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MAXIMIZING THE FIRST 5% OF GDP: AN OPTIMISTIC ASSESSMENT OF THE UNITED STATES ENERGY SECTOR AND POLICY RECOMMENDATIONS FOR THE FUTURE

ES-6706 INDUSTRY STUDY – ENERGY

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PREFACE

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Field Studies, Domestic

- Montgomery County Recycling Center, Derwood, Maryland
- NextEra Energy, Inc., Juno Beach, Florida
- Florida Power & Light (FPL) Next Generation Clean Energy Center, Riviera Beach, Florida
- FPL Physical Distribution Center, Riviera Beach, Florida
- Turkey Point Power Generating Station, Florida City, Florida
- Energy, Power & Sustainability-Intelligence Lab, Florida International University, Miami, Florida
- Microgrid Innovation Site, Florida
- Dominion Energy, Richmond, Virginia
- Oklahoma Gas and Electric Company (OG&E), Oklahoma City, Oklahoma
- Institute for Resilient Environmental and Energy Systems, The University of Oklahoma, Norman, Oklahoma
- Hydrogen Combustion and Fuel Cell Stack Technology Testing Lab, the University of Oklahoma, Norman, Oklahoma
- Energy Sustainability and Carbon Management Laboratory, The University of Oklahoma, Norman, Oklahoma
- Kingfisher Wind Farm, Apex Clean Energy, Okarche, Oklahoma
- Oklahoma City – Air Logistics Complex, Tinker Air Force Base, Oklahoma
- Continental Resources, Hydraulic Fracturing Production Site, Blanchard, Oklahoma

Energy Field Studies Destinations Map

Field Studies, International

- Polish Oil Concern Orlen Public Corporation (Orlen), Warsaw, Poland
- Forum Energii, Warsaw, Poland
- Orlen Oil Refinery, Plock, Poland
- Westinghouse Electric Company, Warsaw, Poland
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Executive Summary

Currently, there is considerable pessimism in the United States. Inflation, political polarization, debt brinksmanship, and protracted conflict dominate headlines. However, the mood is noticeably different in the energy sector. Energy is one of America's greatest strengths, and after decades of languish and underinvestment (in certain parts of the industry), the sector may now be positioned to lead a new era of American leadership and growth. For the first time in decades, there is significant investment from the federal government, and the private sector and academia are eager to accept the challenges the administration has articulated.

The optimism in the sector reflects a growing realization that energy is positioned at the intersection of economic growth, national security, and environmental sustainability. While the demand for energy continues to rise dramatically around the world, the United States has retaken its global leadership position in the pursuit of ambitious transformation.

To meet rising demand while simultaneously cutting emissions, the current administration has called for a significant emphasis on developing and strengthening cleaner sources of energy generation. The administration's domestic, international, and defense strategies have largely reflected this theme. As a result, the consensus among policy professionals, business leaders, and academic researchers is that the "energy transition" is *finally* taking-off, and America is genuinely leading it.

However, the speed and intensity needed to transition to a pollution-free, abundant, affordable energy sector are nearly unimaginable. Energy sources that generate harmful pollution still account for the majority of United States (and world) consumption and production, and those trend-lines cannot change overnight.

Unfortunately, building things at great speed is no longer a United States strength – public infrastructure and large energy projects have become agonizingly slow and expensive, with cumbersome permitting processes, complicated bureaucracy, and the prevalence of "not in my backyard" activism playing a large role.

To rapidly transition America's energy sector, leaders need a focused, data-driven approach to freeing this gridlock. Key policymakers should recognize that the regulatory and administrative environment constructed over the decades (particularly for nuclear power and high-voltage transmission lines) does not fully serve the American people or its defense ecosystem. This, and an underdeveloped workforce, are likely the greatest impediments to maximizing the potential of America's energy sector and its capital investments.

The energy transition, which is fundamental to growth and security, is no longer held back by skepticism or underinvestment. Instead, the constraints on the sector and the challenges it will face are largely self-imposed and policy driven, and, therefore, can be reversed. Our analysis shows how policymakers are doing just that, and our recommendations identify several practical ways that policymakers can do even more, paving a way forward for a robust, clean, and secure energy future.

Introduction

The United States spends less than five percent of its gross domestic product on energy, but, arguably, that is the most important five percent. America's vast energy resources have fueled its growth for nearly two centuries: private industry, government, and academic-led innovations delivered copious amounts of reliable, affordable energy – directly and indirectly – to the world. It is no coincidence that periods of rapid energy discovery and innovation coincided with periods of rapid U.S. advancement and progress (i.e. the early 1900s oil boom, the 1950s and 60s nuclear age, and the fracking revolution that began in the 2010s). Thanks to the investments, attention, and excitement generated by landmark energy legislation in 2021 and 2022, the U.S. might be on the cusp of another such boom.

> *"Energy is only 5% of GDP, but it's the first 5."*
>
> - *Representative Stephanie Bice, OK-5th*

While some sectors of the U.S. economy face substantial challenges, the U.S. energy sector overall has immense potential and should be an engine of American growth and renewal for the ensuing decades. Capital formation, with generous support from recent federal policy, is at record levels, and the sector is booming according to most metrics. The problems the sector does face – cumbersome and slow permitting processes, outdated regulatory structures, inefficiency, and labor constraints – are largely policy-driven; therefore, they can be addressed with strategic thinking and objective, analytical governance. Ultimately, a healthy mix that utilizes all energy sources to different degrees will be important to the evolving energy industry going forward.

Some may argue (particularly in the context of climate change) that this investment is decades late; however, the convergence of multiple world challenges – great power competition, the weaponization of energy resources, increasing global temperatures, and the rapid acceleration of new technologies – offers a clear opportunity for U.S. leadership, strength, and inspiration. This is why the Biden Administration's National Security Strategy places significant emphasis on energy

development, security, and resilience, and it articulates a call-to-action to meet ever-increasing energy demand while simultaneously pursuing ambitious greenhouse gas emission reductions.

Policymakers should seize the opportunity and confront these challenges with an objective and inclusive approach to shaping the energy transition. This means embracing options, processes, and energy mixes that could elicit strong reactions amongst segments of the population.

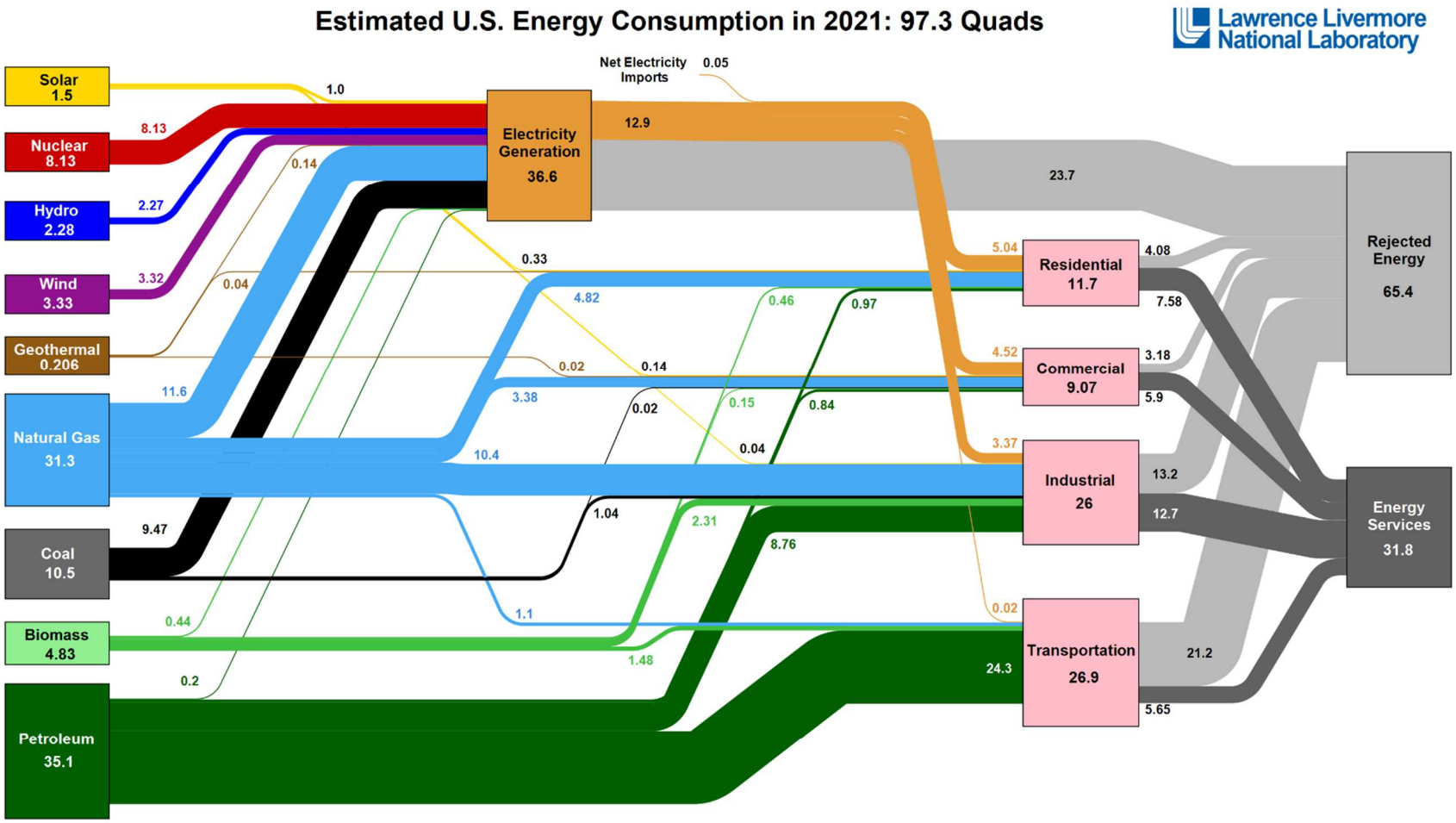
Because periods of rapid technological change are also often accompanied by periods of discontent and instability, U.S. policy needs to address the real concerns of communities that might not benefit immediately from the energy transition. Policymakers (and particularly activist groups) also need to acknowledge the tradeoffs presented by different forms of energy, and all levels of government need to undertake an honest assessment of the often-disappointing pace of critical project delivery.

Defining the Energy Transition

The term "energy transition" is used in different capacities and contexts, but for the purposes of this report, "energy transition" refers to the following principles, trends, and shifts.

- **Large-Scale Adoption of Pollution-Free Electricity Generation Sources:** Most electricity is generated from sources that emit pollution. This includes coal and natural gas, and, particularly in developing nations, oil. The United States has effectively begun a transition towards using less carbon-based energy and more renewables-based energy; however, the world energy system overall is still increasing pollution-emitting electricity sources.
- **Electrify Nearly Everything:** The transportation sector (cars and trucks) is still dominated by oil. Additionally, the residential and commercial heating sectors still rely on natural gas, as well as large portions of the industrial sector.
- **Converting Fossil Energies into Hydrogen or Clean Fuels at Industrial Scale:** The heating content of fossil fuels can be converted into emission-free hydrogen. However, it is still nowhere near the scale needed to transform sectors of the economy.

United States Energy Sector (at a Glance)



Source: LLNL March, 2022. Data is based on DOE/EIA MER (2021). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 21% for the transportation sector and 49% for the industrial sector, which was updated in 2017 to reflect DOE's analysis of manufacturing. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

Technology Review

The technologies and primary energy sources that supply all end use energy all have strengths and weaknesses. Each energy type ought to be judged across a variety of dimensions, and each dimension can be fundamental (i.e., physics based) or imposed (i.e., policy driven).

			Dimensions to Consider										
Energy Source	**Consumption, Quadrillion BTU**		**Cost**	**Land Use**	**Reliability**	**Flexibility**	**Safety**	**Carbon Emissions**	**Non-Carbon Pollution**	**Water Consumption**	**Regulation**	**Defense Applications**	**International Leverage**
Petroleum (Oil)	35.1	IIIIIIIIIIIIIIIIIIIIIIIIIII	↑	→	→	→	→	→	→	↑	↓	→	↑
Natural Gas	31.3	IIIIIIIIIIIIIIIIIIIIIIIII	→	→	↑	→	→	→	→	↑	→	↑	↑
Coal	10.5	IIIIIIIII	↓	→	→	↓	→	→	→	→	↓	↓	→
Nuclear	8.1	IIIIIII	→	↑	↑	↑	↑	→	→	→	↑	↑	↑
Biomass & Fuel	4.8	IIII	*	*	*	*	*	*	*	*	*	*	*
Wind Power	3.3	III	↓	→	→	↑	↑	→	→	→	↑	↑	↑
Hydro Power	2.3	II	→	→	↑	→	→	→	→	→	→	→	↓
Solar Power	1.5	I	↓	→	↑	↑	→	↑	↑	→	↑	↑	↑
Geothermal	0.2		↑	↑	→	→	→	→	→	↑	↑	↑	↑
Converted & Storage													
Liquified Natural Gas			↑	*	*	*	*	*	*	*	→	↑	↑
Hydrogen			↑	*	*	↑	*	*	*	↑	↑	↑	↑
Battery Storage			↑	→	↑	↑	↑	↑	↑	↓	→	↑	↑

Favorable
Average
Unfavorable

↑ Improving
→ Stable
↓ Getting Worse
* Not Assessed

Petroleum & Oil

Petroleum (oil) has been the leading energy consumption source in the United States since government records began in 1950.[1] Oil production boomed in the early 1900s and was a major source of domestic economic growth. However, in the 1970s, a series of oil shocks resulted in a national effort to reduce dependence on foreign oil and consider energy as a national strategic concern. In the 2010s, U.S. technology unleashed a second oil (and natural gas) boom through hydraulic fracturing (fracking) technology.

Today, the U.S. is the world's leading producer and consumer of oil. Despite the growth in electric vehicles (EV) and renewable energy, oil still plays a crucial role in U.S. security, resources, and economic growth. Furthermore, about 40% of industrial energy usage is oil.[2]

A significant challenge to the industry in recent years is price volatility – oil prices have swung by $25 or more per barrel in 16 out of the last 23 years. Prices have remained elevated since the early 2000s as conflict in the Middle East disrupted supply and emerging economies sought to fuel rising lifestyles. World oil demand has increased nearly every year in the last 40 years (except for the 2007-2008 Global Financial Crisis and the COVID-19 pandemic).[3]

The oil industry has also faced mounting pressures from government regulation, environmental groups, and activists. The primary concern is the environmental harm caused by drilling, pipeline infrastructure, oil spills, and air pollution caused by burning these fuels. High visibility environmental events such as the 1989 Exxon Valdez oil spill, 2010 Deep Water Horizon offshore drilling disaster, and the 2018 Sanchi oil tanker collision drive significant media attention.[4] Furthermore, there is significant evidence that areas dense with petrochemical industries, such as Louisiana's "cancer alley," face debilitating health outcomes.[5] Still, the oil industry has become significantly cleaner and safer over the decades.[6]

Burning oil and its end products (gasoline, diesel fuel, and others) contributes about one third of the total greenhouse gas emissions in the world and nearly one half of U.S. total emissions. Furthermore, the exploration of oil (and gas) contributes to methane emissions which is a very potent greenhouse gas.*

Despite the growth in renewables and electrification, oil remains vital within the U.S. energy sector. The U.S. oil industry is one of the most productive and efficient sectors in the world, and technological breakthroughs have led to an enormous increase in production. Unlocking shale and other "tight" oils from the Permian, Eagleford, and Bakken Basins in central North America, and others through fracking has produced an enormous shift in the world energy market. It has created revenue for local communities, and it has helped to keep world energy prices stable. This proved particularly important as many European nations sought alternative energy sources after Russia's invasion of Ukraine.[7]

Natural Gas & Liquified Natural Gas

Natural gas (NG) – once considered a worthless byproduct of oil extraction – has grown to be a significant component to the U.S. energy sector. As a cleaner burning alternative to coal, NG has grown to become the largest source of electricity in the U.S.[8] America is now the world's leading producer of NG, and production levels have reached record highs in recent years. Furthermore, proved gas reserves keep reaching record amounts.[9] The industry has also seen significant investment in infrastructure, including pipelines and liquified natural gas (LNG) export terminals, to support the growing demand both domestically and abroad.[10]

* Notably, the 2022 Inflation Reduction Act imposes a $900 per metric ton of methane emissions charge beginning in 2026. The charge rises to $1,500 per ton after two years.

The NG industry has become an important economic engine, particularly in lower income states like West Virginia. However, despite economic benefits, research suggests that additional emissions and contamination also have economic and health consequences.[11] Methane emissions from gas production and transportation are one of the more serious concerns related to NG because of methane's potency and difficulty with trapping.

As with oil, the industry faces pressures from environmental and activist groups and from competition with renewable energy sources; however, NG (particularly LNG) enjoys more bipartisan support.[12] The LNG industry has risen to heroic status in parts of Europe as it has quickly filled portions of the energy supply gap left by Russia's disastrous decision to invade its neighbor.

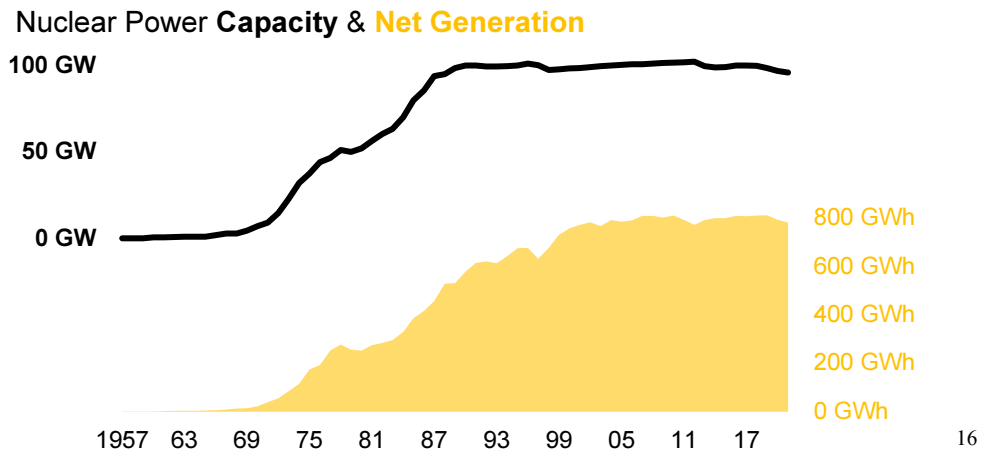
Nuclear Power

The U.S. nuclear power industry has struggled for decades, but thanks to new federal policies, may be gearing up for a renaissance. Cheap NG and competition from solar and wind generation has made new nuclear power plants economically unattractive. Furthermore, the industry faces extremely daunting regulatory hurdles at every stage of the process[13], and public support for the industry is haunted by the disaster at Chernobyl and dramatic incidents at Three Mile Island and Fukushima.[14] †

Despite its challenges, the nuclear sector has remained a constant source of safe, reliable, clean power for decades. The average nuclear reactor is 40 years old, and nuclear generation capacity has remained at a stand-still since 1990.[15] Actual power production, however, has managed to

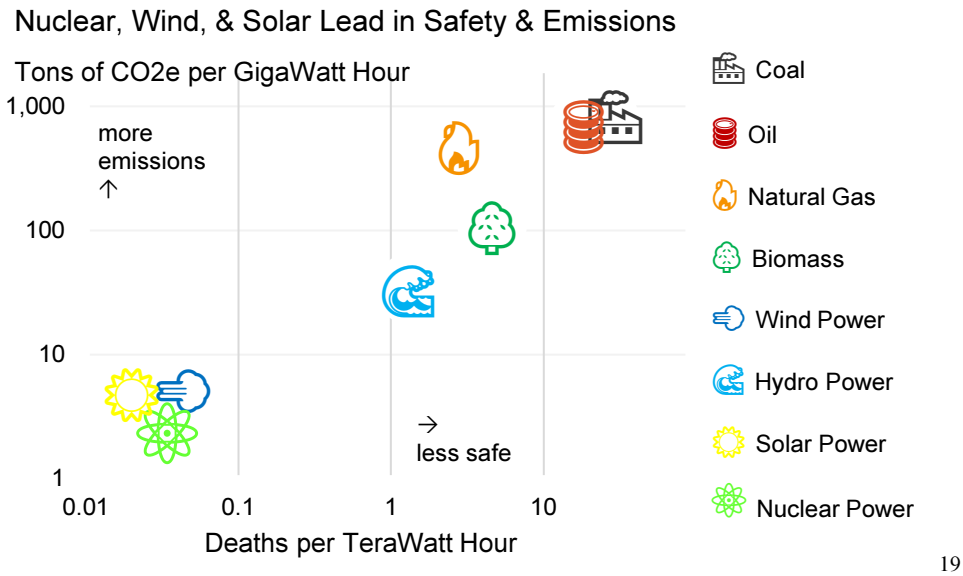
† It is worth noting that Three Mile Island nuclear power plant (reactor unit 1) continued operating safely through 2019. Reactor unit 2 was decommissioned after the accident, but parts of the reactor were repurposed at a different nuclear plant. And, at Chernobyl, 2 out of the 4 reactors (unit 1 and 3) at the site continued to operate through the 1996 and 2000, respectively.

increase since 1990 by 35% because of higher efficiencies, better control strategies, and advanced computer systems. This suggests that, while the U.S. struggles to build new nuclear capacity, it excels at operating, maintaining, and enhancing its existing fleet.



At the same time, our main pacing competitor (the People's Republic of China) is constructing at least one new nuclear power plant every six months, using construction companies that move immediately from one nuclear project to the next, thereby maintaining the knowledge and experience gained from each site, and streamlining the process of new plant construction. China aims to have 70 GW of installed nuclear capacity by 2025, with the possibility of going as high as 120 GW by 2030.[17]

France is one of the few countries to largely decarbonize its electricity sector. It did so by going all-in on nuclear power, including a streamlined permitting procedure for the approval of three standardized reactor designs and a system for "step-by-step" permits that allows companies to start building some components while approvals for others are still in progress. The government also invested heavily in public outreach campaigns, educational programs, and initiatives to increase public engagement, facilitating greater acceptance of the energy transition.[18] France's nuclear sector prevented significant price shocks after Russia's invasion.



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Economic considerations tend to win in a market-based system, and the high costs of nuclear power plant construction and maintenance have forced the delay or cancellation of new plant construction as well as the premature closure (or threat to close if government support is not secured) of various other plants.[20] The 2021 Infrastructure Law created the Civil Nuclear Credit program, which devotes $1.2B in government funding to modernize aging nuclear power plants across the country and bring some shuttered ones back online.[21] It also provides financial incentives for the construction of new nuclear reactors, including expanded tax credits for advanced nuclear facilities and a reauthorized loan guarantee program up to $25 billion that will support advanced nuclear energy projects.[22]

The U.S. Department of Energy's Office of Nuclear Energy (NE) provides financing for research and development focused on enhancing the dependability, flexibility, and efficiency of current nuclear facilities in order to maintain the current fleet of reactors.[23] Additionally, the NE is working towards the creation and application of advanced reactor concepts. The U.S. Nuclear Regulatory Commission (NRC) has also taken action to prolong the operational lifespan of

existing plants. The NRC granted the first subsequent license renewal (SLR) for a nuclear power plant in 2020, extending the plant's initial 40-year operating license by an additional 20 years.[24]

Through the Department of Defense's (DoD) Strategic Capabilities Office (SCO) "Pele" program, SCO is employing U.S. contractors BWXT, Rolls Royce, and a leading software design company to develop ten micro-reactors, with the aim of having the first micro-reactor operational in 2025.[25,26] By doing so, it is incentivizing innovation by private companies, stimulating U.S. supply chains to provide the types of materials and processes necessary for such construction, and clearly demonstrating the applications, both military and commercial of such technology.

Some utilities are investing in newer generation advanced nuclear technologies, such as advanced micro reactors (AMR) and small modular reactors (SMR). These are intended to cut costs and increase safety over large, traditional plants. AMR and SMR technology have significant interest by the military and other large consumers of energy.[27] [28]

Nuclear power is an important component of a diverse energy mix that can help reduce pollution, lower heat-trapping emissions, and deliver predictable and reliable power. The problems that led to the U.S. nuclear power industry's growth freeze are real, but not unsurmountable, so American policymakers should take strong actions to revitalize the nation's nuclear energy industry now.

Coal

Coal is one of the world's oldest sources of energy. It powered the Industrial Revolution and lit the world's first electric lightbulb. However, the industry has been in steep decline in the U.S. for several years. U.S. coal-fired power plants are retiring at a rapid pace, and the industry's share of total electricity generation has declined by nearly 60% from 2005.[29] In addition to market forces, environmental concerns and climate policy have led many utilities to shift away from coal power in favor of cleaner energy sources.

Despite the decline of the coal power industry, coal remains an important energy source in the electric and industrial sector. The industry also continues to support thousands of jobs and contributes to local economies, particularly in Appalachia and the Powder River Basin regions in Wyoming and Montana.[30] The coal industry received support from the Trump administration, which rolled back environmental regulations and sought to promote coal as a key component of U.S. energy policy. However, many analysts believe that the decline of the coal industry is a long-term trend that is unlikely to be reversed by policy changes alone. Despite coal's challenges in the high-income world, coal power capacity is still growing rapidly in China, India, and other developing nations.[31]

Wind Power

Wind energy is the largest renewable energy source and the second fastest growing source of energy in the U.S. Wind capacity grew 13 GW in 2021 for a total of 136 GW[32], led by Texas with approximately 30% of the domestic market. This growth is driven by declining costs, technological advancements, and supportive policies at the federal and state levels. While only at two percent of net U.S. electricity generation in 2010, it reached ten percent of generation in 2022.[33] The industry has also created thousands of jobs and contributed to local economies across the country.

America is home to some of the world's largest wind power projects, including the Alta Wind Energy Center in California and the Roscoe Wind Farm in Texas. Texas is now the leading state for wind power capacity, followed by Iowa, Oklahoma, and Kansas.[34] However, the industry is also growing in other regions of the country, including the Northeast and Southeast, as states seek to expand their renewable energy portfolios.

The wind energy industry faces several challenges, including intermittency, siting and land-use issues, cost of transmission from the point of generation to population centers, protectionism by reactionary state policies favoring fossil fuels, and competition from other renewable energy sources. Ongoing technological advancements in battery storage and pairing of wind and solar farms are helping to address intermittency challenges. Increased interest by many ranchers and farmers in hosting wind facilities on their property as a source of income help to address siting issues.[35] Protectionist state policies may increasingly complicate wind energy buildout as competing energy industry advocates contest the transition to renewable energy.

Hydro Power

Hydropower was the first form of U.S. renewable energy produced in mass. Hydropower facilities are powered by running water occurring along rivers and streams. Pools and dams are built along these bodies of water and use the naturally rushing water to spin turbines that generate electricity.

After extensive buildout in the late 19th and 20th centuries, U.S. hydropower construction has ebbed in recent years. Still, it remains an important part of the renewable energy mix and accounts for 19% of U.S. renewable energy. The U.S.A. is the third-highest global producer of hydropower behind China and Brazil. The U.S. Department of Energy assesses hydropower's future potential for growth as high, with only 3% of existing multi-purpose dams currently being used to generate electricity.[36]

China has invested heavily in hydropower and is the world's largest producer. It sees hydropower as a large percentage of its renewable energy mix and has built three of the five biggest hydropower dams in the world, including the massive Three Gorges Dam with 23 GW in electrical capacity. China set (and exceeded) a goal to reach 300GW of hydropower capacity by

2020, approximately ten times higher than their goal for the next highest renewable source (wind power).[37]

Hydropower facilities present some challenges. The first challenge is the high cost of constructing dams with energy conversion facilities. Other challenges occur once hydropower facilities begin operating. Dams' restriction on natural water flow and their disturbance of natural water temperature have downstream effects on humans and wildlife that must be managed. Hydropower is highly susceptible to decreased rain and snowfall.[38] Similar to wind and solar power, electric grid operators relying on hydropower must have alternatives for electricity generation in times of low rain, wind, and sun.

In addition to producing on-the-spot power, hydro also works well as an "energy battery" or "pumped storage." By using two pools of water, one at a higher elevation and another at a lower elevation, and a pump system, hydro systems can balance peak supply and demand. During times of peak electricity supply, when there is more electricity available than needed for consumer demand, operators pump water from the lower pond to the upper pond. Then, in times of peak demand, operators release water from the upper pool to the lower pool. The water moves due to gravity and creates electricity to assist in meeting peak consumer demand. Hydro energy storage faces challenges in finding appropriate land for siting. Due to the extensive space needed for two large pools, the high costs of excavating, and the resultant environmental effects, these facilities are best built in large open areas with varying elevations. It is a challenge to find these areas close enough to population bases to make electricity transmission economically viable.

Solar Power

The solar energy industry in the U.S. has experienced significant growth in recent years, driven by declining costs, supportive policies, and increased consumer demand for clean energy. According

to the Solar Energy Industries Association, the U.S. added 20.1 gigawatts (GW) of solar photovoltaic (PV) capacity in 2021, bringing the total installed solar capacity to more than 107 GW.[39] Solar power accounted for approximately 3.3% of total U.S. electricity generation in 2021.[40] California leads the country in installed solar capacity, followed by Texas, Florida, and North Carolina.

The solar energy industry faces several challenges, including intermittency, siting and land-use issues, and competition from other renewable energy sources. However, ongoing technological advancements and research efforts are helping to address these challenges, and the industry is likely to continue to play an important role in the U.S.' transition towards a low-carbon energy future.

Efficiency

While the United States has made some progress in general efficiency, it remains a high energy user per capita relative to other rich nations.[41] Americans use about 76,000 kWh per person per year, while Germans use just 42,000 kWh per person. The United Kingdom uses less than 30,000 kWh per person.

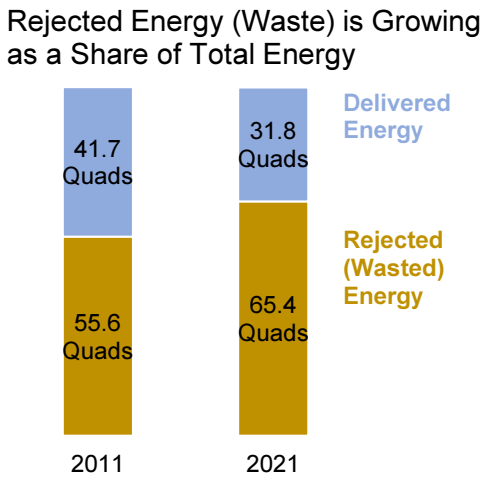
> *"Each American uses the energy equivalent of 60 barrels of oil per person each year. Ours is the most wasteful nation on Earth. We waste more energy than we import. With about the same standard of living, we use twice as much energy per person as do other countries like Germany, Japan, and Sweden."*
>
> - President Jimmy Carter, 1977

The EIA reports that domestic energy consumption has consistently climbed over the previous few decades, rising from 2,913 billion kilowatt-hours (kWh) in 1990 to a projected 4,972 billion kWh by 2050.[42]

Despite increasing energy efficiencies brought about by new technological advances, the rapid expansion of the digital economy and the large growth of data centers (whose ever-increasing numbers of servers need more electricity every year) continue to drive demand upwards. The

International Energy Agency (IEA) projects, "the energy intensity of data centers is falling, but their sheer numbers and increasing demand for digital services mean that total energy consumption is still on the rise."[43]

Combined with population growth and increasing electrification of everything from cars to combines, the American people are putting heavier and heavier loads each year on the nation's aging electrical generation infrastructure. Incentivizing efficient power generation is critical to the economy and to keeping the nation's critical infrastructure – including military bases, hospitals, research centers, and data farms – running.



Energy remains relatively cheap in America, making it hard to incentivize everyday citizens and business leaders to reduce consumption. A significant portion of the improvement of overall energy efficiency has come from the industrial sector. Industrial energy use is slightly less today than it was in 1979 [44]; however, industrial production has doubled during that time.[45] Other sectors – commercial and residential – remain relatively energy intensive when compared to other high-income countries.[46] Increasing energy efficiency across these sectors will have compounding effects year after year through demand reduction.

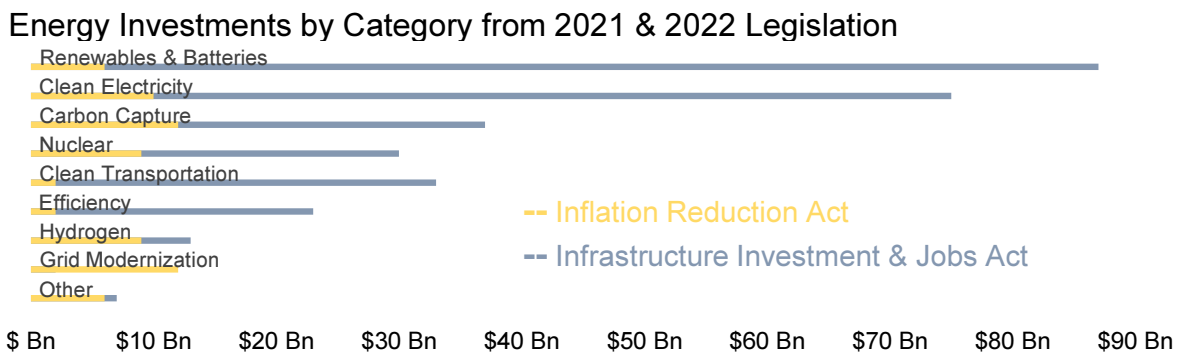
Strategic Environment

The strategic environment of the U.S. energy system is evolving rapidly. Advancement in technology, the political and policy environment, global energy markets, and geopolitical shifts have led to significant changes in a short time. As always, a dynamic and complex strategic environment offers both risks and opportunities for the U.S. and its allies.

In the 1970s, U.S. energy supply was threatened by high oil prices imposed by the recently formed Organization for Petroleum Exporting Countries (OPEC). The United States imported a much higher portion of its energy supply at that time, with net imports of six million barrels per day.[47] U.S. policy response to the oil shocks included establishing a Strategic Petroleum Reserve, government efficiency standards, and efforts to deregulate the oil industry; however, U.S. oil production continued to fall for the next several decades, and America remained heavily dependent on foreign oil until the 2010s. Even after becoming the world's leading oil producer, the U.S. still relies on OPEC nations because most of its refineries are configured to refine higher-grade Middle Eastern oil and blends.[48]

The United States has not pursued comprehensive energy strategy or legislation for several decades. Even laws once considered "landmark" energy policy such as the Energy Policy Act of 2005, the Energy Security & Independence Act of 2007, and the American Recovery & Reinvestment Act of 2009 (ARRA) spent relatively little on energy, despite their headlines.[49] ARRA investments, though small, did appear to have a significant effect on the nascent battery manufacturing sector, however.[50]

Regardless, the pre-2021 legislation pales in comparison to transformational energy policy included the Infrastructure Investment & Jobs Act (IIJA also known as the Bipartisan Infrastructure Deal or BID) and Inflation Reduction Act (IRA).[51]



The overnight influx of federal support and investment in clean energy development is a major change for most within the industry and truly represents a turning-point. Previously skeptical industries, such as traditional utilities, are now engaged and bought-in to the transition.[52]

Furthermore, as outlined in the Biden Administration's National Security Strategy (NSS), energy development, security, and resilience are all vital elements of U.S. national security.[53] The document states the following:

> We have experienced a global energy crisis driven by Russia's weaponization of the oil and gas supplies it controls, exacerbated by OPEC's management of its own supply. This circumstance underscores the need for an accelerated, just, and responsible global energy transition. That is why — even as we continue to explore all opportunities with our allies and partners to stabilize energy markets and get supplies to those who need it — we are also focused on bringing innovative energy technologies to scale as quickly as possible.[54]

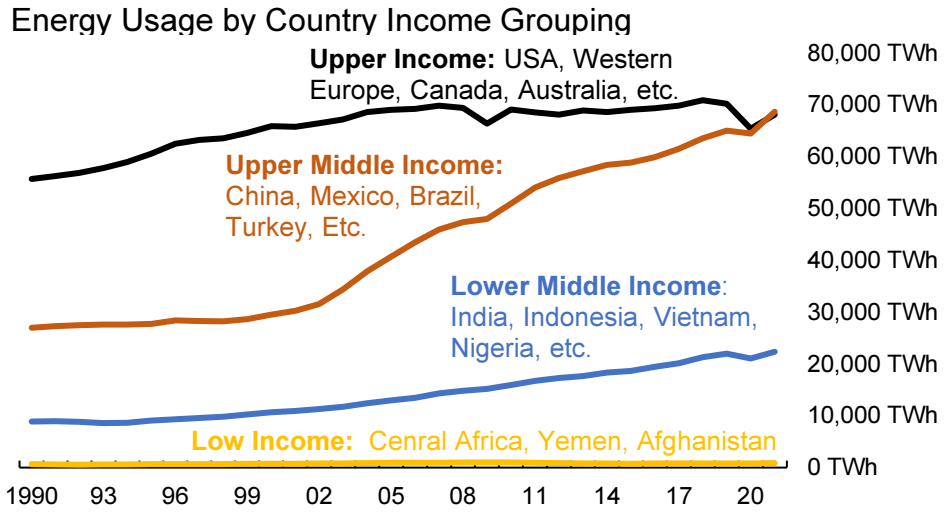
The NSS also states that, in 2022, the Biden Administration enacted the Inflation Reduction Act, to "invest in domestic energy production and manufacturing, and reduce carbon emissions by roughly 40 percent by 2030." The Climate and Energy section of the NSS states, "Combatting the climate crisis, bolstering our energy security, and hastening the clean energy transition is integral to our industrial strategy, economic growth, and security."[55] Responding to the ever-increasing demand for energy while at the same time pursuing ambitious greenhouse gas emission reductions is the essential challenge facing the energy industry today.

Global Strategic Environment

On a global scale, the strategic environment for energy is perhaps the most dynamic and challenging it has been since the 1970s. There is a confluence of long-term trends and short-term acute shocks.

Rising World Demand

Rising demand from developing nations such as China, India, Nigeria, Indonesia, and Brazil is fueling increases in commodity prices and keeping fossil fuels as the dominant energy source.[56]



While this ensures that these nations are increasing their living standards with access to energy, it makes reducing global emissions to the levels urged by the United Nations nearly impossible.

Weaponization of Energy

Energy security quickly returned as a major geopolitical imperative. The "weaponization of energy" has shown that using energy as a means for punishment or coercion is still a powerful tool for many countries.

- "Energy Blackmail": Countries with significant energy resources use their position to extract concessions by threatening to cut off supply or raise prices. Russia's attempts to break the will of the European Union by cutting off gas supplies is a recent example.[57]
- Sanctions: Alternatively, the U.S.A. and many Western nations often use energy sanctions on nations such as Iran, North Korea, Venezuela, and Russia.[58] These sanctions include outright banning their energy imports and preventing access to energy technology in select markets.
- Exploitation: Countries may turn to exploitation of resource rich, weaker nations. For example, China has become a major investor in sub-Saharan African nations' energy sectors,

particularly in oil, gas, and hydropower. The Chinese government and Chinese companies have pursued a strategy of resource extraction and infrastructure development in African and Eurasian countries to secure access to energy resources for China's rapidly growing economy.[59] (See Annex I for more information).

Environmental Degradation & Climate Change

As noted, the U.S.A. enjoys abundant, inexpensive energy; however, most of that energy comes from sources that require burning fuels that release carbon dioxide, methane, and other gases that warm the atmosphere.[60] The science behind this phenomenon is settled, and the consequences of rising global temperatures are already changing the world in profound ways. The DoD has also embraced the challenge of climate change as a key strategic challenge.[61]

Beyond climate change, there are huge benefits to transitioning away from burning fossil fuels. Coal for power emits significant quantities of dangerous pollutants, as Scientific American notes:

> In fact, the fly ash emitted by a power plant—a by-product from burning coal for electricity—carries into the surrounding environment 100 times more radiation than a nuclear power plant producing the same amount of energy.[62]

And, according to Duke University analysis:

> Documented health risks from exposures to the pollutants include premature deaths, cardiovascular diseases, lung cancer, low birth weights, higher risk of developmental and behavioral disorders in infants and children, and higher infant mortality.[63]

Similar analysis has concluded that living near trucking corridors has detrimental health effects from smog and pollution. Even the most efficient gasoline engine converts less than 50% of the energy stored in the fuel to usable energy (the rest is wasted on friction, heat, and noise). In prior eras, international cooperation to tackle global environmental challenges was common. For example, the 1987 Montreal Protocol confronted ozone layer depletion through an international treaty. Confronting environmental challenges is likely one of few ways that the United States and its competitors can cooperate.

“Porter’s Diamond” Model Analysis

Factor Conditions

The U.S. energy industry has abundant natural resources, including coal, natural gas, oil, and renewable energy sources like solar and wind. The country's large reserves of fossil fuels have contributed to the growth of the industry, making it one of the largest energy producers in the world. In terms of infrastructure, the U.S.A. has a vast network of pipelines, refineries, and power plants that facilitate the production and distribution of energy. The availability of skilled labor and access to capital have also been significant factors in the growth of the industry.

Demand Conditions

The U.S. domestic market is one of the largest in the world, with a high demand for energy in various sectors such as transportation, manufacturing, and residential. The country's large population and high standard of living contribute to the high demand for energy. The international demand for energy is also significant, with the U.S.A. being one of the largest exporters of crude oil, natural gas, and refined petroleum products. The country's position as a leading global economy also makes it an attractive destination for foreign investment in the energy sector.

Firm Strategy, Structure, & Rivalry

Various industries within the energy sector have different degrees of competition. For example, oil and coal are heavily concentrated with just a few major firms. However, the wind industry has hundreds of small developers.

The industry's structure is highly competitive, with firms competing based on cost, technology, and innovation. The industry's dominant players invest heavily in research and development to develop new technologies and improve operational efficiency. The industry's competitive environment has contributed to the industry's growth, with firms constantly seeking to improve their competitive advantage.

Related & Supporting Industries

The U.S. energy industry is supported by a wide range of industries, including engineering, construction, transportation, and finance. These industries provide essential services such as designing and building energy infrastructure, transmitting and distributing energy, and financing projects. The U.S.A. also has a robust research and development ecosystem that supports the innovation and development of new energy technologies, including renewable energy. In some sub-sectors (i.e. nuclear construction) deteriorated supply chain and loss of expertise presents major challenges.

International "Porter's Diamond" Model Analysis

Russia & China

		Factor Conditions	Demand Conditions	Firm Strategy, Structure, & Rivalry	Related & Supporting Industries
China	**Analysis**	China has large coal reserves but smaller amounts of oil and gas. China is home to many rare earth and other minerals important to battery and renewable energy industries.	Chinese demand remains high and grows with their increased industry and middle class. Demand outstrips its ability to produce energy with domestic resources. It is a net importer of oil and gas, and demand is expected to continue to increase. Chinese use about 1/3 the amount of energy as U.S. counterparts.	Chinese firms and China's economy operate with a high degree of central government control. Allocation of resources and assignment of tasks is facilitated by a unified central government, but the absence of free market forces often leads to misallocation and financial irresponsibility.	As a manufacturing giant, China has an abundance of capable related and supporting industries who can assist in ramping up new technologies to scale like no other country in the world.
	Sources	"China" International Energy Agency, https://www.iea.org/countries/china, Accessed April 24, 2023 "China Country Commercial Guide - Energy", International Trade Administration, https://www.trade.gov/country-commercial-guides/china-energy, Accessed May 5, 2023			
Russia	**Analysis**	Holds enormous reserves of fossil fuels including largest global reserves of natural gas. Has less availability for renewable energy due to climate. Weakened by falling fertility rate and lesser educational institutions.	As a petrostate, relies heavily on the sale of fossil fuels to fund economy and basic services. Loss in exports to Europe mostly replaced by increased sales to India, China, and others, but at a significant discount.	Business culture heavily impacted by government favoring firms tied to associates of Vladimir Putin, leaving little room for market competition and domestic innovation.	With loss of imported technology due to sanctions, its failure to develop domestic expertise threatens its continued resource extraction and facilities maintenance. Recent conflict and negative outlook led to a brain drain of promising young Russians.
	Sources	U.S. Energy Information Administration. "Country Analysis Brief: Russia. January 17, 2023, https://www.eia.gov/international/content/analysis/countries_long/Russia/russia.pdf. Accessed May 9, 2023. Central Intelligence Agency. "Country Comparisons – Total Fertility Rate." The World Factbook, 2023, https://www.cia.gov/the-world-factbook/field/total-fertility-rate/country-comparison. Accessed April 26, 2023. Douglass, John A. "Russian Universities during and after Putin – the War in Ukraine Is a Turning Point." The Berkeley Blog, March 31, 2022, https://blogs.berkeley.edu/2022/03/31/russian-universities-during-and-after-putin-the-war-in-ukraine-is-a-turning-point/. Accessed April 28, 2023. U.S. Energy Information Administration. "Energy Fact Sheet: Why Does Russian Oil and Gas Matter? March 21, 2022, https://www.iea.org/articles/energy-fact-sheet-why-does-Russian-oil-and-gas-matter. Accessed April 28, 2023.			

Competitive Analysis for Other Key Countries

	Factor Conditions	Demand Conditions	Firm Strategy, Structure, & Rivalry	Related & Supporting Industries
China	(+) Critical Minerals (-) Fossil Fuels	(+) Global and Local increasing	(-) Geopolitical Competition/State Market	(+) Centralized Planning supports long-term strategies. (-) Centralized Planning generally weakens private sector
Russia	(+) LNG, Resources, Nuclear Expertise, Uranium (-) Education / Renewables	(-) Loss of exports to Europe	(-) Oligarchic State Sponsored Competition	(-) Academia / Sanctions / Alternatives
Saudi Arabia	(+) Oil Shares/Aramco	(+) Global Demand for Oil	(+) Oil Influence (-) 90% State Owned	(+) Extraction/Reserves (-) Alternatives
Australia	(+) Coal/Gas/Wind/Solar	(+) Coal export (-) Isolated Renewables	(+) Invest in Renew (-) Few Large Firms	(+) GOV Spot/Academia/Resources
South Africa	(-) Imports (+) Refining Cap	(+) Energy Significant to Economy	(-) Domestic Investment/Innovation	(+) Regional Partners (-) Vendor Options
Brazil	(+) Resources	(+) Internal and Reg Development	(+) Ext Investment / GOV Support	(+) Supporting Industries/Academia
Poland	(-) Reliant Import Fuel / Coal Heating	(-) Over-reliant Fossil Fuels	(+) Diversify/Nuclear (-) EU Standards	(+) Traditional Industry (-) Renewable Edu
India	(+) Coal Deposits (-) LNG/Education	(+) Internal Development	(+) Technology Support / Manufacturing	(+) GOV support (-) Reliance on Imports

(+) Significant positive attribute which directly INCREASES a nation's capability or capacity within the market
(-) Significant negative attribute which directly DECREASES a nation's capability or capacity within the market

Factor Conditions (Expanded)

Limited labor could limit the U.S. expansion of clean energy production, transmission and distribution buildout, and electrification of the economy. U.S. policies promote electric vehicles, wind power, solar power, and electrified homes, but a skilled workforce is needed to reliably connect clean generation capacity to increasing consumer demand.

A National Renewable Energy Laboratory (NREL) survey of wind industry professionals, students, and recent graduates indicated that as the industry expands rapidly, finding individuals with relevant experience is becoming more difficult. The wind industry grew from 77,000 jobs in 2016 to 117,000 in 2020.[64] This number likely grew further since then and is poised to continue its acceleration following the passage of the IRA and IIJA. The Center for Energy Workforce Development (CEWD) noted similar difficulties in attracting new technicians to fill positions in the expanding energy industry. New talent is increasingly needed to fill positions vacated by both new retirees as well as industry veterans seeking employment elsewhere.

Educational pipelines will be critical to finding the workforce necessary for the energy industry to scale as needed. Renewable technicians can currently participate in technical programs at the grade school level, while line workers, electrical engineers, and plant operators require some amount of post-secondary education prior to hiring. For the more technical vocations, firms should continue sponsoring educational programs at high schools, technical schools, and universities to foster a qualified and skilled pipeline. Firms should also consider scholarship or work-study programs to allow qualified students to study while gaining exposure to the industry. The CEWD noted that the non-retirement attrition rate in the industry is increasing.[65]

Stakeholder Interests

U.S. Government & Military

With more than 350,000 buildings and 600,000 vehicles, the federal government is the nation's largest energy consumer.[66] The largest single contributor to this energy consumption is the U.S. DoD.[67] The DoD is the single largest user of energy in the country. DoD is also the world's largest institutional user of petroleum and, correspondingly, the world's largest institutional producer of greenhouse gases.[68]

In response to these vast energy requirements, and guidance received from the latest Biden-Harris NSS, the 2022 National Defense Strategy (NDS) has emphasized energy security initiatives and priorities. It highlighted the opportunity to seed research and development efforts for clean energy alternatives. Further, the 2022 NDS prioritized being a fast-follower of commercial investments in renewable energy generation and storage.[69]

This strategic guidance underlines assessing climate change to build enduring advantages for a flexible, resilient, and ready force. It stressed the need for resilience in our military installations as the foundation from which our deterrence and warfighting capabilities emanate,[70] and the requirement of a credible expeditionary force capable of deterrence to would-be adversaries. Additionally, the 2022 NDS focused on overall energy demand reduction as a key to enduring advantages.[vi] To these ends, the DoD has concentrated on establishing a resilient defense ecosystem that prioritizes energy security as an operational imperative.[71]

The DoD groups these two requirements into Installation Energy and Operational Energy. DoD's installation energy strategy is designed to ensure mission assurance for the warfighter, reduce energy costs, and improve the energy resilience of our fixed installations.[72] Installation energy is critical to mission assurance and, ultimately, warfighter dominance. Assured

installation energy is a national security issue requiring cooperation between all levels of government, the DoD, and energy industry providers.

"The Department defines *operational energy* as the energy required for training, moving, and sustaining military forces and weapons platforms for military operations.[73] This expeditionary force is highly reliant upon hydrocarbons to energize their requirements. Though the DOD is investing in many new R&D efforts such as electrification of vehicles, SMRs for forward basing, and others; limiting factors, such as energy density, reliability, and accessibility globally, ensure that gas and diesel will remain a primary component of the energy mix of the DoD through at least 2035.[74]

Academic & Research Institutions

Seminar visits to two academic institutions highlighted advancements in wireless charging of EVs, software to efficiently manage microgrid operations, the latest in fracking technology, and new opportunities to make hydrogen cleanly from natural gas by capturing carbon for use in carbon fiber materials. The Department of Energy's FY23 budget request included more than $500M in funding for research and development programs to partner with academic and research institutions in support of clean energy demonstrations such as advanced reactor development, grid enhancement technologies, energy storage technologies, and cyber security standards for utility firms.[75] Many of the research and development programs recognize supply chain risks and seek to foster technologies which utilize relatively abundant raw materials, further securing U.S. energy independence into the coming decades.

Residential & Commercial Sector

Residential and Commercial stakeholders are increasingly playing both the role of supplier and consumer of energy. In February of 2023, Commercial and Residential sectors combined to

produce over four million Mega Watt hours of solar electricity, or the equivalent of powering roughly 400 thousand average American homes per year through small or residential scale solar. Increased tax incentives for solar panel installations will continue to increase households offsetting energy consumption with “behind the meter” generation. “Behind the meter” generation buildout will create challenges for utilities in that they will have difficulties forecasting daily power demand as well as potentially limiting future revenue.

The extent to which increased electricity demand outstrips residential solar generation will determine how much increased investment is needed in distribution grid resources and generation capacity. The EIA predicts the electrification of the commercial and residential sectors will add demand for power generation, driving further buildout of renewable wind and solar projects, but also requiring continued nuclear generation and lengthening the life of carbon-emitting natural gas generation.[76]

Transportation Sector

The transportation sector has among the largest direct interests in the energy transition. Transportation is very energy and emissions intensive. For relatively short trips, electric vehicles are clearly making progress in electrifying the sector and lowering emissions intensity per mile; however, for trucking, sea cargo, and airline transportation, there are currently few alternatives to oil-based fuels.

Road transportation accounts for most transportation related emissions, and it is likely that the other forms (particularly aviation) will be the last to transition.[77] Overall, the transition away from oil in the vehicle sector is one of the largest challenges within the energy transition. There are an estimated 1.4 billion cars in the world – most of which are in perfectly good working condition. Contrast this with the 16 million electric and plug-in hybrid vehicles sold in 2021.

Electric Vehicles Have a Long Road Ahead

Supporting Industries & Supply Chains

The energy industry involves a complex interconnected ecosystem of supporting industries and supply chains. All states seeking energy security – allies, partners, and adversaries alike – are competing for relative advantage within this ecosystem while in pursuit of their national interests. Some of the supporting industries or supply chains relevant to the energy industry include the extraction, processing, and utilization of metals, minerals, and rare earth elements; the steel industry; and cybersecurity.

Essential Metals, Minerals, & Rare Earth Elements

As the energy industry continues to increase electrification and develops a greater share of production from renewable sources, the demand for essential metals, minerals, and rare earth elements will increase as well. Examples of materials essential to the current and future industry include copper, lithium, and uranium.

Copper is widely used in power cables, transformers, and other components of the grid, as it is an excellent conductor and highly durable. According to the Copper Development Association, approximately 55% of copper consumed in the U.S. is used in the construction of electrical products and equipment, making it the largest end-use sector for copper (Copper Development Association, 2022).[79] Additionally, one assessment predicts that demand for copper will increase

tenfold by 2030 with the construction of new distributed generation sites, investments in transmission and distribution infrastructure, or the application of renewable sources.[80]

Lithium is a key component in the development of electric car batteries. Nearly 30 years ago, the U.S. produced 37% of the world's lithium, but that share has since dropped to approximately 1%.[81] Currently, Australia produces more than 50% of the world's lithium, 90% of which is then exported to China.[82] These exports, along with China's domestic mines, international acquisitions, and refining capacity, have enabled the PRC to secure a "strong foothold in the lithium supply chain."[83] Therefore, increasing the number of electric cars in the U.S. likely will involve competition for sources of raw materials or require closer cooperation with the PRC.

Uranium is essential in the nuclear energy process and most of the uranium used in the U.S.A. is imported. For example, in 2021, 35% of the total U.S. purchases of uranium came from Kazakhstan, 15% from Canada, 14% from Australia, and 14% from Russia, according to the EIA.[84] In order to continue operating its nuclear power stations, the U.S.A. must rely on allies and partners for critical materials. Additionally, should the United States consider expanding the use of nuclear energy for the benefits of reduced emissions, these resource dependencies will increase in scale.

Steel Industry

The steel industry represents a symbiotic or codependent relationship with the energy industry. Iron and metallurgical coal are key components in the production of steel, and steel is essential to the U.S. energy sector, providing the necessary infrastructure to support the production, transportation, and distribution of various forms of energy. Steel also is used in a range of energy-related applications, including oil and gas pipelines, wind turbines, and transmission and

distribution infrastructure for electricity. According to the American Iron and Steel Institute, the U.S. steel industry supplied 52 million tons of steel to the energy sector in 2020.[85] Unfortunately, the steel-making process also entails significant carbon dioxide emissions. In fact, one estimate asserts that for every ton of steel produced, approximately 1.8 tons of CO_2 emissions are generated.[86] New production techniques to reduce the steel industry's impact on the environment are reportedly under development but not yet technologically mature or cost-effective.[87] Therefore, initiatives to incentivize green energy, such as by taxing pollution, could also impact the steel industry, which is codependent on the energy industry.

Cybersecurity

Cybersecurity is crucial in the energy sector due to its heavy reliance on digital technology and interconnectedness. The industry faces the risk of cyber-attacks targeting control systems, data breaches, and intellectual property theft. Attacks on control systems can disrupt energy supply and cause power outages and infrastructure damage, posing risks to public safety. Data breaches can result in the theft of sensitive information, reputational damage, and financial losses for energy companies. The increasing number of remote, distributed energy sources like wind and solar farms also introduces potential vulnerabilities.

Policy Recommendations

Enact Comprehensive Permitting Reform & Fully Staff Offices with Permit and Regulatory Oversite

Permitting reforms have been proposed by members of both political parties. The permitting process slows down all types of energy development (renewable, nuclear, and fossil) and infrastructure upgrades. For example, a recent report projected that net U.S. emissions would be higher than baseline if electrical transmission lines grew at the recent slow pace.[88] Permitting is

often cited as a reason why projects stall, and there is a complex patchwork of local, state, and federal permits.[89]

Most recently, Senator Joe Manchin introduced legislation to address elements of comprehensive reform.[90] This reform – and more – should be fully embraced by all levels of government.

Furthermore, the offices that oversee permitting (including the Federal Permitting Improvement Steering Council [91]) should be staffed appropriately. Studies have identified understaffed offices as a key reason why the permitting process is slow.[92] Simply staffing offices at appropriate levels would speed up the process without degrading any of the critical environmental and safety requirements.

Build On and Accelerate Bi-Partisan Efforts to Improve, Streamline, & Facilitate Rapid Nuclear Expansion

The nuclear industry is likely the most regulated industry in the world (and for good reason). However, several countries have proven that a strong nuclear electric sector can serve as the consistent, reliable backbone of a pollution-free electric sector. France's fast-track authorizations for standardized reactor models is a very successful model.

Furthermore, the legislation should allow for step-by-step permitting and real-time conversations with firms who are building reactors so that companies can easily and quickly resolve issues and move forward on an expedited timeframe (as the SCO's Pele program was able to do).

Invest in Direct Energy Transition Partnerships

There is significant overlap between legacy fossil technologies and the key technologies for an orderly and fast transition. To be successful, policymakers must foster and encourage deep partnerships and collaboration between unlikely industry partners. In some cases, the

government may need to fund these transitions directly, provide loan guarantees, or other mechanisms. These partnerships may include:

Transition From → To	Notes
Coal Fired Power Plants → Nuclear Power Plants	▪ DoE estimates that nearly 300 coal sites – both operating and recently retired – could convert to nuclear power[93] ▪ Nuclear power plant operators have higher wages ▪ Avoids the problem of needing new transmission lines ▪ Other costly infrastructure can be re-used
Oil & Gas Drilling → Geothermal Power & Ground Source Heat Pumps	▪ Oil industry is extremely good at analyzing geological data, drilling, and moving water ▪ Ground source heat pumps will be necessary for cold climate heating – especially where electrical transmission cannot absorb winter heating loads
Offshore (Deepwater) Oil Drilling → Offshore Wind Power	▪ Oil industry has been mapping and drilling in areas off the coasts for decades ▪ They understand the risks and process for securing a large platform to the ocean floor
Coal Mining → Copper, Lithium, & Rare Earth Mining	▪ Coal is on a decline, but there is considerable need to extract resources from the Earth for the energy transition – copper, iron, lithium, rare earth minerals etc.
Natural Gas & Liquified Natural Gas → Hydrogen Production & Transportation	▪ Hydrogen ignites without any pollution will likely be a critical piece to the energy transition puzzle ▪ Separating the hydrogen on an industrial scale will likely occur near traditional natural gas storage and major pipelines ▪ To transport clean hydrogen, the industry will likely look to the expertise developed for the liquified natural gas (LNG) industry. ▪ Liquid hydrogen must be super cooled and compressed for delivery in highly specialized tanker ships (just like LNG)

Provide Direct Support Towards Developing the Energy Workforce

The energy workforce needs talent and labor. This could include approving energy as a Dept. of Education-approved career cluster. The federal government could provide investment towards getting more Americans into skilled trades necessary to support the nuclear industry by providing tuition credits, education grants, interest-free loans, and financial incentives for students to pursue training and education in the skill areas needed for these vital industries.

A comprehensive national buildout of the domestic energy transmission network could create a workforce of trained Americans ready to meet the energy sector's demand for skilled workers. A force of workers trained to expand the electric grid network could assist the energy industry's

current personnel. Once the electric transmission buildout is complete, the newly trained workforce can use their acquired skills working with electricity to backfill the aging domestic populations of electric line workers.

Repeal (or Reform) the Jones Act

The Jones Act (JA) is a 100-year-old law that requires interstate goods be shipped on U.S. flagged, manufactured, and crewed ships. In other words, to legally ship anything – fuel, food, steel – between U.S. ports, the boat must be JA compliant. The JA has not proven to be beneficial to the U.S. shipbuilding industry, and it is beginning to hamper sectors of next-generation energy technologies.

For example, the advanced ships that carry liquified natural gas are not JA compliant, and, therefore, they cannot deliver gas from Texas to Massachusetts. As the hydrogen economy evolves, this same issue will plague hydrogen producers and consumers. Furthermore, as the U.S.A. tries to develop its offshore wind energy capacity, limited JA compliant ships are a major barrier.[94] However, Europe, unhampered by similar rules, has a relatively well-established offshore wind sector. There is a reason the JA is "suspended" after major natural disasters: fuel is essential for areas devastated by events such as hurricanes, earthquakes, and floods, and JA prevents fuel from being shipped to those areas affected.[95]

Use Military Bases for the Development of Clean Energy

DoD currently has approximately 9 million acres of land in the United States. If even just some of this land was dedicated to green energy production, DoD could become a significant player in the industry. For example, if 5% of military land acreage could be designated with a specific, streamlined fast-track for energy development, that could translate to over 150 million MWh of solar electricity generation (approximately equal to the total electric generation of Alabama).[96]

In some cases, the land may serve as an excellent site for a nuclear power plant or geothermal power plant and could avoid some of the "not in my backyard" activism that plagues projects in more residential areas.

Create a Regulatory Framework for Nuclear-Powered Civilian Shipping Sector

The U.S. has experimented with nuclear powered civilian cargo ships in the past, and Russia still has several nuclear powered ice-breakers in operation.[97] Nuclear powered ships have been common in the military for over 50 years, and the Navy is one of the sole sources of nuclear engineering expertise. As small and micro reactor designs enter service, they should be considered as a replacement for the inefficient and thirsty engines that power massive cargo ships. A permitting structure that anticipates the development of small and micro reactors as energy sources for commercial vessels would likely require a harmonized process between the U.S.A. and its closest nuclear allies (England, France, Germany, South Korea, and Japan), as well as stringent control mechanisms to ensure the reactors would not fall into the wrong hands.

Implement a Pollution Tax

A modest tax on pollution may be the most straightforward way to reduce emissions and accelerate development and adoption of cleaner alternatives and storage. Energy companies are currently not directly taxed for the pollution they create. Particularly for greenhouse emissions and for harmful byproducts such as sulfur dioxide and fine particulates. The United States does have a range of taxes and fees on individual fuels and emissions like gasoline, diesel, and sulfur; however, a more economically efficient system would be to adopt a uniform standard across all combustion energy. The revenue generated could be used to pay down the national debt, fund additional energy research, invest in energy system upgrades, or be returned to consumers

through lower payroll taxes. It would also provide a market force incentivizing industry to become cleaner and more efficient.

Other Policies

- **Maximize the Potential of Existing Non-Powered Damns:** DoE and Oak Ridge National Laboratory studied the power output potential for existing damns and found an additional 12 GW of renewable, consistent electrical generation capacity is available at these sites (2% of total capacity).[98] The Federal Energy Regulatory Commission (the regulatory agency in charge of hydro power) should establish a fast, simple process for adding electricity generation to these damns. The advantage of focusing on these damns is the environmental impact of damning the rivers has already occurred – in some cases decades ago.
- **Create a Strategic Transformer Reserve:** Per the DoE's 2017 report.[99]
- **Encourage States to Adopt a More "Technology Neutral" Approach to Clean Energy Development:** Currently many states have policies in place to encourage renewable energy (wind and solar in particular).[100] This is overall a good thing; however, there are states that have invested heavily in technologies that are not a good geographic fit. For example, New Jersey has generous tax incentives for solar power, despite low overall sunshine. Meanwhile, Arizona has limited incentives for solar and lower solar capacity than expected.
- **Invest in a Major Public Outreach Campaign for Nuclear Power:** One reason France was able to quickly build and maintain a significant nuclear power sector was through a committed public outreach campaign. This would help to ground discussions about nuclear power in facts about the limitations of other power sources, the real safety record of nuclear, and the advantages nuclear reactors have for providing reliable base-load power with virtually no carbon emissions.

Conclusion

As detailed, America is blessed with a rich tapestry of energy sources, each of which plays an important part in supplying abundant, affordable, and reliable energy to critical infrastructure, institutions, homes, and businesses. While each energy source comes with challenges and opportunities, the nation's diverse energy mix is a national security asset, overall. Geopolitical conflicts highlight the need for a comprehensive energy portfolio and offer U.S. energy firms inroads into markets dominated by adversaries.

Energy policy is vital to national security over the next few decades as the United States and many of her partners and Allies pursue dramatic increases in energy production to meet growing demand, while at the same time pursuing ambitious greenhouse gas emission reductions to combat climate change. As the resulting energy transition takes off in earnest, America is well positioned to lead it. Recent U.S. legislation essentially funds the industry's transition in this country and incentivizes major investments in energy infrastructure, research, innovation, and a rapid expansion of clean energy generation, transmission, and distribution. These policies allow American companies to take on the risks involved in developing new technologies and processes—risks they would be far less likely to take on if the energy transition was left to market forces alone.

While there are abundant reasons for optimism about the future of the American energy industry, policy makers must be clear-eyed about the challenges of undertaking such ambitious goals on accelerated timelines. The speed and intensity needed to transition to a pollution-free, abundant, affordable energy sector is daunting. In many parts of the industry, the United States has struggled to rapidly ramp up new projects in timely and affordable ways, plagued by an underdeveloped workforce and skilled labor shortages, a loss of expertise in certain areas (like nuclear reactor construction) after decades of flat growth, cumbersome permitting processes, and a prevalence of "not in my backyard" activism that has stymied new development. Meanwhile, our primary pacing competitor (the PRC) has been ramping up new energy projects on a scale and pace never before seen.

There are no quick fixes to these issues, but U.S. policymakers can address them through targeted and pragmatic actions. Indeed, the current administration has already made game-changing investments in doing so. The policy recommendations laid out in this paper take those actions even further. If adopted, those policy recommendations would pave the way for a more successful, well-resourced, and nimble energy industry, keeping the United States at the forefront of a world energy transition that has the potential to influence global power dynamics for generations to come.

Annex: Assessment of the United States Energy Industry as it Relates to the Chinese "Belt & Road Initiative"

Throughout history, U.S. adversaries and competitors have used development aid to strengthen their position in the global pecking order, but rarely on the scale of China's Belt and Road Initiative (BRI). This massive and ambitious economic, developmental, and geopolitical effort dwarfs U.S.-led marquee development efforts like the Marshall Plan, PEPFAR, and the Millennium Challenge Fund. The term "Belt and Road" was coined in 2013, in part to give focus and a theme to Chinese development projects in the region already underway. The BRI includes projects spanning the spectrum of the energy industry from extraction of natural resources to energy generation, transmission, and distribution projects.

Underwritten by loans from Chinese banks with varying degrees of central control by the Chinese Communist Party, these projects are primarily in countries close to China and developing countries in the southern hemisphere. Projects also exist in the developed world and Western Europe, although to a lesser extent. China's stated purpose is to provide mutually beneficial infrastructure that links partner nations with China's booming economy. However, critics argue that the BRI does not help partner nations and only advances China's agenda of gaining access to natural resources and creating economic and political dependencies they can exploit to counter U.S. hegemony.

The title's simplicity belies the complexity of the convergent and divergent efforts that make up the BRI. Because it is such a large program with so many varied parts, it is difficult to make general statements that hold true throughout the BRI. One thing that cannot be denied is that the BRI has had a profound impact on the United States, our Allies, and Partners in its first decade. This appendix takes the BRI's energy projects as its focus to analyze what the Belt and Road

Initiative means in the short and long term to the United States, our Allies, and our partners. Finally, this appendix will answer the question: What can the U.S.A. do to present viable non-BRI options globally?

Short-Term Impacts to the U.S.A., our Allies, and Partners

As the BRI gained steam, it shocked the pre-existing status quo that led to alarm in the United States and inspired competition for primacy in the arena of global development. States and regions that used to depend on the U.S.A., our Allies, and partners for development aid can now solicit development aid from the PRC instead, throwing into question our ability to wield the influence we previously enjoyed. Funding and contracts for development projects that might have previously gone to U.S., Allied, or partner financial institutions and companies often go to China instead.

BRI projects such as pipelines to oil and gas fields in Eurasia give the PRC access to natural resources they lack for their domestic energy needs. All the while, infrastructure projects in the Democratic Republic of Congo facilitate the movement of raw materials like cobalt, which China needs to maintain its dominance in the electric vehicle battery industry. These energy projects strengthen ties between China and BRI Partners and increase China's global influence in the short term. Coal projects, hydroelectric dams, and transmission power line projects allow the Chinese industry to make good use of excess capacity while attempting to help partner countries improve their conditions. When these projects succeed, they earn the PRC gratitude from partner nations and the political influence that comes with it. When they fail, they create resentment and economic dependence on partner countries who may struggle to repay their loans. More ominously, analysts have noted that many BRI infrastructure projects that facilitate the

movement of energy-related natural resources could also facilitate the movements of the Chinese military.

The United States, our Allies, and partners have responded to these short-term impacts by publicizing shortcomings of BRI projects in terms of environmental impact, predatory lending, employment practices, and failure to achieve their stated goals. We have attempted to educate BRI partners and would-be partners about the economic and environmental risks of BRI projects and we offer support to countries already suffering BRI project fallout with environmental clean-up or debt relief.

Long-Term Impacts on the United States, Allies, and Partners

BRI backlash has already shown that the long-term impacts of the BRI can be blunted by U.S. and world opinion. Regarding energy projects, China has canceled or delayed coal power plant projects not already in process to make the Belt and Road Initiative comply with global trends toward green energy. There are no new hydroelectric power projects planned because of a reevaluation of the environmental damage they cause. The pandemic and current economic situation have also led to a slowdown in BRI activity. Difficulty getting partner nations to repay BRI loans has likewise forced China to reconsider its lending practices. BRI projects increasingly include more modest ambitions and non-Chinese financial partners.

As with the China 2025 plan, the PRC will likely continue to pursue BRI projects more quietly, while they attempt to manage U.S. and global opinion. China needs the BRI to deal with the excess industrial capacity, a deficit of energy-generating resources, and a large population searching for employment. BRI energy projects have undoubtedly earned the PRC access to resources and increased global influence and will continue to do so. Developing countries will likely experience expanding development opportunities as the U.S., our Allies and partners, and

the PRC propose competing or complementary development projects. The impact of any military benefits from BRI projects will also be blunted to the degree that partner nations might struggle with the after-effects of a BRI project and feel less positive about their involvement with the PRC.

The United States, our Allies, and partners should continue to be vocal about the real and potential downsides of BRI projects and be ready to assist BRI partner countries with any negative issues they experience because of their involvement. We should continue to emphasize the importance of human rights, environmental protection, transition to green energy, and fiscal responsibility which are often lacking in BRI projects.

Countering China's Belt & Road Initiative Energy Projects in the Indo-Pacific

The National Security Strategy (NSS) addresses the PRC as America's most consequential geopolitical challenge[101], and the supporting National Defense Strategy (NDS) articulates China as the most serious challenge to U.S. national security along with their desire to refashion the Indo-Pacific region to suit its interests[102]. Based on this guidance, much progress has been made across the Total Force to deter China and to maintain access and promote a free and open Indo-Pacific. Should integrated deterrence fail, the U.S.A. must be prepared to defend our Allies and partners to protect interests and values. To this end, a comprehensive approach to that conflict must consider corresponding energy requirements.

Each military service has contributed, developed, or conceptualized how they will fight as part of the Joint Force across the competition continuum in the Indo-Pacific region. The generally preferred method is for land, amphibious, air, and space power to foster partnerships, establish interior lines, provide early warning during competition, and then attack China's anti-access and

aerial denial capability from the inside out during the onset of conflict[103][104]. This ideally, would open a window of opportunity for further all-domain integration and allow air and sea power to penetrate deep into and beyond the 1st Island Chain and mass combat power at an advantageous location and time of our choosing.

The challenge to power the Total Force has historically required a large and vulnerable supply chain[105]. Distributing smaller, agile, and lighter forces to support a significant Indo-Pacific theatre opening[106], will be no less challenging and require even more energy options to fuel our combat platforms spread across the islands. Without dedicated basing for baseload power, we may need to rely on the energy sources of our Allies and partners to meet our energy demands.

China has likely noticed this and responded by drastically increasing BRI energy investments in Malaysia (+877%), the Philippines (+578%), and Cambodia (+371%) over the past two years[107]. These investments include renewable and non-renewable energy sources that can provide baseload power for power projection and fuel for their combat platforms.

This development underscores a two-fold conundrum for the United States: the military must have access to unhindered power sources near the 1st Island Chain[108] (Figure 1) while also considering that the PRC needs the same.

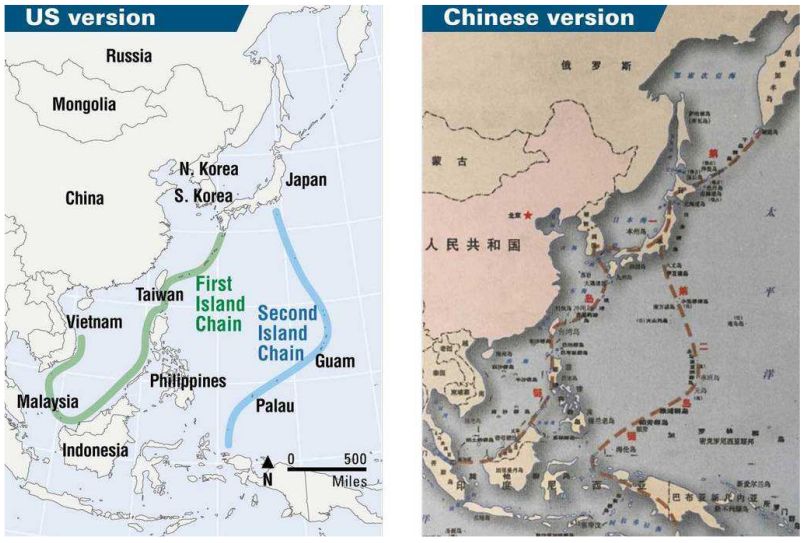


Figure 1

As of 2022, key nations along the 1st Island Chain have established BRI energy ties with China. Specifically, China is investing most heavily in the nations where the U.S.A. is also trying to exert the most influence: Indonesia, Malaysia, Philippines, Lao PDR, Thailand, Cambodia, and

Vietnam. Located intermittently between these nations are vast numbers of small islands, making up the remaining portions of what we refer to as the 1st Island Chain. As China courts these nations, America is busily establishing partnerships through strategic exercises and demonstrating its commitment to the sovereignty and security of these nations[109]. However, the scale of China's energy investments is a strong counterweight to U.S. influence.

Mainland China enjoys a stand-off range from the bulk of U.S. military power projection due to the PRC development of an intricate A2AD network. But even so, China understands the high potential for conflict to spread across the island chains. With this, China is making a concerted effort to disrupt U.S. efforts to gain an economic and military foothold in the 1st Island Chain.

By focusing on the economic strength of their BRI energy initiatives in these locations, China can counter any substantial gains made by the West. As a result, the U.S.A. should act to counter China's BRI energy initiatives in the 1st Island Chain before the PRC advances.

An example of China's tightening energy grip is the staggering amount of economic support dedicated to the energy industry compared to the other industries. Figure 2 (next page) shows cumulative construction and investment in energy as the leading industry throughout the lifecycle of the BRI. [110]

Most of these BRI energy engagements comprise fossil fuels with a significant decrease in coal and a steady increase in renewable energy sources. Figure 3 (next page) depicts a drop in total energy engagement in the BRI, but an uptick in renewables such as solar, wind, and hydro. [111]

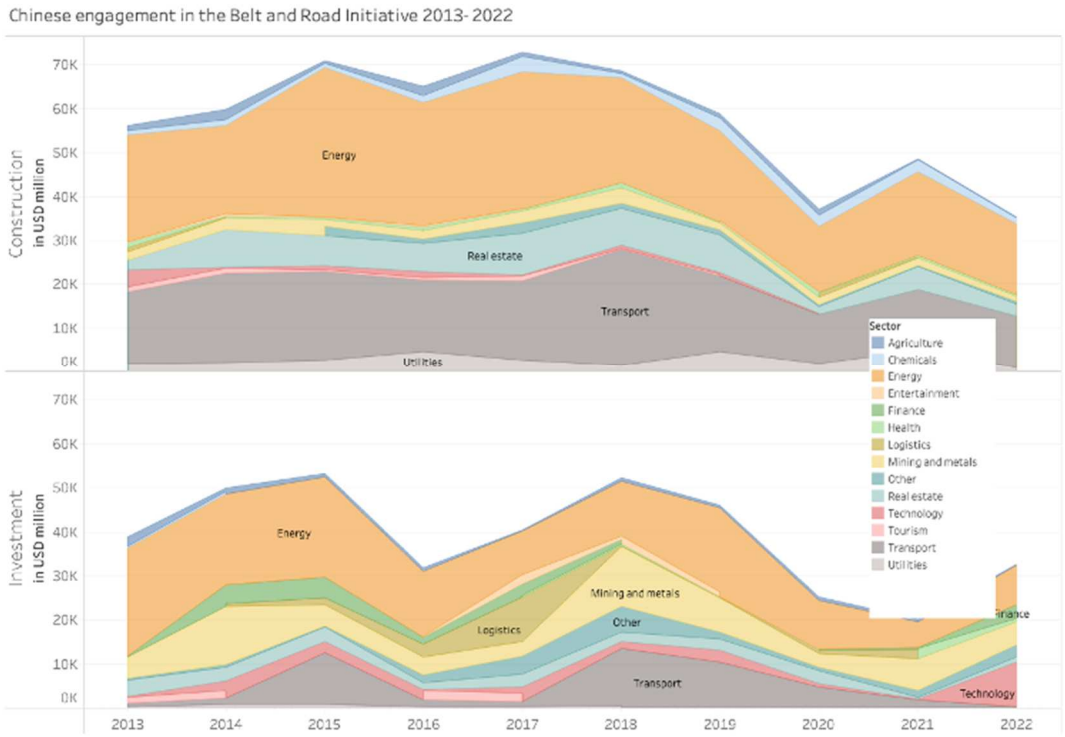


Figure 2

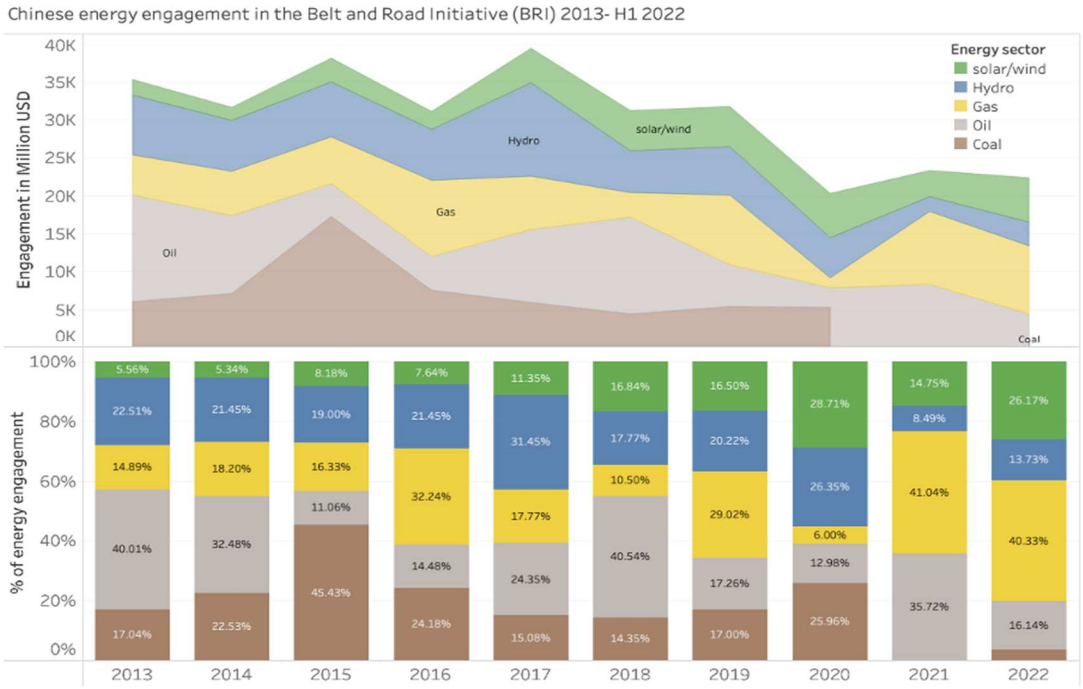


Figure 3

Interestingly, total fossil fuel engagements decrease for the BRI up to 2019. This aligns with the BRI energy strategic plan to increase renewables. Further, 2020 is likely an anomaly, and the massive reduction in fossil fuel engagements can be attributed to the supply chain constraints spurred by COVID-19.

However, 2021 and 2022 saw a rebound in fossil fuel investments, with 2021 having the largest cumulative investment in fossil fuels since the inception of the BRI even as coal investments continue to wane. Figure 4 depicts worldwide locations where the largest portion of BRI fossil fuel and renewable energy engagements occur. [112] Strikingly, in 2022, the 1st Island Chain has the world's second highest BRI fossil fuel investment and only a small renewable energy

.

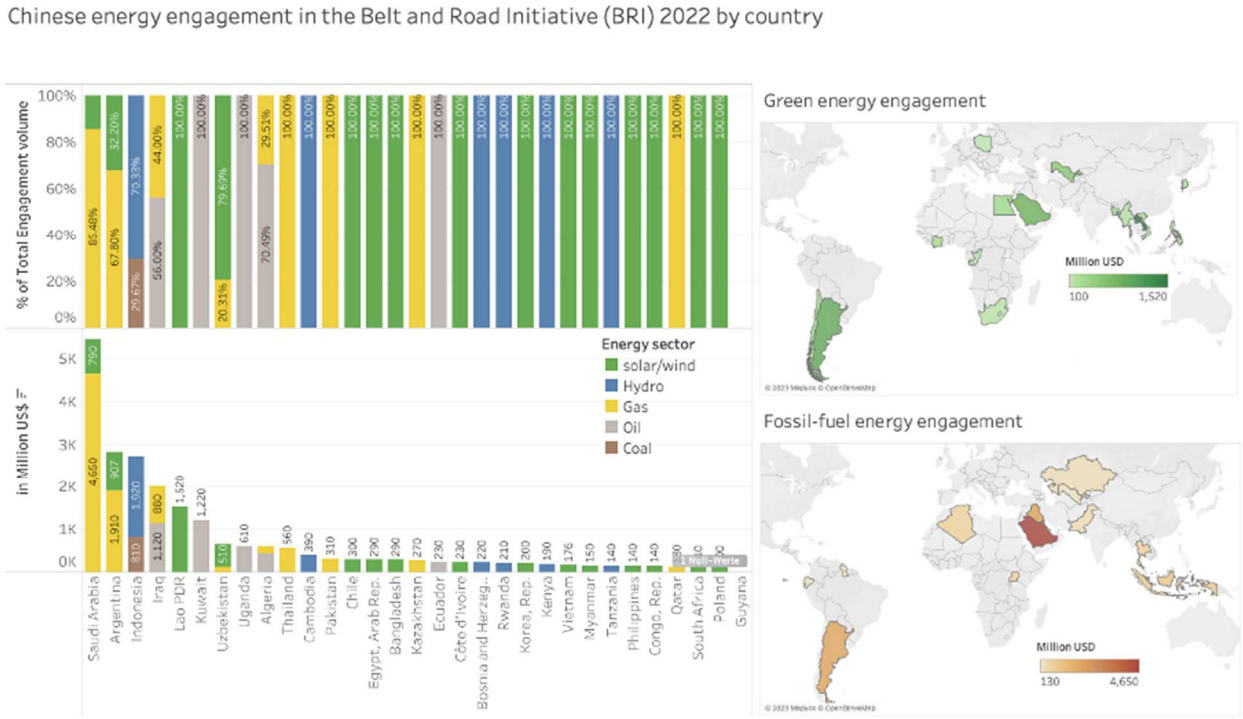


Figure 4

The obvious takeaway at face value from China's BRI energy investments in their neighborhood is that fossil fuels provide reliable baseload power for industry and military capabilities at scale and on the cheap. Investments in renewables are simply in line with their overall strategic plan for energy investments (Figure 5). [113] China's strong and vocal emphasis on renewables supports its reputational, social, and environmental information campaign.

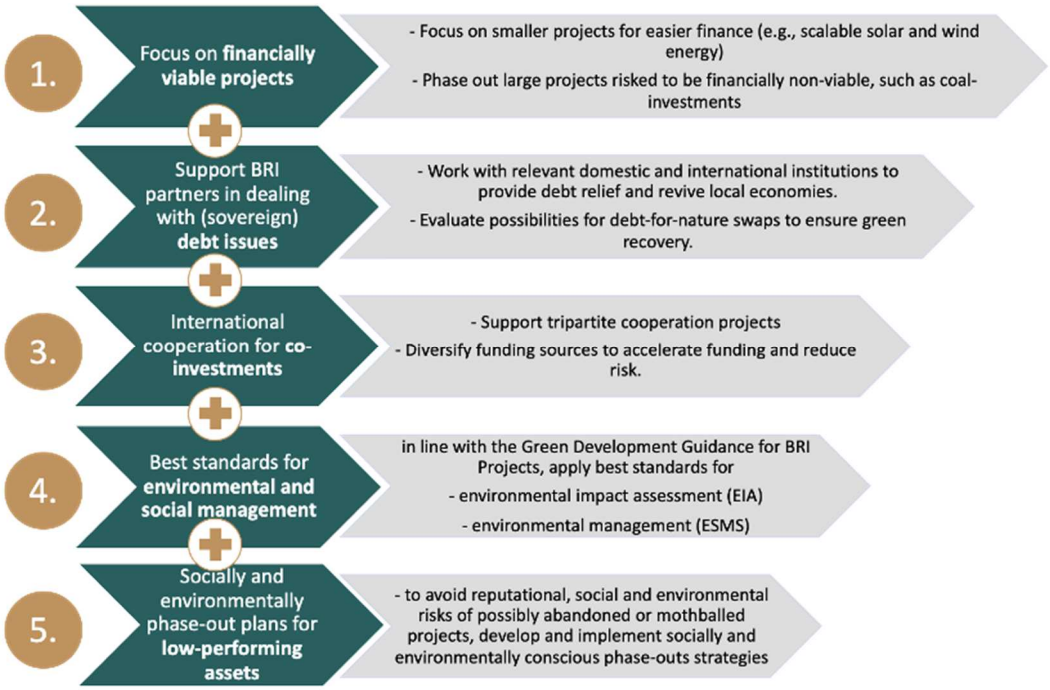


Figure 5

However, the actions we are witnessing by China involve heavy investment in fossil fuels along the 1st Island Chain. The less obvious takeaway is that China is likely setting the theatre to power their fossil fuel-based military platforms in case of a conflict with the United States. A cursory assessment of other plausible explanations- such as coincidental timing- does not pass the common sense test.

Why would China invest in a massive coal project in Indonesia, and in comparison, make very small renewable investments along the rest of the 1st Island Chain? Why are they decreasing

energy investments globally, and increasing energy investments in the Indo-Pacific region? Why now?

Policy Recommendations to Counter China's Indo-Pacific BRI Energy Engagements

- Conduct further research to gauge the scope and scale of BRI energy engagements coinciding with future US distributed force locations along the 1st Island Chain. This research would provide in-depth assessments of energy source threats and opportunities to support the Joint Force operating concept.
- Consider developing a U.S. Strategic Energy Program focused on power projection platforms such as installations and aircraft carriers, where baseload power is the focus. This program would differentiate operational energy requirements for smaller tactical combat platforms and capabilities, from strategic energy baseload requirements to project the Total Force.
- Create a U.S. energy strategic partnership plan for the Indo-Pacific that makes us the partner of choice along the 1st Island Chain. This strategic plan would provide better energy and security options than China, while also supporting the Joint Force operating concept.

Policy Recommendations to Present Non-BRI Options Globally

At a recent site visit to a Polish energy company, our group asked what the United States could do to assist Poland, considering the energy crisis facing Europe since the escalation of the war between Russia and Ukraine. Instead of assisting with developing power plants, improving the grid, or increasing shipments of LNG, they simply responded that the United States should continue providing security assistance. The implication was not that Poland expected imminent

conflict and wanted assurances that we would help them fend off invaders, but rather that they recognized the importance of the U.S. military to secure global trade routes and shipping lanes. It's also possible they feared the U.S.A. might be moving towards a more isolationist stance based on statements by the previous administration. Later the same day we learned how Poland would partner with an American company to develop a nuclear power plant.

These two meetings highlighted that security and innovation, not loans and infrastructure, are probably the best way for the United States to respond to the BRI. America can and should continue to provide development assistance to her Allies and partners along the same lines of effort she has traditionally practiced. The United States has been incredibly successful with organic targeted development efforts inspired by global crises. Countries impacted by the Marshall Plan, PEPFAR, the Millennium Challenge Fund, and USAID-administered assistance will not soon forget the value of American development leadership. A reactionary "BRI made in America" would likely fail for the very reason that it is merely a reaction to the somewhat flawed plans of our competitor. Furthermore, developing nations prefer not to choose between rivals, especially when their development needs are dire.

Undertaking development loans on the scale of the BRI would have to infringe on funding for either the military or entitlements like social security and it is hard to imagine the American public agreeing to either. Instead, the United States should focus on what we do best: provide security for the current rules-based world order and innovation in the energy sector. China may gain increased access to resources, and they may increase their global influence through the BRI, but in the long-term, countries who fail to benefit from BRI projects will sour on them and this will lead to an erosion of PRC's global influence.

The CCP has shown it is willing and able to make positive changes to the BRI based on international opinion. While this in no way portends similar changes to their domestic human rights and international economic relations issues, it is worth considering in our assessment of the BRI. If the United States military retains the role of guarantor of security of international shipping lanes, and as long as the U.S.A. continues to be a leader in innovation, the BRI in and of itself is unlikely to threaten our global status.

Conclusion

Colonization and decades of development aid from the U.S.A. and our Allies and partners have thus far failed to create dramatic improvements in many of the BRI partner nations. There is no reason to assume BRI investment will be any different. The BRI does offer countries a development option with fewer ideological strings attached compared to the World Bank or U.S. developmental aid. The choice is double-edged, however, as the economic and human rights costs of choosing Chinese-style development can just as often lead to ruin.

Global problems like the development of the global south and climate change exceed the ability of the United States, our Allies, and our partners to resolve on our own. At some point, and on some level, we must find a way to work with the PRC to resolve them. If the United States, our Partners, and allies can continue to steer the BRI in a positive direction, away from pollution and environmental degradation and towards a cleaner energy future, the impacts on climate change and the development of the global south could be transformational. If developing countries can manage to leapfrog polluting energy sources and fulfill their energy needs with green or renewable sources, the world stands a better chance of mitigating the most harmful effects of climate change. In the meantime, the United States must gain an energy security foothold in regions where China is expanding the BRI to the long-term detriment of our Allies and partners.

Appendix: International Energy Comparison

	Factor Conditions	Demand Conditions	Firm Strategy, Structure, & Rivalry	Related & Supporting Industries	Sources
Saudi Arabia	Possesses 16% of the world's known petroleum reserves and is the largest exporter of petroleum in the world. Influences 80% of the world's reserves as leading member of OPEC.[1],[2]	Despite climate concerns and broad interest in transition to renewables, global industry remains largely dependent on fossil fuels to function.	Aramco is the largest oil company in the world by revenue and is 90% owned by the Saudi government. Saudi Arabia has unilaterally, and sometimes through OPEC, adjusted production rates for political and economic self-interests (2014-2015 in response to U.S. shale production, and in October 2022 in response to U.S. human rights criticism).[3]	Saudi Arabia has some refining capability in its related and supporting industries, but they do not dominate or have a significant influence on the market on a scale comparable to Aramco's influence.	1. "Saudi Arabia | Economic Indicators | Moody's Analytics," accessed May 8, 2023, https://www.economy.com/saudi-arabia/indicators. 2. Stefan Ellerbeck, "What Are OPEC and OPEC+? How Do They Influence Oil Prices? | World Economic Forum," World Economic Forum, November 11, 2022, https://www.weforum.org/agenda/2022/11/oil-opec-energy-price/. 3. Brian Katulis et al., "Special Briefing: The Policy and Geopolitical Implications of the OPEC+ Oil Production Cuts," Middle East Institute, October 13, 2022, https://www.mei.edu/blog/special-briefing-policy-and-geopolitical-implications-opec-oil-production-cuts.
Australia	Very large reserves of natural resources, such as coal, gas, iron ore, and other minerals. World's largest exporter of coal. Also, reportedly possesses "world-class" wind and solar opportunities.[1]	Strong demand persists for Australian coal and natural gas exports, primarily in the Indo-Pacific region. For renewables, there is some political will and public support for climate-related action that emphasizes a transition to renewable energy.	Energy industry dominated by a few large publicly-traded firms. Fossil fuels dominated by two firms, and the electricity market, which began deregulating in 1998, by three other firms. Collectively, firm strategies appear to continue to pursue fossil fuel extraction, export, and internal use, while making some effort to transition to renewables.	Australia's related and supporting industries possess many, if not all, "ingredients" for energy security, including large reserves, abundant minerals, wide expanses of land (suitable for solar or wind farms), a skilled workforce, and deep access to capital.[2]	1. Rod Sims, "Green Energy Is a Bigger Opportunity for Australia than the Resources Boom. Let's Not Waste It," The Guardian, April 20, 2023, sec. Opinion, https://www.theguardian.com/commentisfree/2023/apr/21/green-energy-is-a-bigger-opportunity-for-australia-than-the-resources-boom-lets-not-waste-it. 2. Blair Comley and Hatfield-Dodds, "The Energy Superpower Opportunity: Can Australia Seize the Advantage in a Net Zero World?," EY, May 1, 2023, https://www.ey.com/en_au/sustainability/the-energy-superpower-opportunity.
South Africa	South Africa imports 100% of its crude oil requirement, with 43% of that coming from Saudi Arabia. They have the second-largest refining capacity in Africa, amounting to 718,000 barrels per day. They produce 66% of petroleum products for local consumption and export 11%. Natural gas is imported (88%). South Africa's indigenous energy resource base continues to be dominated by coal, and its dependency on coal-based energy is unlikely to change significantly in the next two decades. Coal is meeting around 80% of installed power generation capacity.	In South Africa, energy is an important sector of the economy that creates jobs and value by extracting, transforming, and distributing energy goods and services throughout the economy. Energy is consumed by various sectors of the economy, and these include industrial, transport, agriculture, residential, commerce, and public services. Industries consume 51% of the demand sector.	50% of refineries in the country are owned and operated by the government.South Africa's export share has remained flat, despite the country's focus on growing natural resource-driven clusters. The inward foreign direct investment has increased recently, but South Africa remains well below its potential. Domestic investment is increasing but continues to fall short of peer countries and the benchmark set by the government. Innovation output is falling behind peer countries due to the international competitiveness of supplier industries and due to a large informal economy with low productivity that provides jobs for a large share of the population, especially the poor.[3]	Eskom, the largest energy company in South Africa, dominates the production of electricity. Eskom generates, transmits, and distributes electricity to industrial, mining, commercial, agricultural, and residential customers in South Africa. An integrated grid connects the Southern African Power Pool (SAPP). The utility also imports electricity from Lesotho, Mozambique, Zambia, and Zimbabwe and export to Botswana, Eswatini, Lesotho, Mozambique, Namibia, Zambia, and Zimbabwe.	[1] Department of Mineral Resources and Energy, "The South Africa Energy Sector Report" (Republic of South Africa, June 2022), https://www.energy.gov.za/files/media/explained/2021-South-African-Energy-Sector-Report.pdf. [2] Pierce, Warrick and Le Roux, Monique, "Statistics of Utility Scale Power Generation in South Africa" (CSIR Energy Center, February 22, 2023), https://www.csir.co.za/csir-releases-statistics-on-power-generation-south-africa-2022. [3] "South Africa - Countries & Regions," IEA, accessed May 9, 2023, https://www.iea.org/countries/south-africa.
Brazil	Brazil has abundant natural resources, including large reserves of oil and gas. Lots of promise for renewable energy thanks to its abundant sun, wind, biomass, and geothermal resources. In 2020, renewable energy supplied 85% of the electricity sector demand and it is expected to reach 88% by 2030.[1] Brazil ranks among the top producers of ethanol in the world, using sugarcane as a sustainable energy source. Brazil is also one of the world's top producers of hydropower. With the addition of the Angra 3 power plant planned for 2028, nuclear energy is growing, as well.[2]	Brazil uses the most energy of any country in the region as a result of its expanding population, rapid urbanization, and continued industrialization. Since 1990, Brazil's total prima energy demand has doubled, driven mostly by high increases in power consumption and the demand for transportation fuels as a result of strong economic expansion and an expanding middle class.[3]	Brazil benefits from related and supporting sectors that promote the development of its energy-related industrial base. Exploration, production, refining, and distribution are all parts of the nation's well-established oil and gas sector. The existence of this business supports the growth of a knowledgeable workforce, cutting-edge technology, and auxiliary services including engineering, production of equipment, and logistics. Brazil also has a thriving ecosystem of renewable energy-related sectors, including those that produce solar panels, wind turbines, and biofuels. These sectors collaborate and share knowledge, promoting innovation and competitiveness across the whole energy sector.	Brazil's government and its energy firms have made great efforts in recent years to support alternative energy sources and lower carbon emissions. To encourage private investment in renewable energy projects, the government has developed measures like subsidies and auctions. These initiatives have promoted competition and the entry of new players, which has reduced costs and enhanced technological improvements.[5] Brazil's state-operated nuclear energy program links it to global nuclear supply chains and networks.[6]	[1] [2] International Trade Administration, "Energy" in Brazil Country Commercial Guide. Published March 27, 2023. Accessed at https://www.trade.gov/country-commercial-guides/brazil-energy on May 8, 2023. [3] International Energy Agency (IEA). "Brazil" in Country Reports. Accessed at https://www.iea.org/countries/brazil#overview on May 8, 2023. [5] Inter-American Development Bank, "Brazil to push private investment in clean energy with $750 million in IDB resources ," News Release, December 15, 2016. Accessed at https://www.iadb.org/en/news/brazil-push-private-investment-clean-energy-750-million-idb-resources on May 8, 2023. [6] World Nuclear Organization, "Nuclear Power in Brazil." Published November 2022. Accessed at https://world-nuclear.org/information-library/country-profiles/countries-a-f/brazil.aspx on May 8, 2023.

Poland	Professes an intent to transition to a more balance mix of energy sources, but still relies on fossil fuels for 85% of its power generation.[1] Energy industry primarily dominated by state-owned enterprises (e.g., SOEs account for 75% of all oil product sales in Poland).[2]	Challenged to overcome over-reliance on coal and dependency on Russian energy sources. Also must contend with demands from European Union to contribute to collective climate goals of 55% reduction in GHG by 203 and climate neutrality by 2050. Domestic lobbies (e.g., coal) also influence energy policies and decision-making.	Adopted an "all-of-the-above" strategy that seeks to increase the share of renewables and develop nuclear energy, while maintaining capacity for power generation from non-renewable sources. Despite challenges, Poland has consistently reduced its import of Russian crude oil since 2014, diversified suppliers, and invested in infrastructure.[3]	Poland possesses sufficient industry capacity and the skilled workforce necessary to extract and process coal, as well as refine petrochemicals	1. International Energy Agency, "Poland Needs a Stronger Push to Reduce Emissions and Ensure Secure Energy Supplies, New IEA Policy Review Says - News," IEA, May 12, 2022, https://www.iea.org/news/poland-needs-a-stronger-push-to-reduce-emissions-and-ensure-secure-energy-supplies-new-iea-policy-review-says. 2. "Executive Summary – Poland 2022 – Analysis," International Energy Agency, accessed April 23, 2023, https://www.iea.org/reports/poland-2022/executive-summary. 3. Trading Economics, "Poland Crude Oil Imports From Russia - March 2023 Data - 2008-2022 Historical," March 2023, https://tradingeconomics.com/poland/crude-oil-imports-from-russia.
India	India has large coal deposits and has historically relied heavily on coal for power production.[i] Despite indigenous supply India still depends on imports to meet its energy needs. To supplement its domestic supply, India imports LNG from nations like Qatar and the United States. India predominantly imports crude oil from Middle Eastern nations.[ii] India has a substantial potential for renewable energy, including solar, wind, and biomass resources. India's energy sector has challenges, however, including a dearth of well-developed fossil fuel supply chains and a shortage of well-trained workers in some regions.[iii]	According to the International Energy Agency, "India is the world's third-largest energy consuming country, thanks to rising incomes and improving standards of living. Energy use has doubled since 2000, with 80% of demand still being met by coal, oil and solid biomass."[iv] The country's energy usage is influenced by expanding industrialization and the growth of data farms and other energy-intensive IT industries, a rising middle class, and electrification of rural areas.[v]India is well-positioned to be a desirable location for investments in both conventional and renewable energy due to its sizable domestic market and new commitments to sustainable energy solutions.	India's highly developed and internationally competitive IT (Information Technology) and software sector can help the energy sector improve technologically and innovate, especially in areas like smart grids, energy management systems, and data analytics.[vii] Additionally, India has a robust manufacturing sector that can support the creation of machinery for renewable energy sources, such as solar panels and wind turbines.[viii] Within the larger energy industry, several allied industries offer chances for information sharing, teamwork, and cost savings	The Indian government has established goals for renewable energy and reduce reliance on coal, though slower than International partners would like. The government has put legislation in place, offering financial incentives, and made it easier for foreign investment.[ix] The nation is also making aggressive efforts to improve energy efficiency, like smart grids, and other innovative technologies.[x] All of this is driving innovation, technology adoption, and increased competition in the sector. Additionally, India has an ambitious nuclear energy program, aiming to expand its nuclear power capacity.	[i] Gareth Price, "Mining India's troubled history of coal and politics." Chatham House 2022. Accessed at https://www.chathamhouse.org/2021/11/mining-indias-troubled-history-coal-and-politics on May 9, 2023. [ii] Marwa Rashad, "India's future crude oil supplies will mostly come from Gulf -oil minister." Septebmer 5, 2022, Reuters online, accessed at https://www.reuters.com/world/india/indias-future-crude-oil-supplies-will-mostly-come-gulf-oil-minister-2022-09-05/ on May 9, 2023. [iii] Charles Rajesh Kumar and M. A. Majid, "Renewable energy for sustainable development in India: current status, future prospects, challenges, employment, and investment opportunities," in Energy, Sustainability and Society volume 10, Article number 2 (2020). Accessed at https://energsustainsoc.biomedcentral.com/articles/10.1186/s13705-019-0232-1 on May 9, 2023. [iv] International Energy Agency (IEA), "India Energy Outlook 2021." February 2022. Accessed at https://www.iea.org/reports/india-energy-outlook-2021 on May 9, 2023. [v] Ibid. [vi] Gareth Price, "Mining India's troubled history of coal and politics." Chatham House 2022. Accessed at https://www.chathamhouse.org/2021/11/mining-indias-troubled-history-coal-and-politics on May 9, 2023. [vii] Archana, Ravi Shankar and Shveta Singh, "Development of smart grid for the power sector in India," Cleaner Energy Systems, Volume 2, 2022. Accessed at https://www.sciencedirect.com/science/article/pii/S2772783122000103 on May 9, 2023. [viii] Kumar and Majid, p. 2. [ix] Renewable power's growth is being turbocharged as countries seek to strengthen energy security - News - IEA [x] IEA, "Renewable power's growth is being turbocharged as countries seek to strengthen energy security." December 6, 2022. Accessed at https://www.iea.org/news/renewable-power-s-growth-is-being-turbocharged-as-countries-seek-to-strengthen-energy-security on May 9, 2023.

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