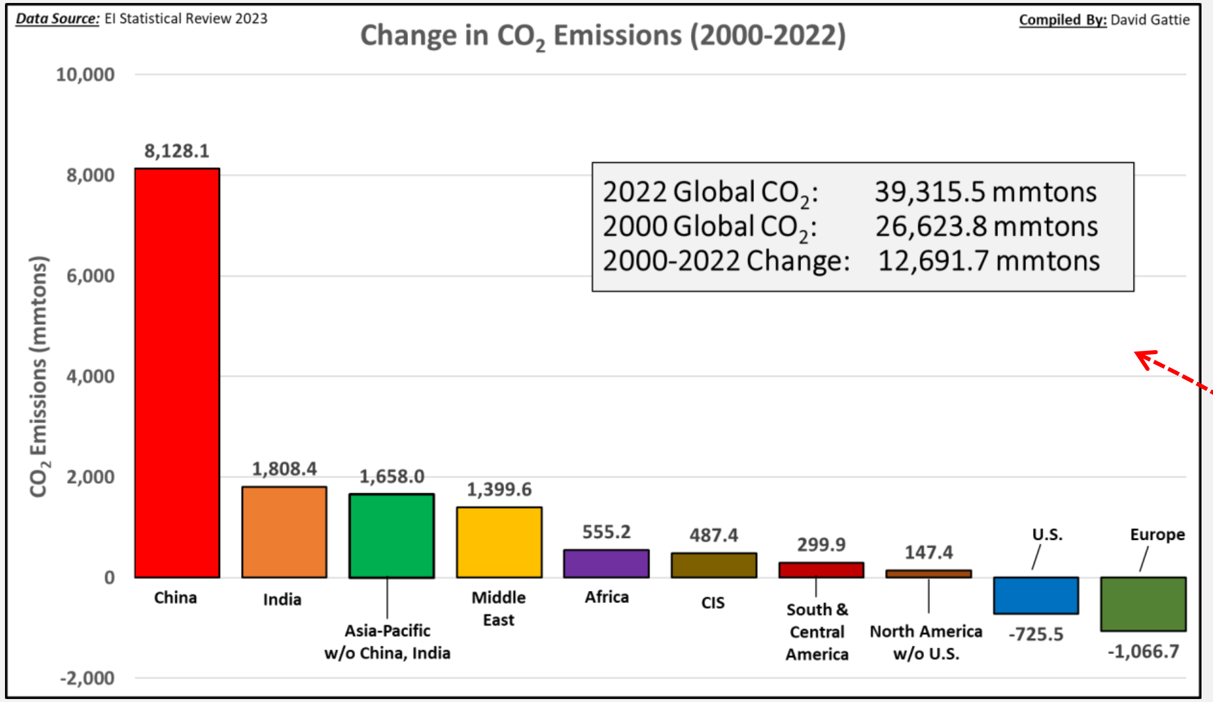




CO_2 emissions for total U.S. energy consumption is at 1987-88 levels.
CO_2 emissions for the U.S. electric power sector is at 1983-84 levels.

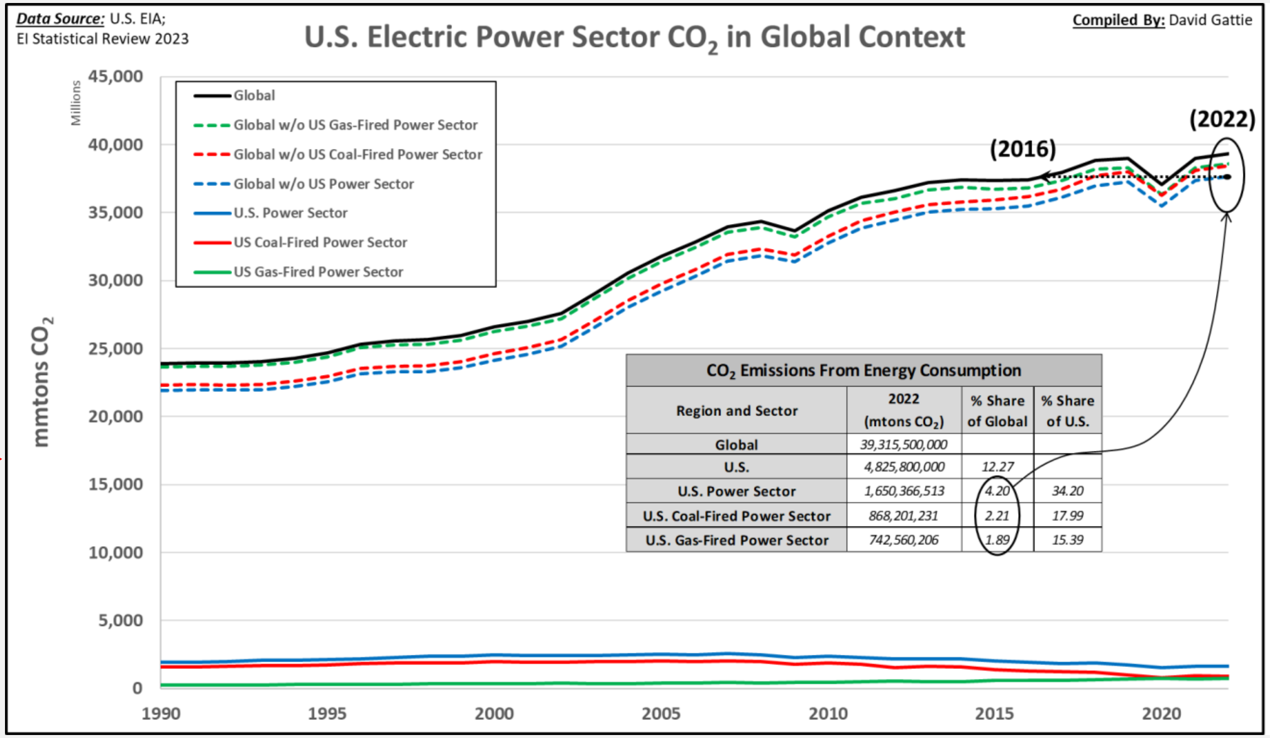






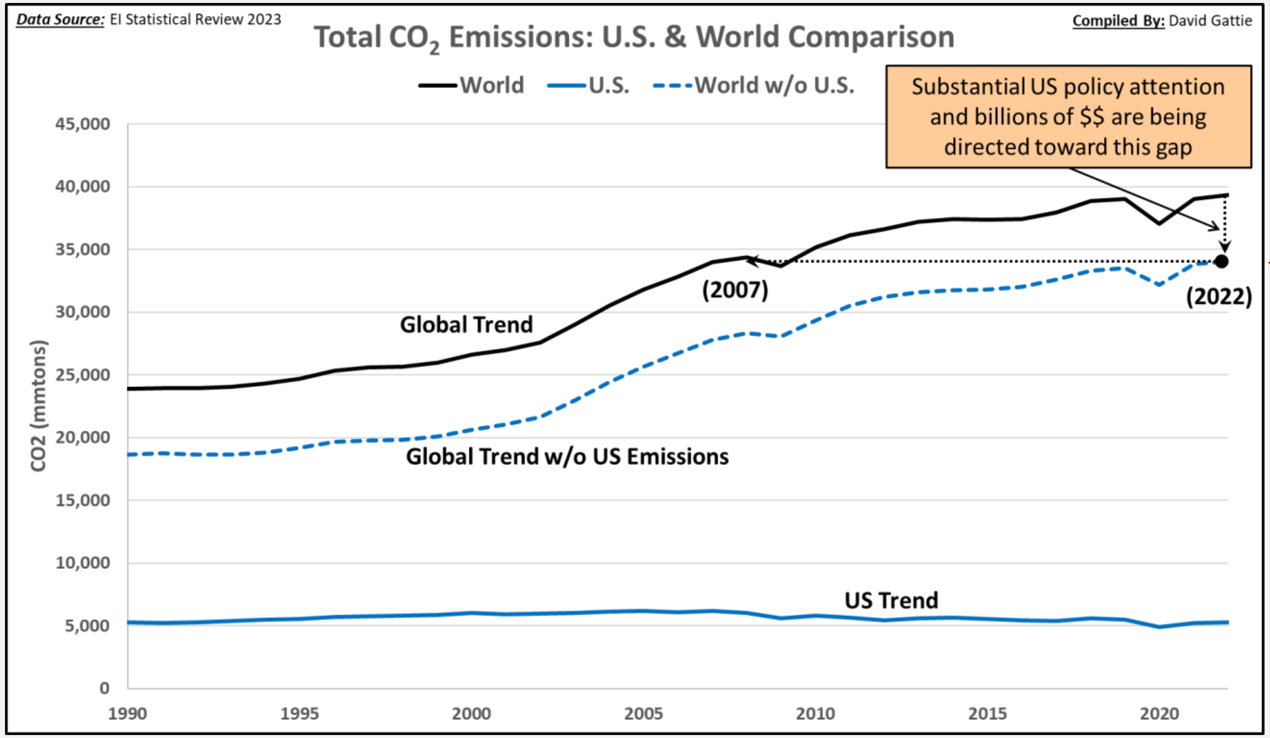
Only the U.S. and Europe have contributed to a net reduction in CO_2 emissions over the past 23 years.

Eliminating all CO_2 emissions from the U.S. grid would reset 2022 global emissions to 2016 levels, yet continuing to trend up. *If global climate change was an issue in 2016 with US power sector emissions, it will be an issue in 2022 without US power sector emissions.*



CO_2 Emissions From Energy Consumption

Region and Sector	2022 (mtons CO_2)	% Share of Global	% Share of U.S.
Global	39,315,500,000		
U.S.	4,825,800,000	12.27	
U.S. Power Sector	1,650,366,513	4.20	34.20
U.S. Coal-Fired Power Sector	868,201,231	2.21	17.99
U.S. Gas-Fired Power Sector	742,560,206	1.89	15.39

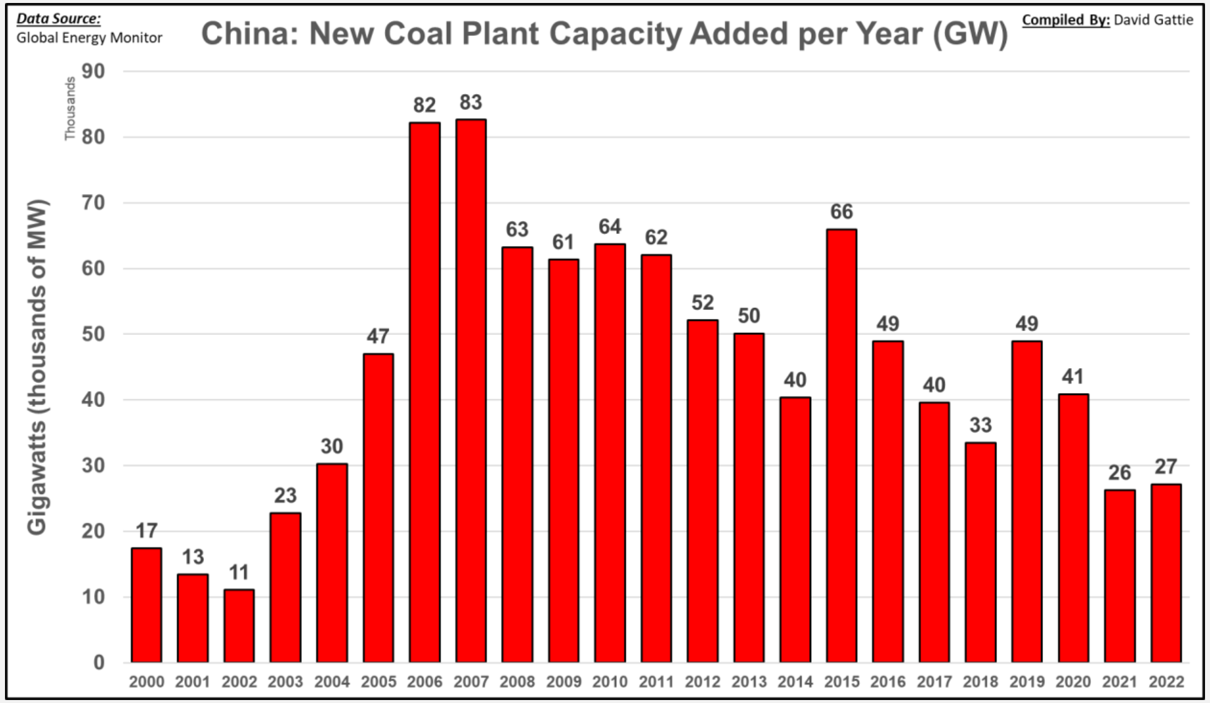


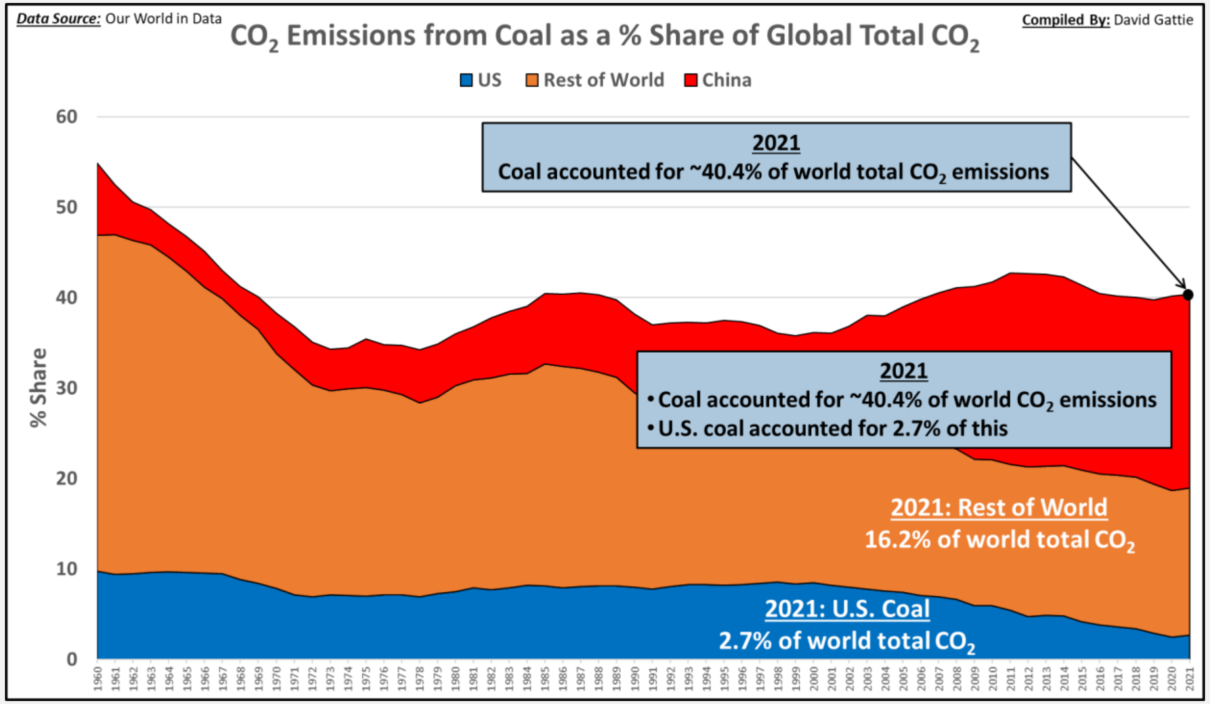
Zeroing out all US CO_2 emissions would reset 2022 global emissions to 2007 levels, yet continuing to trend up. *If global climate change was an issue in 2007 with US emissions, it will be an issue in 2022 without US emissions.*

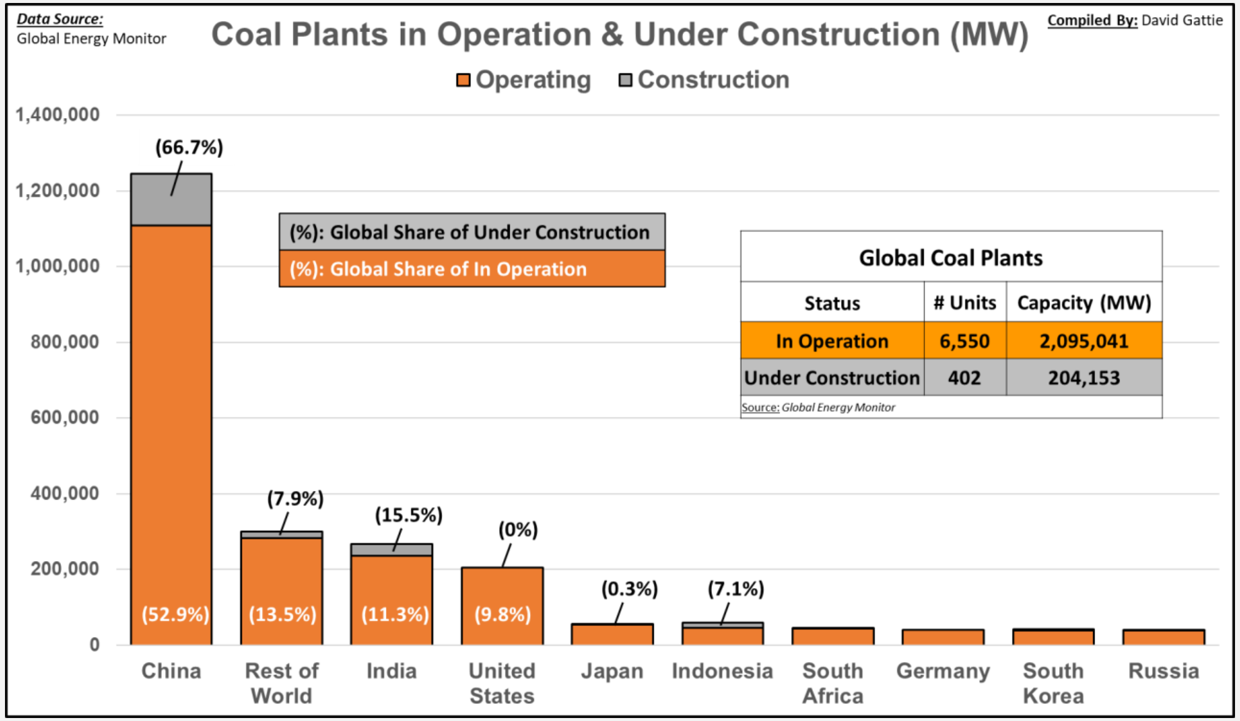
America's Strategic Competitor And Pacing Challenge

CHINA

BASELOAD COAL







China approved the construction of another 106 gigawatts of coal-fired power capacity last year (2022), four times higher than a year earlier and the highest since 2015, driven by energy security considerations, research showed... Over the year, 50 GW of coal power capacity went into construction across the country, ***up by more than half compared to the previous year***, the Centre for Research on Energy and Clean Air (CREA) and Global Energy Monitor (GEM) said.“ The speed at which projects progressed through permitting to construction in 2022 was extraordinary, with many projects sprouting up, gaining permits, obtaining financing and breaking ground apparently in ***a matter of months,***" said GEM analyst Flora Champenois.

…driven by concerns about power shortages. Source: [Reuters]

NUCLEAR POWER

Status	Plant	Capacity (MW)	Location	Generation (MWhrs)	Retirement Year (or announced)
Retired (13)	Crystal River	860	Florida	7,000,079	2013
	Kewaunee	566	Wisconsin	4,990,254	2013
	San Onofre 2 & 3	2,150	California	18,097,173	2013
	Vermont Yankee	604	Vermont	5,060,582	2014
	Fort Calhoun	483	Nebraska	3,425,235	2016
	Oyster Creek	608	New Jersey	4,585,091	2018
	Pilgrim	674	Massachusetts	5,414,318	2019
	Three Mile Island 1	803	Pennsylvania	5,214,196	2019
	Duane Arnold	601	Iowa	5,235,716	2020
	Indian Point 2	1,016	New York	8,351,945	2020
	Indian Point 3	1,038	New York	9,108,821	2021
	Palisades	772	Michigan	5,995,123	2022
	Total	***10,175***		***82,478,533***	
Planned But Stayed by State Action (22)	Diablo Canyon 1 & 2	2,240	California	16,258,298	2024, 2025
	Dresden 2 & 3	1,797	Illinois	15,478,888	2021
	Byron 1&2	2,300	Illinois	15,524,894	2021
	Davis-Besse	894	Ohio	7,228,063	2020 (Hold)
	Perry	1,240	Ohio	10,990,962	2021 (Hold)
	Beaver Valley 1 & 2	1,808	Pennsylvania	15,393,393	2021 (Hold)
	FitzPatrick	848	New York	6,588,676	2017 (Hold)
	R. E. Ginna	581	New York	4,332,888	2017 (hold)
	Clinton	1,065	Illinois	9,462,481	2017 (Hold)
	Nine Mile Point 1&2	2,054	New York	15,640,608	2017, 2018
	Quad Cities 1 & 2	1,819	Illinois	15,712,445	2018 (Hold)
	Salem 1 & 2	2,295	New Jersey	16,145,436	2020, 2021
	Hope Creek	1,172	New Jersey	10,592,697	2021 (Hold)
	Millstone 2 & 3	2,073	Connecticut	15,714,855	2020 (Hold)
	Total	***22,186***		***175,064,584***	
	Total All	***30,551***		***257,543,117***	

Since 2013, the U.S. has retired 10,175 MW of nuclear power with another 22,186 MW under threat of premature closure.

__Data Source:__ US EIA; NEI; Congressional Research Service

__Retirement Years:__ Third Way; Congressional Research Service

NUCLEAR POWER IN THE 21ST CENTURY

Since 2000, 170 reactors have been connected to the grid or are under construction. Of these, 114 are associated with China or Russia—either by location or by reactor technology.

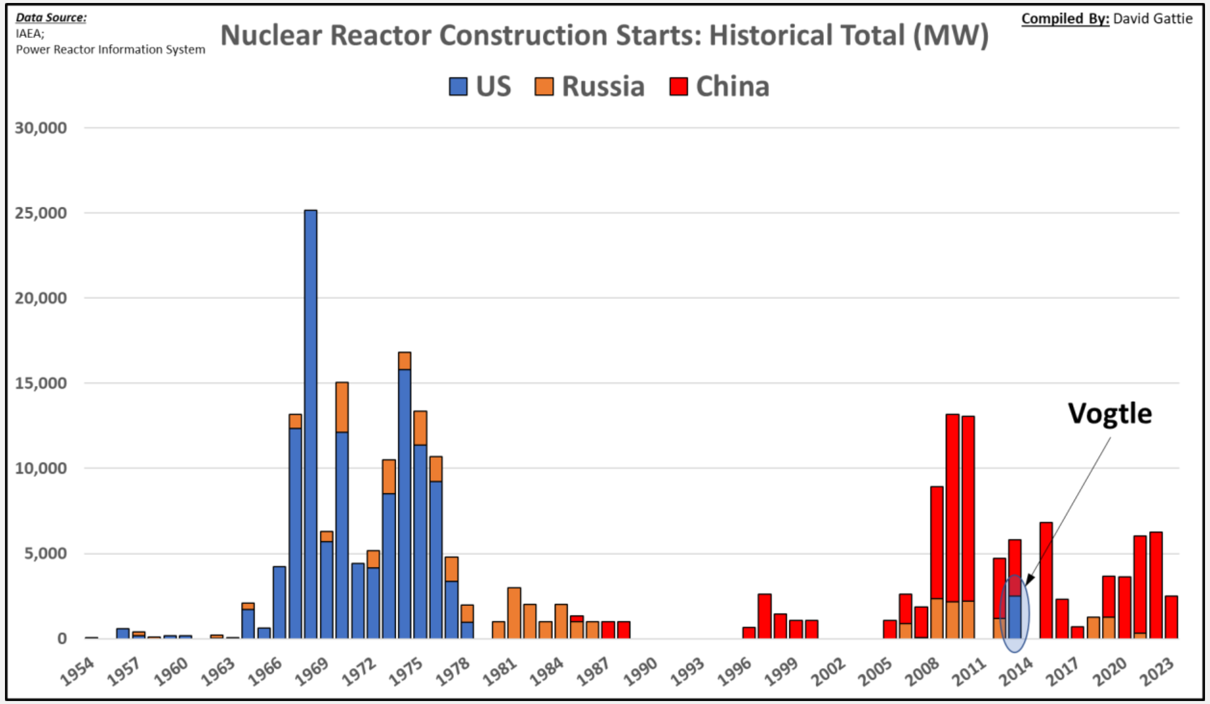
__Source:__ World Nuclear Association; IAEA (2023)

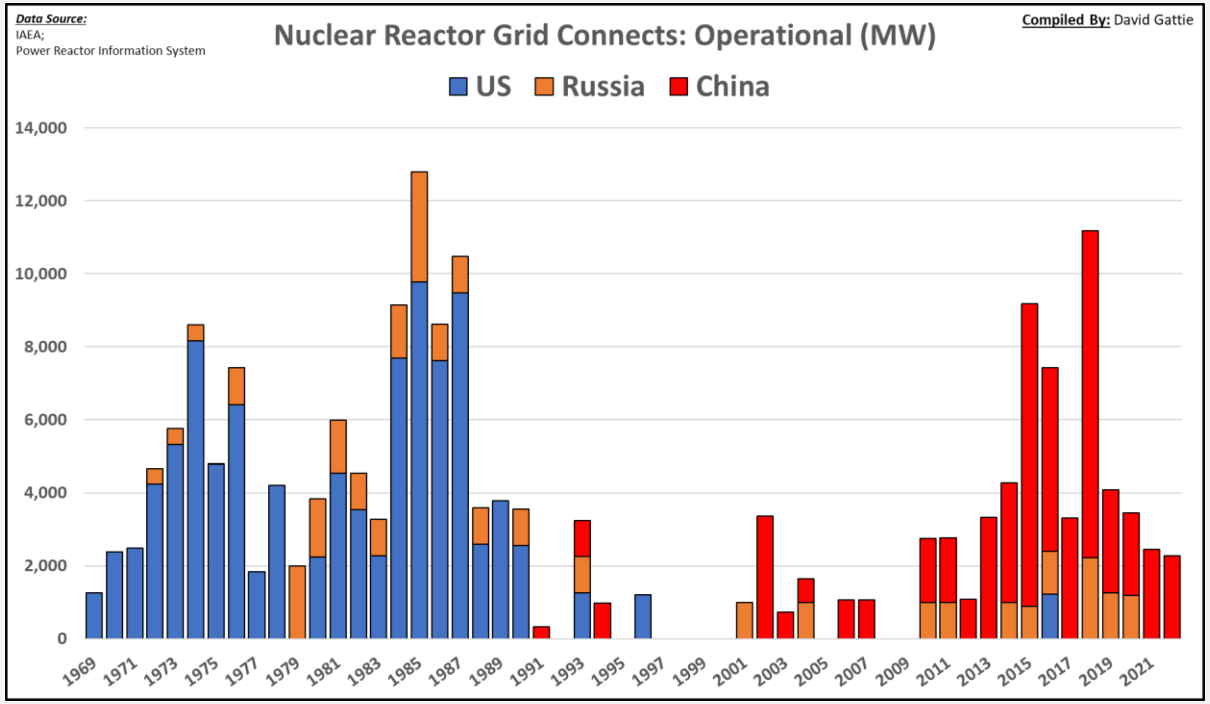
Number of Reactors Since 2000			
Country	**Connected to Grid**	**Under Construction**	**Russian or Chinese**
China	52	21	73
Russia	13	3	16
India	12	8	4
South Korea	11	3	0
Japan	5	2	0
Pakistan	6	0	6
Czech Republic	2	0	2
Ukraine	2	2	2
Argentina	1	1	0
Belarus	2	0	2
Brazil	1	1	0
Iran	1	1	1
UAE	3	1	0
US	2	1	0
Romania	1	0	0
Bangladesh	0	2	2
Finland	1	0	0
France	0	1	0
Slovakia	1	1	2
Taiwan	0	0	0
Turkey	0	4	4
UK	0	2	0
Total	***116***	***54***	***114***

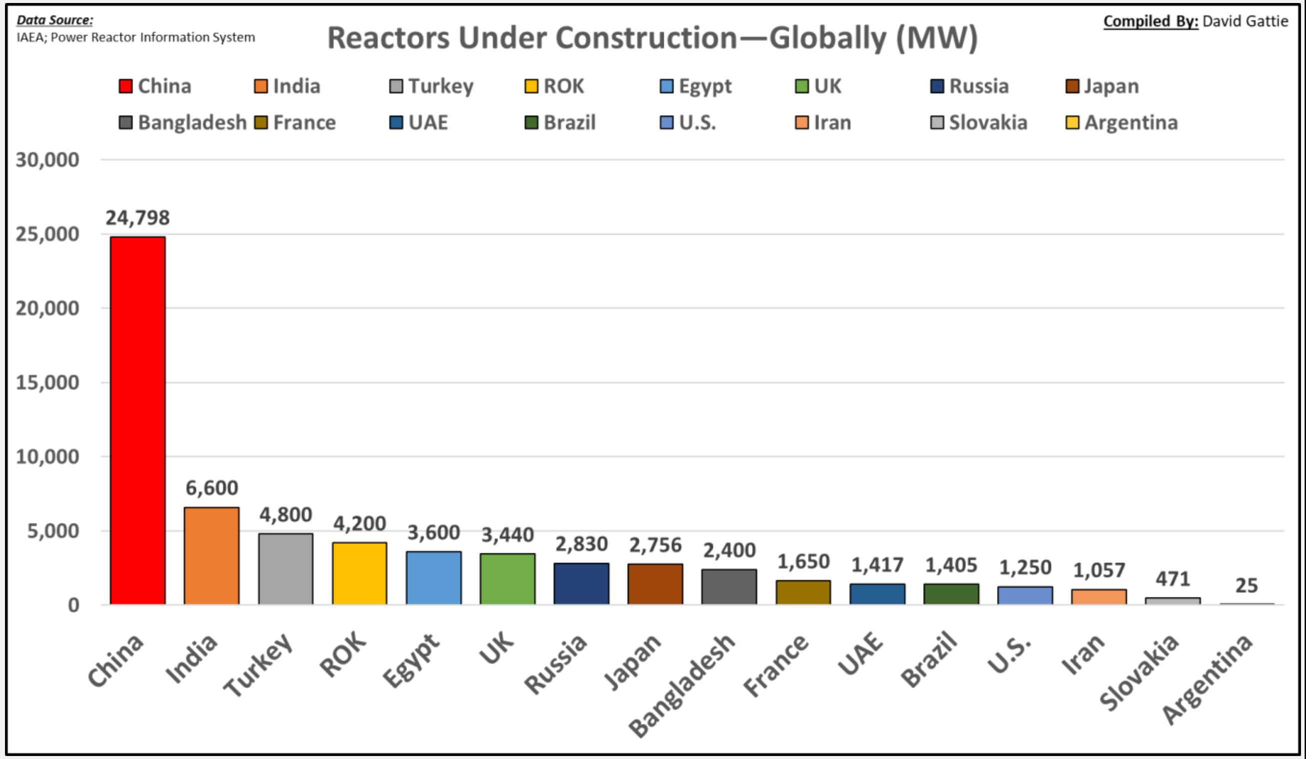
NUCLEAR POWER

Nuclear Reactor Construction Trends

The U.S. is lagging China and Russia in civilian nuclear reactor construction. While nuclear power generally is treated as a market commodity in the U.S., China and Russia leverage their state-owned nuclear enterprises to leverage it as an instrument of national power for 1) Ensuring their own respective energy security, and 2) Establishing long-term geopolitical relationships in developing economies.

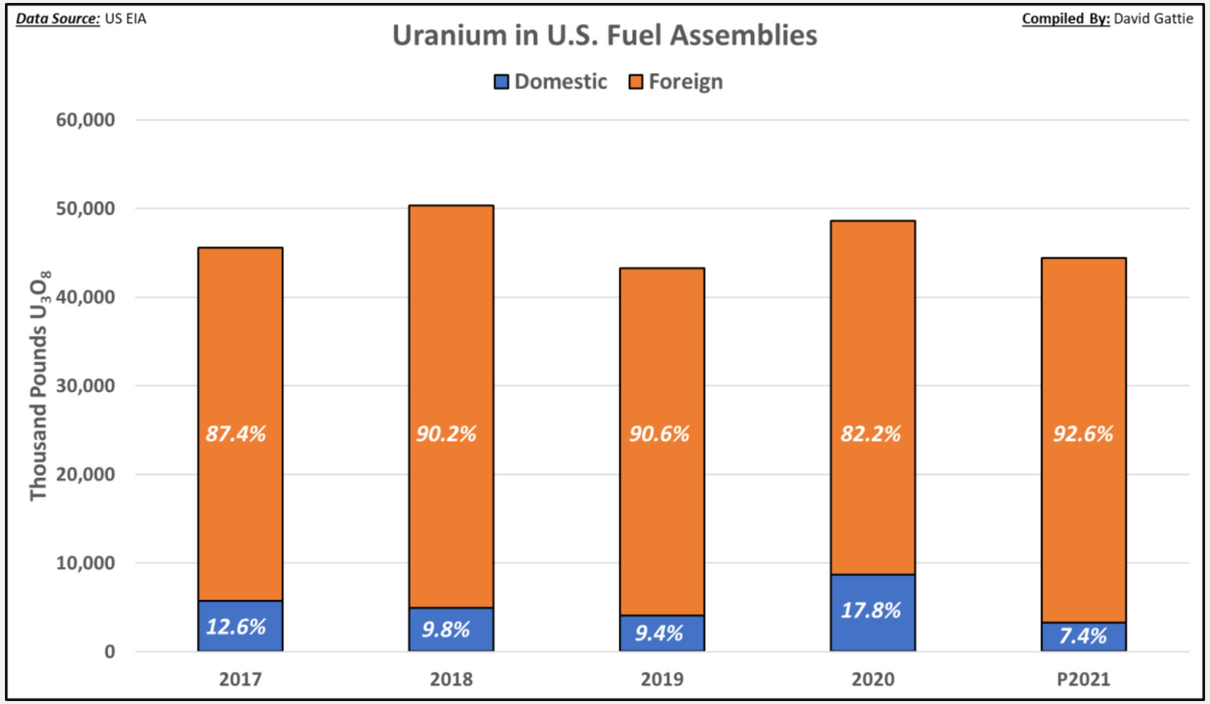


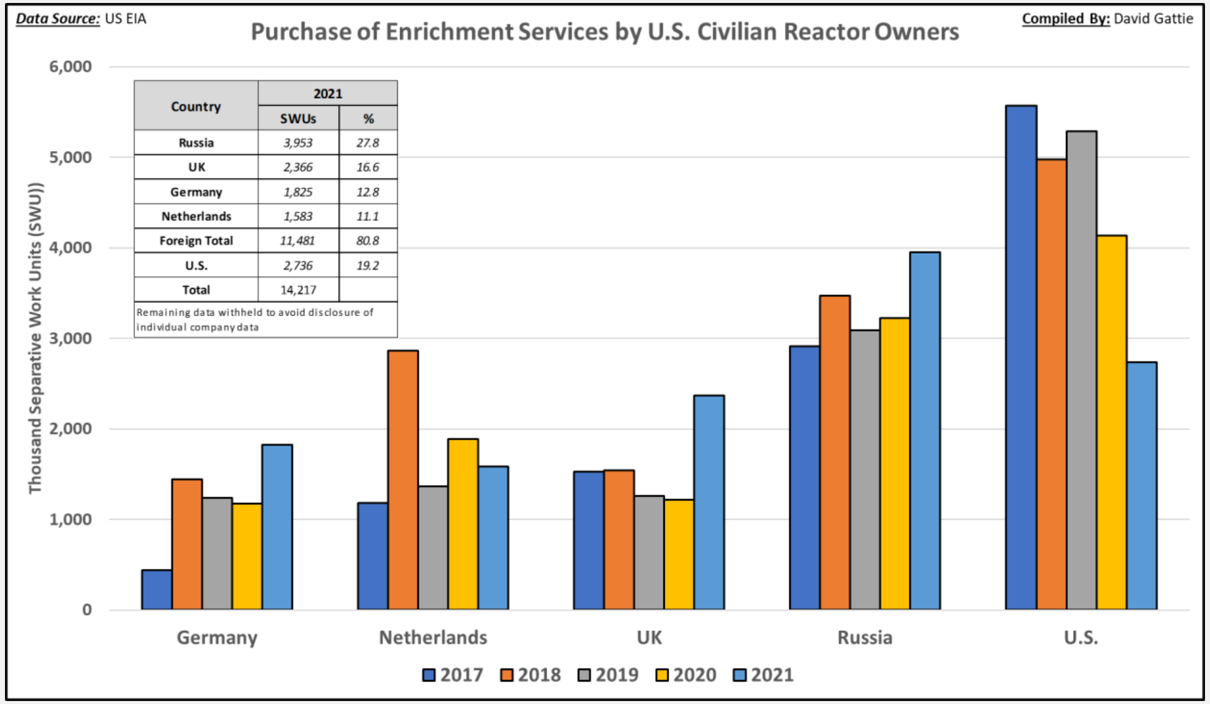




NUCLEAR FUEL

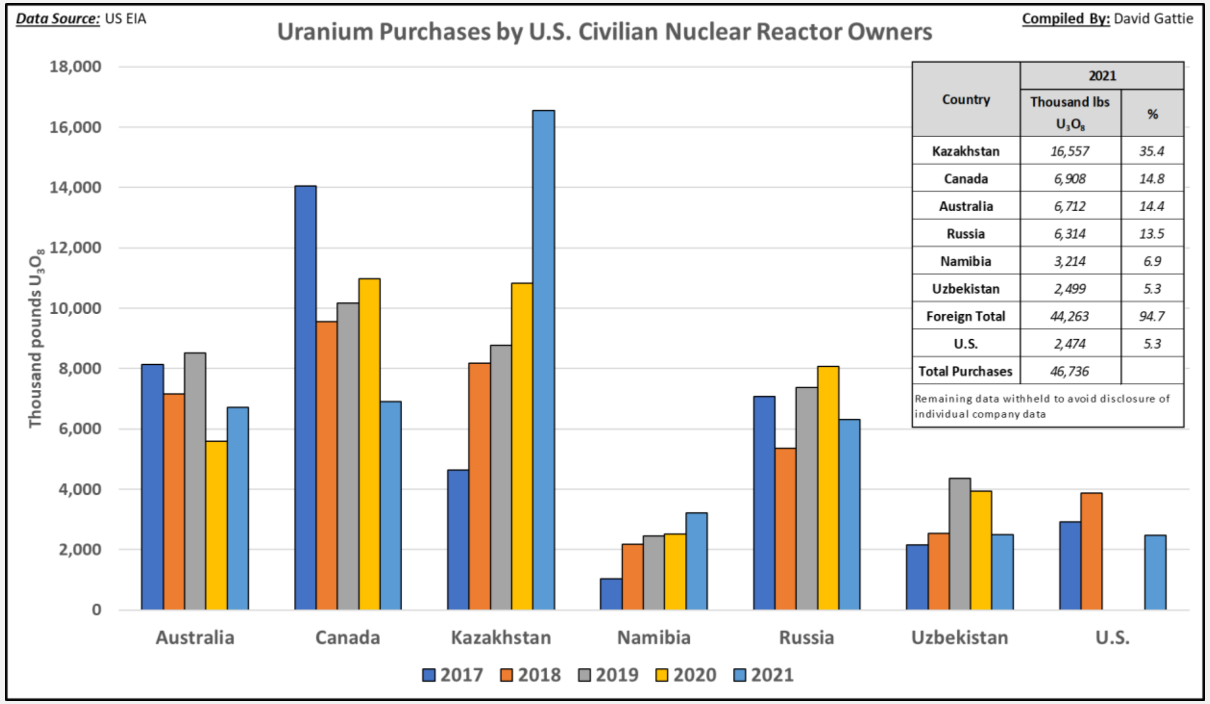
The U.S. has become dependent on foreign sources for fueling domestic reactors. This includes a dependency on Russia for enrichment services.





Country	2021	
	SWUs	%
Russia	3,953	27.8
UK	2,366	16.6
Germany	1,825	12.8
Netherlands	1,583	11.1
Foreign Total	11,481	80.8
U.S.	2,736	19.2
Total	14,217	

Remaining data withheld to avoid disclosure of individual company data

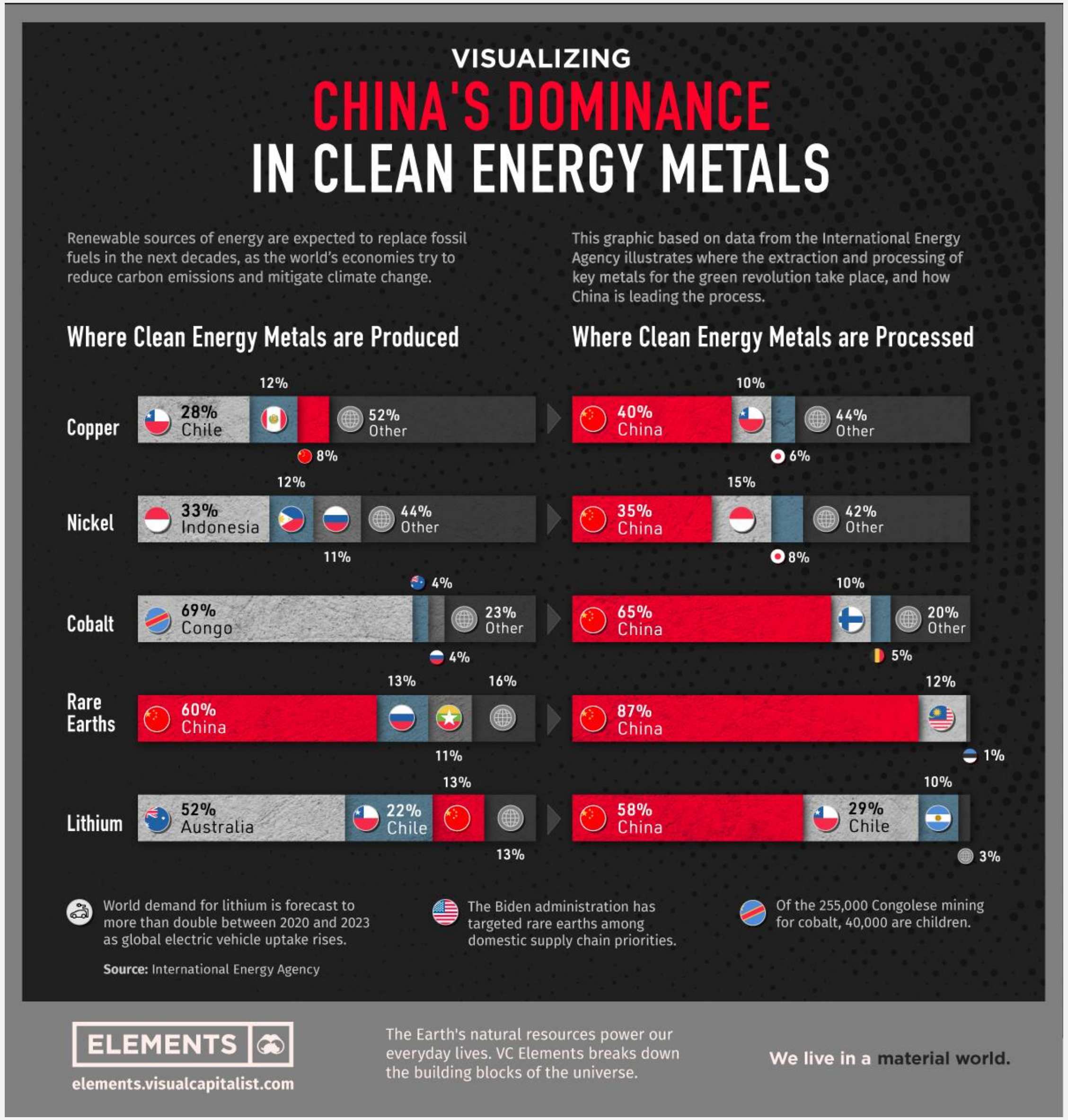


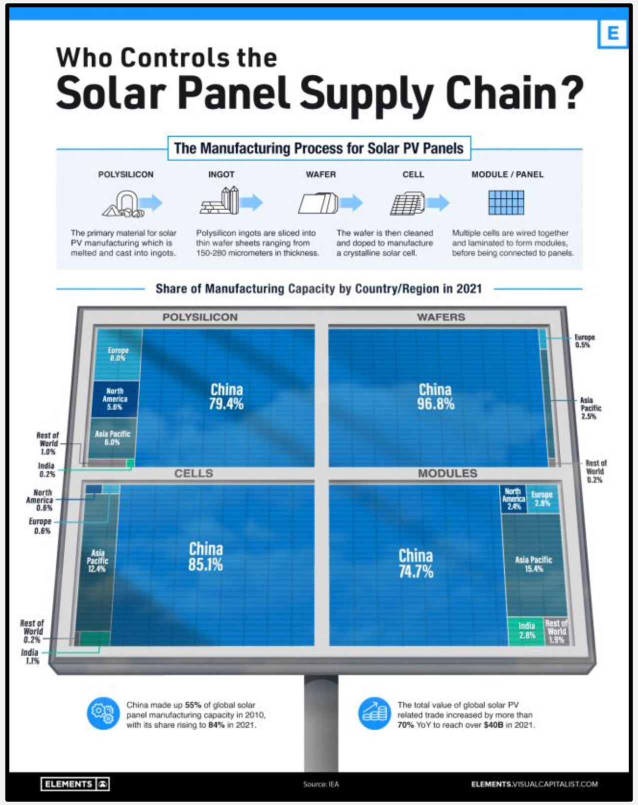
Country	2021	
	Thousand lbs U_3O_8	%
Kazakhstan	16,557	35.4
Canada	6,908	14.8
Australia	6,712	14.4
Russia	6,314	13.5
Namibia	3,214	6.9
Uzbekistan	2,499	5.3
Foreign Total	44,263	94.7
U.S.	2,474	5.3
Total Purchases	46,736	

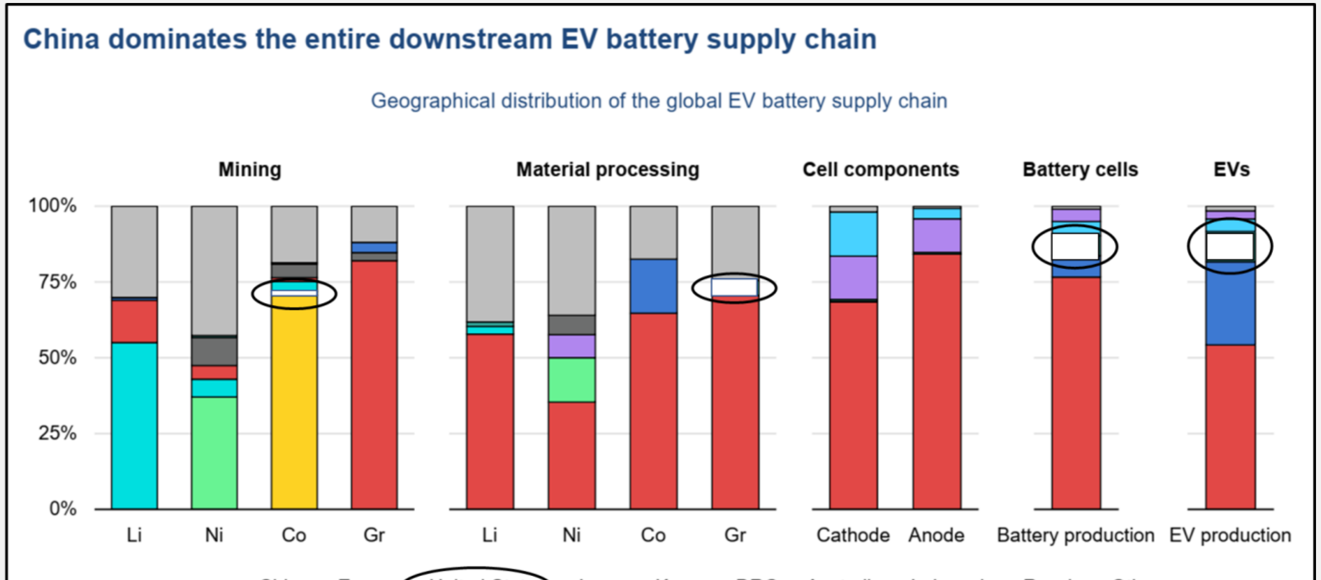
Remaining data withheld to avoid disclosure of individual company data

Renewables, EVs & Metals

China dominates the supply chain: upstream, midstream and downstream







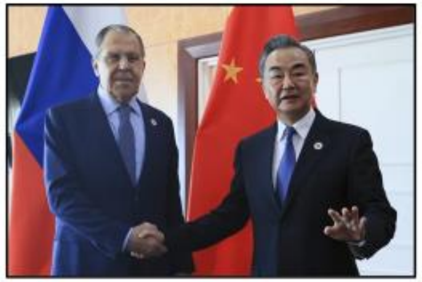
Joint Statement of the Russian Federation and the PRC on the International Relations Entering a New Era and the Global Sustainable Development

Each nation "*can choose such forms and methods of implementing democracy that would best suit its particular state, based on its social and political system,*" where "*it is only up to the people to decide whether their State is a democratic one.*" (February 4, 2022)

China's foreign minister signals deeper ties with Russia

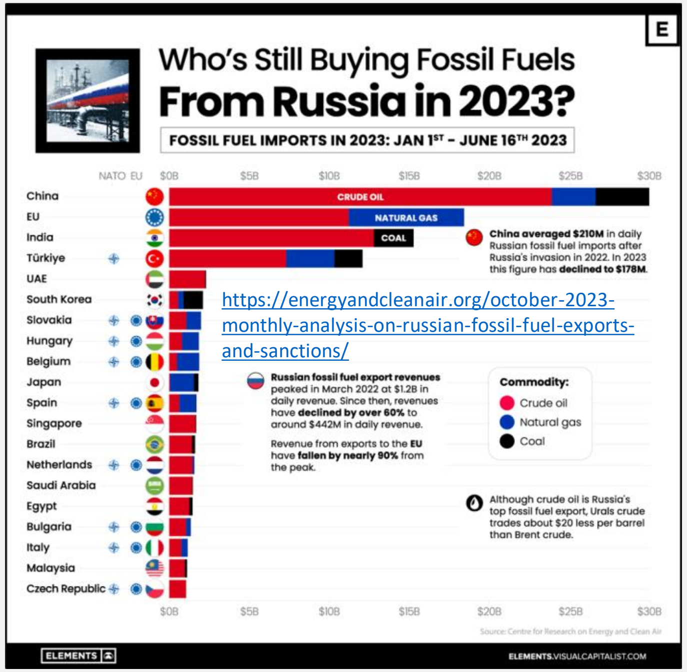
Chinese Foreign Minister Wang Yi defended what he said was his country's position of impartiality on the war in Ukraine on Sunday and signaled that China would deepen ties with Russia in the coming year and would "deepen strategic mutual trust and mutually beneficial cooperation" with Russia. Wang, speaking by video to a conference in the Chinese capital, also blamed America for the deterioration in relations between the world's two largest economies, saying that China has "firmly rejected the United States' erroneous China policy." (December 25, 2022)

https://www.yahoo.com/news/chinas-foreign-minister-signals-deeper-054323244.html



China and Russia as Strategic Partners

"…the two nations have grown confident they can reshape an international order that both view as biased in favor of the West and its allies."



https://energyandcleanair.org/october-2023-monthly-analysis-on-russian-fossil-fuel-exports-and-sanctions/

Xi Doubles Down on Alliance With Putin

October 28, 2022

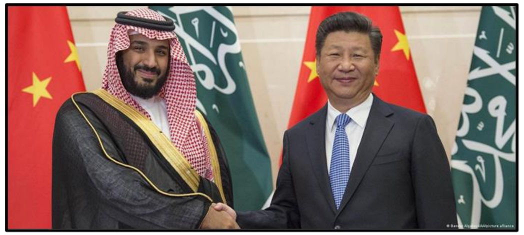
China's top diplomat signaled that Chinese leader Xi Jinping, fresh from extending his power for a norm-breaking third term, intends to double-down on his tight relationship with Russia's Vladimir Putin—*driving an even deeper wedge between the two authoritarian rulers and the West*. Russia and China are also conducting more financial transactions in the ruble and yuan, rather than the euro or dollar, a move that helps insulate the two against future sanctions and put the Chinese currency into wider circulation. In a written statement, China's Foreign Ministry said "China and Russia are *comprehensive strategic cooperative partners* of each other. The development of bilateral relations is based on the principles of non-alliance, non-confrontation and non-targeting of third parties."

Russia and China have long sought to dull the U.S.'s influence in the world, a shared objective that has come into sharper focus in recent years as *the two nations have grown confident they can reshape an international order that both view as biased in favor of the West and its allies*.

Photo Credit: The Wall Street Journal

Sources: Xi-Putin CN RF Relations; CN Nods to Tighter Ties With RF

Xi Pledges More Energy Deals With Gulf Producers



"Saudi Arabia has always considered China as a strategic partner, and that the Committee strives for further alignment between the Saudi and China visions of the future, especially in the energy sphere, where there are multiple synergies," Prince Abdulaziz said. In the meeting, the co-chairs discussed areas where Saudi Arabia and China look to strengthen their relationship, such as oil and petrochemicals, decarbonization technologies, electricity and renewables, hydrogen, energy efficiency, civil nuclear energy, and supply chain security, in addition to industrial cooperation, the fourth industrial revolution, mining and logistics, civil aviation and aviation security, and digital economy." (October 27, 2022)

Source: https://www.zawya.com/en/projects/bri/saudi-arabia-china-agree-on-coordinating-investments-in-bri-states-jw964kz8

Xi Visits KSA

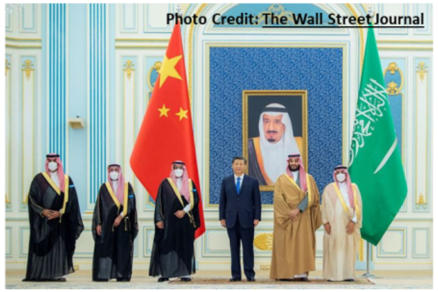
December 8, 2022

Chinese leader Xi Jinping traveled to Saudi Arabia this week for a series of summits with countries from around the Middle East, cementing over thirty energy and investment deals and basking in a good bit of pageantry courtesy of the host nation. From the Saudi side, China is the Kingdom's number one trade partner, a major tech supplier, a long-term energy customer, and *a comprehensive strategic partner* with a permanent seat on the United Nations Security Council

The Saudi energy minister on Wednesday said Riyadh would stay *a "trusted and reliable" energy partner for Beijing* and the two would boost cooperation in energy supply chains by setting up *a regional centre* in the kingdom for Chinese factories.

One of the main reasons behind Xi's visit to Saudi Arabia is to further advance the Belt and Road Initiative, China's ambitious plan to connect Asia, Europe, and Africa through infrastructure projects and trade. *Saudi Arabia is a key partner in the BRI, as it sits at the crossroads of Asia and Europe and is a major transit hub for goods and energy*.

Endowed with rich energy resources, including 30 percent of the oil reserve and 20 percent of the natural gas reserve of the world, *GCC countries are an energy tank for world economy*.



Sources:
Xi Letter to KSA; Key Takeaways from Xi's Visit to KSA
What Xi's Visit to KSA Means

CHINA IN THE MIDDLE EAST

China is building long-term energy partnerships in the Middle East around oil and natural gas. It is not divesting from fossil fuels.

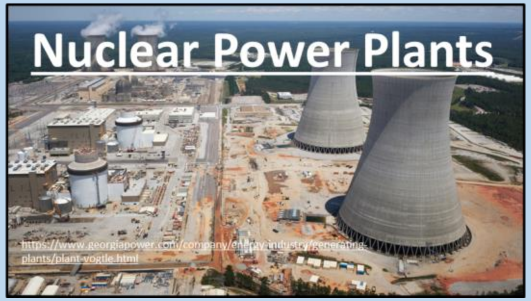
National Security Implications of U.S. Energy

STRATEGIC ADVANTAGE

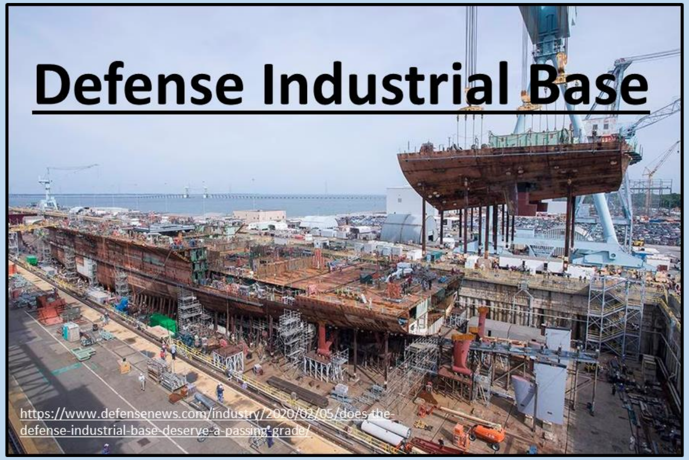

OTR Freight
https://www.fleetequipmentmag.com/us-bank-freight-payment-index-shipments/

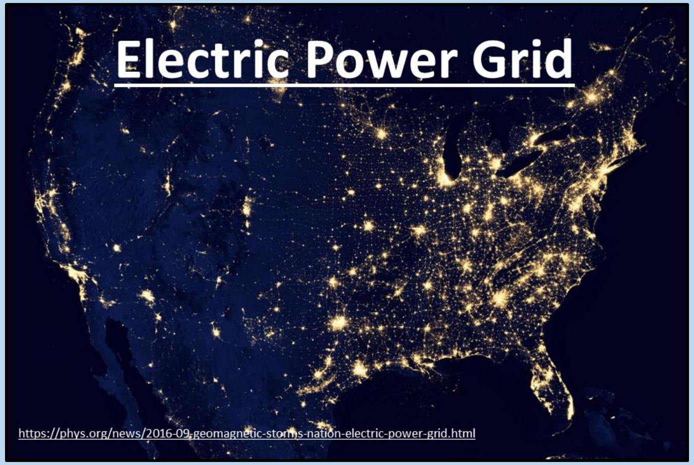

Mining
Oil, Natural Gas,
Coal, Uranium,
Minerals, Metals
https://resource-erectors.com/career-blog/integrated-operations-management-in-minerals-metals-and-mining/


Natural Gas-Fired Power Plants


Nuclear Power Plants
https://www.georgiapower.com/company/energy-industry/generating-plants/plant-vogtle.html


Rail and Shipping
https://www.cato.org/publications/policy-analysis/jones-act-burden-america-can-no-longer-bear


Defense Industrial Base
https://www.defensenews.com/industry/2020/02/05/does-the-defense-industrial-base-deserve-a-passing-grade/


Electric Power Grid
https://phys.org/news/2016-09-geomagnetic-storms-nation-electric-power-grid.html


Agriculture &
Food Production
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Cement Production
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Coal-Fired Power Plants
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Chemical Production
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Iron and Steel Forging
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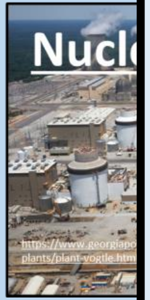
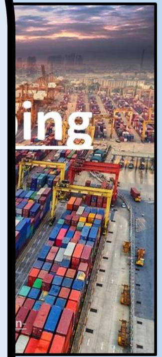
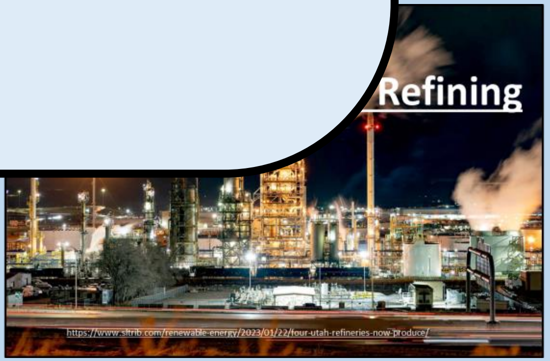
Oil and Natural Gas Refining
https://www.sltrib.com/renewable-energy/2023/01/22/four-utah-refineries-now-produce/





America's Industrial Base

Depth, Diversity and Innovative Capacity Will Underpin Relative Advantage




To Which Great Power Competitor Belongs the Relative Advantage?
ARCTIC OCEAN
ARCTIC OCEAN
PACIFIC OCEAN
ATLANTIC OCEAN
PACIFIC OCEAN
SOUTHERN OCEAN
SOUTHERN OCEAN
ANTARCTICA
OTR Freight
Mining
Oil, Natural Gas, Coal, Uranium, Minerals, Metals
Natural Gas-Fired Power Plants
Nuclear Power Plants
Rail and Shipping
Industrial Strategy
Energy Transition
OTR Freight
Mining
Oil, Natural Gas, Coal, Uranium, Minerals, Metals
Natural Gas-Fired Power Plants
Nuclear Power Plants
CHINA AEROSPACE STUDIES INSTITUTE
CHINA'S MILITARY-CIVIL FUSION STRATEGY
Electric Power Grid
Rail and Shipping
Industrial Strategy
All Energy Resources

National Security Concerns

1. America's geopolitical competitors are strategically exploiting fossil fuel resources and technologies and leading in nuclear deployment as the U.S. debates moving away from fossil fuels and as developing economies move in the same direction as China, Russia and other authoritarian states
   - Will reduce the diversity of energy resources and technologies in America's industrial base while great power competitors diversify theirs
   - Emerging economies looking for energy partnerships will be vulnerable

National Security Concerns

2. Will policymakers in China and Russia subject their respective energy enterprises, industrial bases and state-owned enterprises to an all-in effort to reduce carbon emissions and solve the climate crisis?

Fundamental Security Questions

Can the U.S., with its industrial base restructured around low- and zero-carbon energy, predominantly renewable energy,:

1. Retain its 20th century economic, military, industrial and geopolitical advantage relative to 21st century strategic competitors?
2. Attract emerging economies in need of proven, reliable energy resources?
3. Outcompete its pacing challenge, China, and deny the CCP of its intentions to disrupt a rules-based international order and displace America as the world's greatest superpower?

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