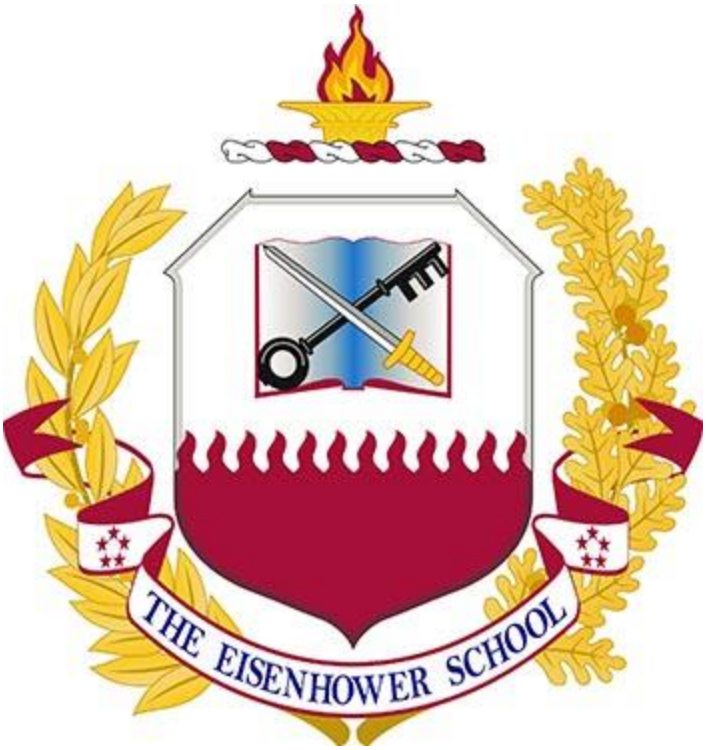
Spring 2020

Industry Study

Final Report

ENERGY



The Dwight D. Eisenhower School
for National Security and Resource Strategy
National Defense University
Fort McNair, Washington, D.C. 20319-5062

ENERGY

The Eisenhower School (ES) Energy Industry Studies seminar is a practical course integrating real-world perspectives through domestic and international guest lectures, industry visits, policy maker and think-tank expert engagements, and, discussions analyzing the domestic and international policies and market forces affecting the U.S. and global economies, and, national and international security. Specifically, the Energy Industry Studies seminar focuses on the confluence of energy sources, transition, security, diplomacy, geopolitical influence and mobilization and its significance within the United States (U.S.) National Security Strategy (NSS) and the U.S. National Defense Strategy (NDS). Students examine energy sources to include fossil fuels (oil, gas, coal), solar, wind, geothermal, hydropower, nuclear, and tidal, and, explore the energy industrial eco-system to include stakeholders and supply chains (generation, transmission, distribution); energy efficiency and storage; emerging technologies and innovation; financing; markets; and human capital. The seminar prepares our national security practitioners to comprehend and conceptualize the role of energy; the global energy transition (fossil fuels to zero carbon); the impact of an energy transition on national and global security, its influence on the alignment of global economies and strategic geopolitical influence. The seminar culminates with policy recommendations that integrate U.S. instruments of power to further U.S. energy security and dominance and fulfill the NSS and NDS objectives.

Eisenhower School Energy Industry Seminar:

Last Name	First Name	Grade	Service
Sullivan, PhD	Paul	Faculty	Professor, NDU Industry Lead
Zerby	Daniel	Faculty	Dean of Academics, Lead Assistant
Acosta	Gerard	LTC	USA
Anderson	Stephen	LTC	USAF
Donahue	Kathleen	GS-14	DOS
Hills	Crystal	COL	USA
Jarratt	Christopher	COL	ANG
MacGarvey	Mason	LTC	USAF
Mai	Michael	LTC	USA
Marshall	Jaja	CAPT	USN
Martinez	Daniel	GS-15	DOD - DA
Radzikowski	Phillip	LTC	USA
Ray	Diane	GS-15	USAID
Rodriguez	Edna	LtCOL	USMC
Smith	Jarrod	CDR	USN
Starr	Brena	GG-15	DOD-DIA
Swartz	James	COL	USA
Wilhelm	Lesley	GS-13	DOD - DON
Kociuba	Krzysztof	COL	Poland: Army
Navratil	Karel	COL	Czech Republic: Army
Rizkallah	Georges	COL	Lebanon: Army
Stien	Connie	CAPT	Norway: Navy

Energy Industry Studies: Guest Lectures and Industry Visits*

Legislative and International:

- Senator Sheldon Whitehouse (D-RI) discussed the challenges of promoting and implementing renewable energy
- Congressman Don Bacon (R-NE) discussed the Republican Party energy platform and policies, including the party's support of continued domestic fossil fuel exploitation, increased nuclear generation, and continuation of research into next generation technology.
- Congressional Research Service (CRS), Washington DC, Energy Policy Analysts Brent Yacabucci, Mark Holt, Heather Greenley and Ashley Lawson briefed on the Congressional role in Energy Policy and policy developments in the 116th Congress; data driven analytic reviews of oil and gas; nuclear energy; renewable energy; climate change; minerals and energy security considerations.*
- Honorable Edgars Rinkevics, Latvian Foreign Minister, discussed the Government of Latvia's energy policies and current state of international relations with Russia, China, and the Baltic States.
- Ambassador Maris Selga, Latvian Ambassador to the United States, discussed the Baltic States' energy security and national security policies.
- Ambassador Jonatan Vseviov, Estonian Ambassador to the United States, discussed history of Estonia, national security policies and U.S.-Estonia relations.
- Aaron Annable, Energy Counselor, Andrew Dawe, First Secretary and John R. Barnwell, Natural Resources Officer, Embassy of Canada to the United States, provided a broad overview of U.S-Canadian energy relations to include common economic, security, and environmental issues and specific energy challenges for Canada.
- Dr. Ricardo Ranieri, Former Minister of Chile, discussed U.S.-Chile relations and the energy markets.
- Ambassador Mikael Eriksson, Swedish Ambassador to Estonia & Former Swedish Energy Ambassador discussed EU energy diplomacy and the Baltic States, and, the impact of Nordstream 2.
- Colonel Romualdas Petkevicius, Director, NATO Energy Security Centre of Excellence, discussed current NATO energy security challenges, initiatives, and innovation.

U.S. Government Agencies:

- Virginia Palmer, Principal Deputy Secretary of State, Bureau of Energy Resources, along with DoS Energy Advisors: Anya Brunson, Stu Hoffman, Brad Simmons, and Dr. Jennifer Mergy provided an overview of the Department of State's role in developing and executing international energy policy with a specific focus on Europe, Russia, and China.
- Mr. Roberto Guerrero, Deputy Assistant Secretary of the Air Force for Operational Energy, discussed current USAF Operational Energy policy and initiatives.
- Brigadier General Albert Miller, USAF, Commander, Defense Logistics Agency-Energy, accompanied by the DOD's energy control point officers: COL Eduardo Santiago, Army Petroleum Center; COL Phillip Noltemeyer, Director, Air Force Petroleum Office, and CAPT Matt Holman, Officer in Charge, NAVSUP Naval Petroleum Office discussed DLA's role in the U.S. energy market and support to National Defense Strategy objectives.

- Brigadier General Matthew D. Dinmore, USAF, Cyber National Mission Force & Chief of Staff, Maryland Air National Guard provided an overview of DOD Cyber Security systems, policies, research & development, and support to National Military Strategy objectives.
- Brigadier General (Ret) Robert Spalding III, author-*Stealth War*, discussed U.S.-China relations and how the U.S. needs a new 21st Century vision of security to counter China's gray zone tactics in economics, supply chain, data, and international institutions.
- Benjamin C. Richardson, Acting Director, Industrial Security Integration and Application Directorate within the Defense Counterintelligence and Security Agency (DCSA), discussed industrial security issues and policies, and cybersecurity, and supply chain vulnerabilities.
- Max Tuttman, Technology-to-Market Advisor, Advanced Research Projects Agency-Energy (ARPA-E), Department of Energy, explained ARPA's role in emerging energy research and development highlighting transformational storage applications and AI/ML geared to revolutionize the energy industry.
- Ronald Keen, Senior Advisor, Department of Homeland Security, provided an overview of DHS' energy security policies and cybersecurity resiliency programs.
- Kara Sidener, Special Agent, InfraGard Coordinator, Federal Bureau of Investigations, discussed the role of InfraGard and its partnership with the FBI and the private sector to collaborate on the protection of U.S. Critical Infrastructure.
- Ollie Fritz, Deputy for Operational Energy, Office of the Secretary of Defense, provided an overview of DOD energy resilience efforts highlighting operational energy investments, war games, data analytics and initiatives in support of U.S. combatant commands.
- Jim Caley, Director of Operational Energy Research, Development and Acquisition, Department of the Navy, provided an overview of Department of Navy's energy objectives to include an increase in operational reach, reduce deployment energy requirements and increase resiliency through innovation and technology.
- Curtis Melvin, Analyst, Bureau of Intelligence and Research (INR), Department of State, provided an in depth look at the North Korean state of national affairs, North Korean energy policies and geopolitics of the region.
- Ray Palmer, Former Chief, Energy Innovations Sector and Chief, Energy Markets Analysis Branch, Federal Energy Regulatory Commission (FERC), provided an overview of energy regulation and security at the federal and state levels.

Private Sector:

- Scott Sklar, President, Stella Group, provided a counterargument which emphasized the resiliency of renewable energy technologies without the waste and emissions of conventional fuels.
- Genevieve Cullen, President, Electric Drive Transportation Association, explained how EDTA promotes battery, hybrid, plug-in hybrid and fuel cell electric drive technologies and infrastructure. She emphasized the entire electric drive value chain with an emphasis on artificial intelligence as a key enabler.
- John Peeler, Former CEO of VEECO Instruments discussed China's industrial security policies and China's dominance of the LED market.
- National Rural Electrical Cooperative Association (NRECA), Arlington, Virginia, and Jeffrey Connor, Chief Operating Officer; Jay Morrison, VP for Regulatory Issues; Cynthia

Hsu, Principal Cyber Security; Moin Shaikh, Principal, Cyber Security; Russell Tucker, Chief Economist; Adaora Ifebigh, Senior R&D Engagements Manager; and Ted Cromwell, Senior Director for Environmental Issues discussed the role of NRECA and the role of cooperatives in supplying energy to the U.S. market, particularly in rural areas.

- Dennis Cakert, Director of Regulatory Affairs and Market Policy, National Hydropower Association provided an overview of the U.S. hydropower market and energy production.
- Alexander Whittington, International Affairs, Cheniere Energy, discussed the global energy international market and implications to U.S. national security.
- Exelon Corporation, Baltimore, MD, met with Mr. Brian Weatherford, Executive Director Mid-Atlantic Sales; Ed Wilson, Executive Director, Association Sales; and Johan Ulloa, Manager, Energy Efficiency Sales provided an overview of Exelon mission and operations; U.S. grid modernization, renewable resources, and energy markets and trading.*
- PJM, Audubon, PA, met with Troy Cawley, Operations, provided an overview of energy systems operations; grid management within the Eastern Interconnection; energy markets and regulations.*
- Bill Murray, VP and Dan Weekly, Dominion Energy, discussed Dominion's electric school bus initiative along with development of battery and energy storage.
- J. Clay Sell, CEO of X-Energy, discussed the role of nuclear energy in reducing carbon emissions and shared progress of advanced reactor technology to develop modular reactors.
- Sean Strawbridge, CEO, Port of Corpus Christi, discussed the effects of sea transport to the U.S. energy industry and maritime infrastructure to support U.S. mobilization.
- Alex Rendon, Director of Operations, Kinder Morgan, discussed U.S. energy storage and impacts of the current fossil fuel pricing environment on the company's operations at the Port of Houston.

Academia, think tanks, non-governmental organizations:

- John Hofmeister, Member, United States Energy Security Council & Former President of Shell Oil, provided an overview of the U.S. energy relations and state of the U.S. energy industry.
- Francisco Monaldi, Fellow in Latin American Energy Policy, Rice University's Baker Institute for Public Policy, discussed the current state of Venezuela's energy industry and the South American energy markets, geopolitics and the impact to US National Security.
- Alexander Richter, Managing Director, Iceland Renewable Energy Cluster, provided and overview of the European renewable energy market and Iceland RWS innovation policies.
- Otto Tabuns, Scholar, Baltic Security Foundation, Brookings Institute provided an overview of the Baltic States' energy policies and support to the Baltic States national security.
- Shoichi Itoh, Senior Analyst, Japan's Institute of Energy Economics, provided an overview of Japan's energy industry and innovation policies.
- Dr. Benjamin L. Schmitt, Harvard Postdoctoral Fellow, discussed Russian energy issues and implication to U.S. national security.
- Dr. Aldo Flores-Quiroga, Former Deputy Energy Minister for Mexico & Professor, University of Texas discussed U.S.-Mexican relations, trade, and energy cooperation.

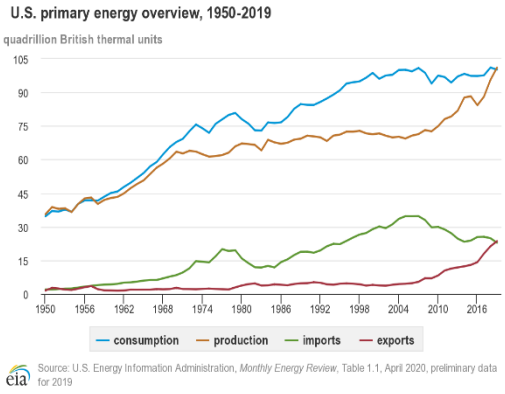
- Samuel Ciszuk, founding partner of ELS Analysis, an advisory focused on the intersection between energy markets, regulation, and policy, discussed Scandinavian energy issues, particularly how Sweden's increased import dependence impacts its security situation.
- Paul Murphy, Murphy Energy & Infrastructure Consulting, LLC, discussed the geopolitics of nuclear power plants and lessons learned, and, current and future trends in the global nuclear industry and marketplace.
- Atlantic Council, Washington DC, met with Ditte Juul-Jorgensen, Director General for Energy of the European Commission, and Ambassador Richard Morningstar, Chairman of the Global Energy Center, and others, to discuss international energy issues and European Green Deal.*
- Center for Strategic and International Studies, Washington DC, met with Greg Poling, Jane Nakano and Stephen Naimoli to discuss allies and energy issues in the South China Sea, China and India energy transition and geo-politics.*
- Dr. Thomas X. Hammes, Institute for National Strategic Studies, National Defense University, discussed Baltic Defenses and an alternative for defending small states.

Contents

EXECUTIVE SUMMARY

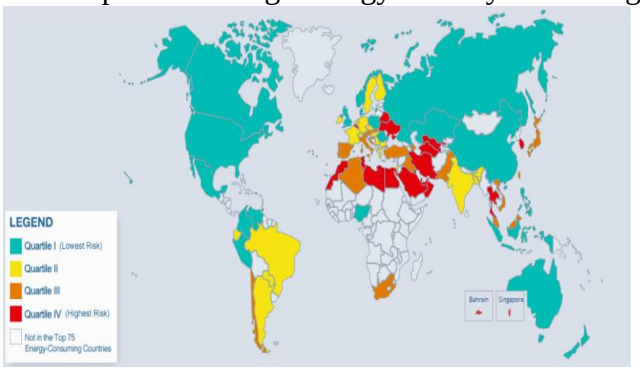
"For the first time in generations, the U.S. will be an energy dominant nation."
- 2017 U.S. National Security Strategy

The 2017 United States (U.S.) National Security Strategy (NSS) includes "energy dominance" as a strategic objective, however achieving energy dominance is not a fait accompli. The U.S. energy landscape has changed drastically over the last decade, as hydraulic fracturing greatly increased U.S. oil and natural gas production. In 2019, for the first time since the late 1950's, the U.S. became a net energy exporter (see Figure 1). Though this is not equivalent to "energy independence," this reality has strengthened the U.S. posture along the economic and geopolitical spectrums. The U.S. enjoys many attributes to achieve this NSS objective: abundant fossil fuel reserves, premier research institutions, a culture of innovation required to develop emerging technologies, and a commitment to renewable energy and the environment.



This report finds that from a national security and mobilization perspective, the U.S. energy domain is postured to support U.S. power projection and expansion of American manufacturing and production capabilities. Vulnerabilities exist in the U.S. energy eco-system to include: an outdated national grid that lacks resiliency and the capacity to implement smart grid technologies; a reliance on international supply chains, specifically the acquisition of strategic materials and renewable energy hardware from China; the weaponization of energy in geopolitics; and ability to counter physical and cybersecurity threats. Currently, the Coronavirus Disease 2019 (COVID-19) and associated economic impacts are exposing these limitations in the U.S. energy industry.

Although the U.S. maintains a competitive advantage in energy security and influence in the global energy eco-system, Russia, and China both exhibit strong energy industries and market power. Though energy security does not guarantee prosperity it can play a key role in achieving a country's economic, security, and diplomatic objectives. Russia's strength emanates from its status as a resource-rich exporter, while China is valued in its standing as the world's largest energy importer. It is also dominant in many renewable energy equipment exports. In the context of the great power competition (GPC), Russia and China use energy in their quest for global dominance. Russia's pursuit of the Nord Stream II pipeline has direct effects on NATO's energy security. While China's Belt & Road Initiative (BRI) and other global investments, many directed at gaining and retaining access to



energy, afford them market control and influence over strategic materials. Additionally, both Russia and China are dominant nuclear power plant exporters and are pursuing nuclear energy partnerships around the world, rivaling U.S. and Western alternatives, and risking the proliferation of nuclear weapons.

To enable the U.S. to achieve energy dominance, below are the highest priority recommendations to mitigate our national energy domain shortfalls.

Recommendations for U.S National Policy

- Continue and deepen engagements with resource-rich allies, such as Canada and Australia.
- Require resource conservation laws and regulations to address the Water-Energy-Food (WEF) Nexus.
- Support and expand the U.S. renewable technology industry with expanded research grants thorough Advanced Research Projects Agency–Energy (ARPA-E), tax credits, and other incentives.
- Expand section 123 language of the U.S. Atomic Energy Act to shape the small modular reactors market and reduce export barriers to gain a competitive advantage in the global market against Russia and China state owned enterprises and domestically facilitate a U.S. mobilization with distributed, flexible power generation capacity.
- Mature our use of Artificial Intelligence (AI) in the energy sector through federal incentives and the investment in AI-related science and technology education initiatives.

Recommendations to the National Security Enterprise

- Counter China's BRI, by investing BUILD ACT resources and expanding initiatives such as America CRECE to compete in global development programs in BRI international economic zones and Increase Nonproliferation, Antiterrorism, Demining, and Related programs investment in countries undergoing bi-lateral negotiations with China.
- Counter Russia energy development in Europe and Asia by Supporting the *Three Seas Initiative* by facilitating the rapid processing of U.S. firms' export licenses competing for liquefied natural gas (LNG) construction projects in the global market
- Increase the North American Electric Reliability Corporation (NERC) Electricity enforcement authority to include the Information Sharing and Analysis Center by requiring all power entities to report physical security incidents
- Allow for Military construction funds to be combined with third-party financing to improve our military installation grid reliability.
- Perform regular global supply chain risk analyses of tiered suppliers supporting the U.S. energy industry to identify vulnerabilities.
- Explore the capabilities of developing a secondary national energy cluster, such as in Colorado, an area rich with natural resources, industrial and academic innovation networks, energy-focused capital firms, and agricultural/mining intellect.

FOREWORD

"For the first time in generations, the U.S. will be an energy dominant nation."
- 2017 U.S. National Security Strategy

The 2017 United States (U.S.) National Security Strategy (NSS) includes "energy dominance" as a strategic objective, however achieving energy dominance is not a fait accompli.[1] The U.S. energy landscape has changed drastically over the last decade. In 2019, for the first time since the late 1950's, the U.S. became a net energy exporter (see Figure 1).[2] Though this is not equivalent to "energy independence," this reality has strengthened the U.S. posture along the economic and geopolitical spectrums. The U.S. enjoys many attributes that are necessary to achieving this NSS objective: abundant fossil fuel reserves, premier educational institutions, a culture of innovation and entrepreneurship required to develop emerging technologies, and a commitment to environmental stewardship.

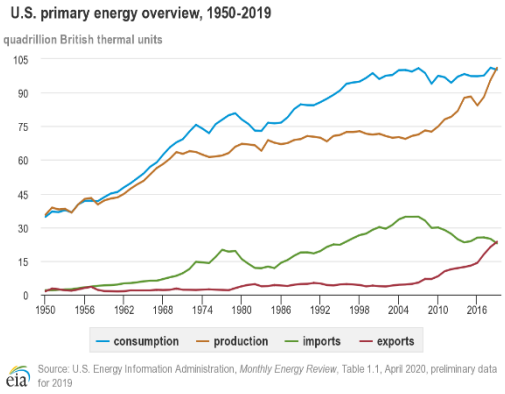


Figure 1 U.S. Primary Energy Overview, 1950-2019

The global energy industry consists of a complex web of geopolitical and private interests that touches every facet of modern life. As such, the resources that power this industry are a constant source of global tension across economic, military, and diplomatic domains. Within these contested domains, the United States (U.S.) and its competitors seek the natural resources, intellectual property, and trade agreements that lead to influence and a competitive advantage in the global market. This competition is founded on the basic principle that a modern society is powered by and reliant on energy. To wit, the United Nation's Human Development Index, a composite that measures a country's achievement among different measures of well-being such as life-expectancy, education, and standard of living, shows a clear positive correlation between energy consumption and development scores (see Figure 2).[3] More importantly, the populations in nearly every developed country have come to expect their governments will ensure secure, affordable, and reliable energy as a prerequisite for popular support. Therefore, the energy policy of world governments is instrumental to their survival and the prosperity of their citizens.

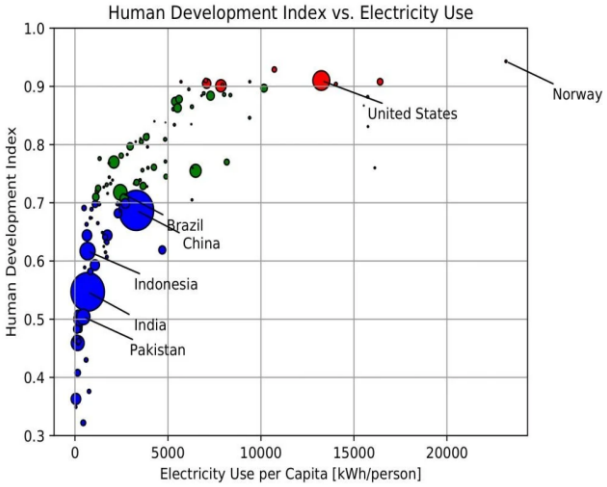


Figure 2 Human Development Index vs. Electricity Use

This report first uncovers the current state of U.S. fossil fuels and renewable resources, and our potential to innovate and economically gain a competitive advantage to achieve energy dominance. This study then analyzes the U.S. energy's public and private entities' posture to support a U.S. national mobilization, specifically focusing on the vulnerabilities in the U.S. energy supply and distribution chains. Next, this paper evaluates the various national security and diplomatic associations of energy in the context of the great power competition (GPC) and how our adversaries and competitors, particularly China and Russia, use energy to achieve their interests in their quest for hegemony and leverage.

Finally, this study provides reviews of three highly relevant areas directly impacting today's energy geo-economic environment: energy and pandemics, specifically Coronavirus Disease 2019 (COVID-19), an assessment of the city of Houston's national energy cluster through the lens of Michael Porter's Diamond Model, and a review of specific U.S. energy markets within a context of Michael Porter's Five Forces model.

The purpose of this study is to provide a national security practitioners' overview of our current state of energy and its effect on national security, and proposed recommendations to U.S. policy makers and the energy industry to best achieve our strategic aim of energy dominance. The U.S. has achieved several milestones on the way to energy dominance, but this resource-intensive objective requires constant technological innovation; policy and law revisions balancing environmental and market principles, and understanding our allies', partners', and competitors' desired outcomes.

U.S. AND THE GLOBAL ENERGY INDUSTRY

Fossil Fuels still dominate the market for energy around the world. Even with growth in nuclear energy and renewables, fossil fuels still comprise nearly 85 percent of global consumption as of 2018 (see Figure 3).[4] However, realizing that fossil fuels are finite, the U.S. and the world look to the future of energy and to the "energy transition" of renewables as it seeks energy dominance. An "energy transition" generally occurs when a new energy source supplants an existing one as the dominant form of energy. Transitions have always occurred at different rates depending on a variety of factors including geography, culture, government policy, and technological penetration; future transitions will follow this same trajectory.[5] The world has experienced two energy transitions so far (from biomass to coal and coal to oil), and likely will proceed through the third energy transition to natural gas in the next few years; the expected fourth transition to "zero-carbon" sources would be the first transition that takes us to a less dense form of energy.[6] This section will explore the industry for energy sources, providing context for how the U.S and the world are positioned with existing sources and the energy transition that will define energy dominance in the future.

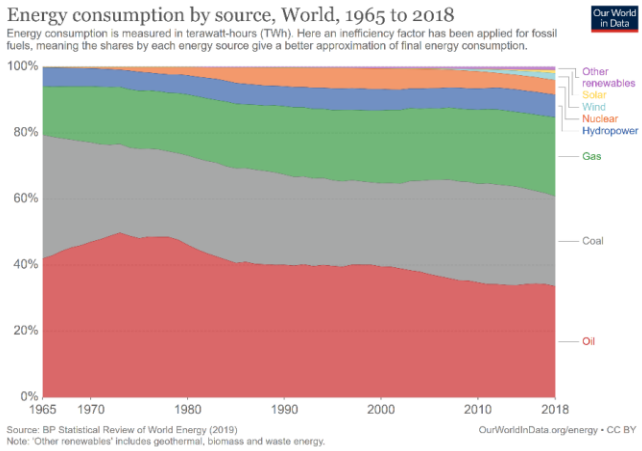


Figure 3 Energy consumption by source, World 1965-2018

Oil: Still the Dominant Fuel

The world relies on oil[7] to meet its energy needs. The oil industry is the largest contributor to fossil fuel consumption. In the U.S., oil and its petroleum byproducts are used by industry, military, consumers, retailers, manufacturing, and aviation. Figure 4 shows Petroleum oil usage in 2019. The U.S. shale industry with advanced well technologies and hydraulic fracturing has propelled America as the number one supplier in world oil markets[8] and is positioned to adjust production to respond to global demands. Crude oil is produced in 32 U.S. states and along U.S. coastal waters with 15 percent produced from offshore wells.[9] Oil companies are typically large,

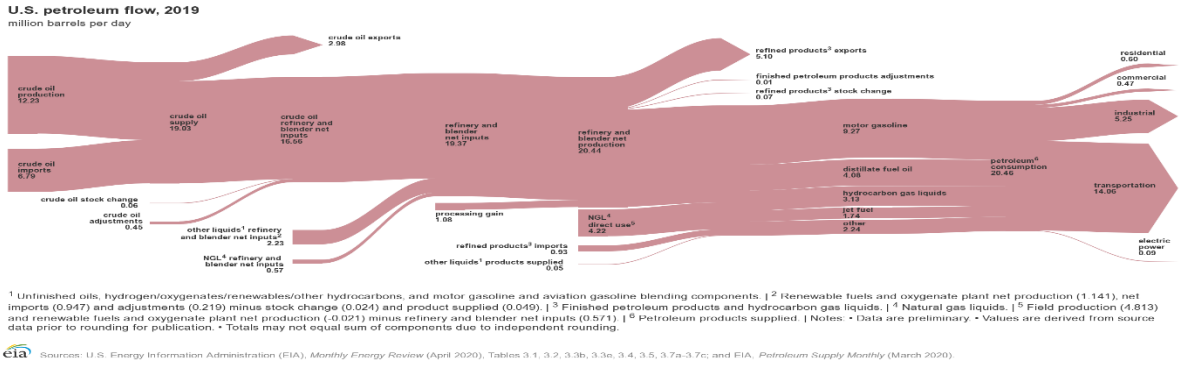


Figure 4 U.S. Petroleum Flow, 2019

integrated players that are engaged across the full spectrum of the oil market from exploration to refinery to production.[10] Figure 5 shows how one barrel of crude oil can produce gasoline, jet fuel, heating oil, fuel oil, and other everyday products.[11] For transportation purposes, oil comprises 92 percent of the source fuel, the highest share of any fuel for any use.[12] Oil companies are typically large, integrated players that are engaged across the full spectrum of the oil market from exploration to refinery to production.[13]

The oil market is impacted by many factors such as diplomacy, politics, regulations, currency fluctuations, and substitute products. For example, the European Union's Green Deal initiative to reduce carbon emissions to net zero aims to slow the future demand for oil products. The oil industry also influences, and is influenced by, the global economy. Most recently, as a result of a dispute between Russia and Saudi Arabia that resulted in high oil production, combined with decreased demand due to the global economic slowdown caused by the COVID-19 pandemic, on April 20, 2020 U.S. oil prices turned negative for the first time in history.[14] EIA describes key factors that could influence oil markets and crude oil prices as supply (OPEC and non-OPEC), demand (OECD and non-OECD), spot prices, financial markets, and inventories.[15]

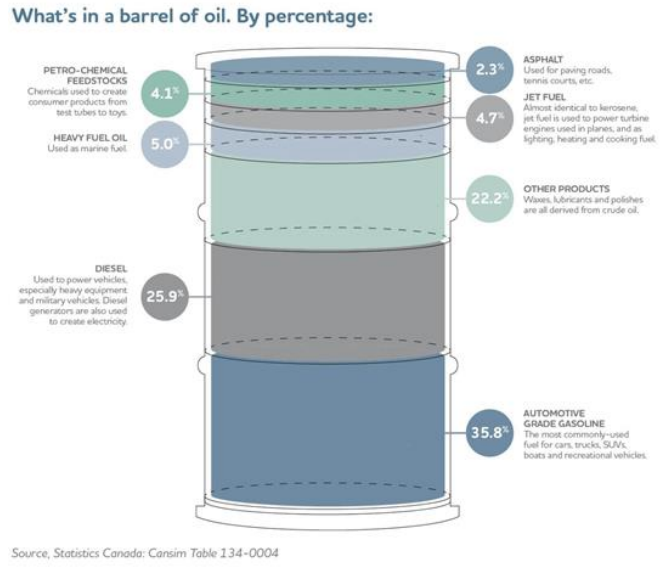


Figure 5: What's in a barrel of oil: By Percentage

At the end of 2017, the U.S. had 61.2 billion barrels of proven oil reserves, and oil consumption per capita in the U.S. decreased by 1.2 percent from 2007-2017 to approximately 20.4 million barrels per day.[16] In fiscal year 2019, the DOD alone procured 94.2 million barrels of oil.[17] Recently, the EIA projected that the U.S. would experience a growth in production of crude oil in 2020 and coupled with a decrease in domestic consumption will continue the nation's status as a net oil exporter.[18] However, as the world navigates the impact of the COVID-19 pandemic, the short and long term outlook for global oil market and the U.S. oil industry is uncertain.

Natural Gas: The Abundant Transition Fuel

As recently as 2003, the EIA determined the U.S. had approximately 200 trillion cubic feet (Tcf) of proved natural gas reserves.[19] As of 2018 that number was approximately over 438 Tcf of proved reserves plus another 2,400 Tcf of unproved reserves (see Figure 6).[20] This boon in natural gas has led to very profound changes both within the U.S. and globally. At this moment in time, the abundance of natural gas is serendipitous as we see multiple domestic and international issues coalesce around its geopolitical impacts. Russia has been able to use its natural gas exports to execute its foreign policy to the detriment of U.S. allies and partners. The

use of natural gas serves as a less environmentally damaging transition fuel reducing the impact of greenhouse gases while the government and private sector seek innovative solutions to reduce fossil fuels dependency.

There are essentially two types of natural gas available for extraction – conventional and unconventional. For decades, U.S. producers extracted conventional natural gas and these fields were used to calculate proved reserves. Conventional fields include natural gas trapped in large spaces within layers of rock and natural gas that could be produced in concert with traditional oil drilling and production, known as associated natural gas. Unconventional natural gas, known as shale gas, is trapped between tiny spaces of sedimentary rock and there was no way to economically extract it until the last 20 years.[21] The only means by which to extract natural gas from shale formations is through hydraulic fracturing (fracking). Though the method is quite old, originating during the Civil War, the process of fracking only recently became an economical way to extract tight shale oil and gas.[22] When oilman George Mitchell pioneered fracking as a feasible process, the U.S. increased its energy security immensely.[23] U.S. companies can now export natural gas to buyers globally by processing the gas in liquefactions plants and shipping the liquefied natural gas (LNG) on specially-designed vessels.

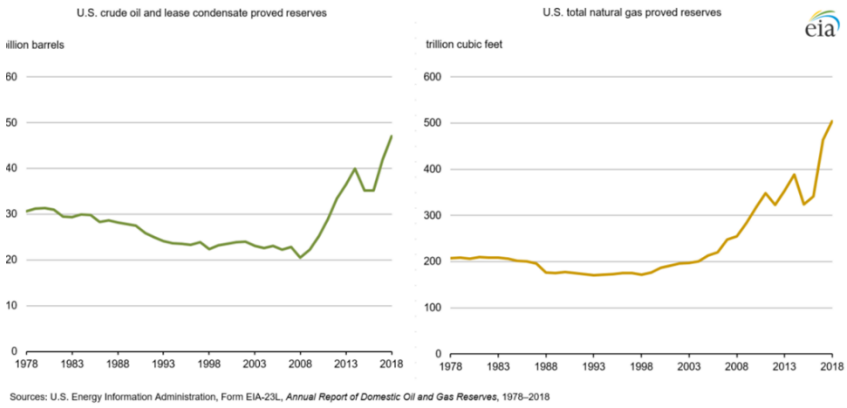


Figure 6, U.S. proved reserves, 1978 – 2018 [20]

As noted above, with fracking proved reserves more than doubled and it substantially lowered the price of natural gas. From the period between 1995 and 2008, natural gas usage within the U.S. fluctuated between 21 and 23 Tcf, annually. However, after 2008 the yearly usage has steadily increased to current usage of approximately 30 Tcf annually.[24] Even with steadily increasing consumption rates, the U.S. has several decades of natural gas reserves remaining, ensuring energy security. Natural gas makes up 38 percent of electricity generation as of 2019, which is more than any other single source. The abundance of supply and the low prices make natural gas an attractive fuel for electricity generation but as supply has increased prices have dropped. Many domestic companies cannot produce gas at the current prices without taking a loss and at the same time, storage for natural gas is reaching capacity.

Coal: Hated but Necessary

Coal is a proven and abundant energy source with a tarnished reputation. It is also critical to national security. One quarter of the world's known coal is found in the U.S.[25] The EIA estimates there is enough coal in the U.S. to last another 332 years at current demand levels. Coal was the dominant form of worldwide energy generation from 1910-1965 and maintains widespread usage.[26] Today, however, coal is under attack from three significant market forces

including man-made climate change, product substitution, such as shale gas and renewables, and government regulations. The industry expected to rebound under a friendly Trump administration, but the recovery failed to materialize.[27] Domestic coal production continues to decline with mounting closures, and the EIA estimates the trend will continue well into the 2020s.[28]

Financially, coal's importance to the U.S. economy is shrinking.[29] The industry value-added for coal is expected to decline at an annualized rate of about one percent.[30] Within the domestic market, there is no escaping simple economics. Coal is roughly twenty dollars more expensive per megawatt hour than natural gas.[31] Additionally, more than half of the coal capacity in the U.S. had a higher operating cost than renewables.[32] It is difficult, if not impossible, to counter opposing forces when economics are not favorable.

Globally, coal demand is increasing primarily due to increased consumption in China, India and Southeast Asian countries.[33] Consequently, U.S. coal exports increased dramatically in 2017.[34] Exports continued to increase through 2019, resulting in eight percent of U.S. coal being exported.[35] Coal may see a slight improvement domestically, but its profit share will continue to decline. Consequently, the coal industry hopes to offset negative financials by increasing exports to satiate a growing Asian appetite for coal.

Coal is in a challenging market position, but it is also ripe with opportunity. Two technologies, carbon capture usage and storage (CCUS) and integrated gasification combined cycles (IGCC), have shown great promise to make coal cleaner and more efficient. The Petra Nova CCUS plant in Houston, Texas, is the lone large-scale CCUS facility in the U.S. It has demonstrated the capability to remove 90 percent of carbon when operating at full capacity.[36] This technology would essentially make coal cleaner than natural gas. While CCUS technology is promising, it is also expensive. Petra Nova cost $1 billion with a $190 million Department of Energy grant.[37] Deploying at scale would prove to be difficult at present. Additionally, IGCC increases the efficiency rate of coal and could reduce emissions by 20 percent. Coupling CCUS and IGCC would bring coal close to net zero carbon emissions. If these advanced technologies deliver, coal could rebound domestically and be the long-term guarantor of U.S. energy security.

Nuclear Energy: Adapting to Future Changes

Nuclear power is a sustainable, reliable, and low carbon energy source that contributes almost 20 percent of the nation's energy. Nuclear energy has been in a decline in the U.S. due to low profits-high costs for reactor operations, growth in renewable subsidies, natural gas alternatives, no energy planning, and fear of nuclear disasters.[38] Nuclear plants have higher upfront costs than other energy sources such as coal and natural gas because they are technically complex and have strict licensing and design requirements. The high construction costs, strict regulations, and extensive timeline have made it difficult for nuclear power to compete with other energy options and has resulted in decline in nuclear power construction.[39] Currently there are only 96 licensed reactors after closure of Three Mile Island in September 2019 with three reactors scheduled for deactivation in 2020.[40] A significant concern with operating nuclear power is proper disposal of nuclear waste which is currently stored on nuclear plant sites. The U.S. government has been unable to designate a permanent nuclear waste storage site due to

ongoing political and legal oppositions.[41] However, there are alternative options with the development of advanced reactor technology.

SMRs are “next generation” advanced design nuclear reactors with electric generating capacity of 300 megawatts and below, with enhanced safety features, smaller footprint, and lower cost than legacy reactors.[42] Many countries see nuclear power as potential energy sources to improve their energy infrastructure and reducing carbon emissions. SMRs should be considered for non-traditional applications such as water desalinization, remote energy sources, mining, environmental benefits, and tailored applications.[43]

The U.S. government has the power to engage in, and influence government-to-government relationships, reduce nuclear proliferation restrictions in section 123 of the U.S. Atomic Energy Act’s, titled "Cooperation With Other Nations", to enable cooperation expansion with developing nations and expand the domestic market to create a niche for U.S. businesses in small modular reactors.[44] These actions will leverage strategic alliances and partnerships to promote collaboration with the U.S. on advanced nuclear technology vice Russia and China, and maintain national security advantage.

As pioneers in nuclear energy innovation, the United States developed world-class products and was a dominant force in the global civilian nuclear trade.[45] The U.S. yielded their position as lead exporter and producer of nuclear power to Russia and China, who use nuclear power for their own geo-political and strategic influence. Russia and China are highly active in the nuclear proliferation market and copied some of the U.S. playbook to build relationships with developing and disenfranchised countries, with technology and financing offers. China uses its state financial capital for predatory lending and Russia offers all-inclusive packages for nuclear power plant construction and operation.[46] Furthermore, Russian and China do not adhere to the same standards as the U.S. and are not members of the Organization for Economic Co-Operation and Development (OECD). Therefore, U.S needs to create its own strategy and should use its decisive advantage in technological capacity, manufacturing productivity, and innovation to compete in this valuable nuclear power market.[47] To better support a new strategy, U.S. must provide better financing options for international nuclear exports through the BUILD (Better Utilization of Investments Leading to Development) Act and U.S. Export-Import Bank (EX-IM). Additionally, Congress must continue to support nuclear innovation and increase appropriation of funds. The U.S. can regain relevance in the world’s nuclear chess game by leveraging advanced nuclear technology in form of small modular reactors (SMRs) to achieve geopolitical influence, create long term partnerships, and enhance international cooperation.[48]

Wind and Solar: The Fastest Growing Renewables

Wind and solar energy have garnered the most attention recently as the most promising sources of additional renewable energy capacity on the planet. Logically, this makes sense, as these two sources are nearly limitless in their capacity to meet the world’s energy needs on a daily basis (see Figure 7).[49] Technological advances, along with cost profiles, have improved drastically over the last ten years, providing amazing prospects for these energy sources.

Unfortunately, though wind and solar energy are nearly infinite, the materials and technological expertise necessary to harness the maximum yield of these sources are not. For wind energy, the Betz Limit theorizes that the maximum efficiency of a turbine is 59.3 percent; the best designs today operate at approximately of 45 percent efficiency.[50] Solar energy is likewise inhibited and displays only slow, incremental technological and manufacturing advances over the last decade.[51] There are many promising advances taking place, but they just are not happening quickly enough to transition off of fossil fuels in the near-term.

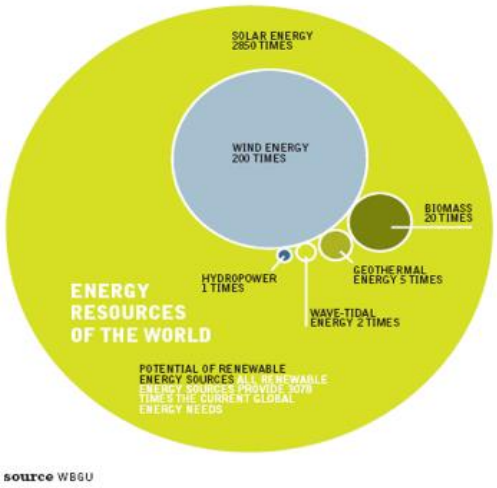


Figure 7: Renewable Energy Resources Potential

These two sources, along with storage batteries necessary for a continuous supply-demand equilibrium, also have many hurdles to overcome to compete with existing sources on an apples-to-apples cost basis. Outside of hydropower, renewables comprise less than one percent of current worldwide consumption and are only growing at a rate of 15 percent annually.[52] Optimal locations for wind and solar installations to ensure cost effectiveness are limited, and, renewable technology and infrastructure are highly dependent on materials and elements from war-torn or adversarial countries resulting in a geopolitical challenge. The supply chain for these materials are also subject to disruption from black swan events such as COVID-19. (see also Energy Storage, Section II) COVID-19 has delayed renewable utility projects in the U.S., such as Invenergy's Badger Hollow Solar Farm Project, because receiving the necessary hardware, primarily from China, were halted for weeks.[53] Though wind and solar will continue to grow as a source of U.S. energy supply, to realize the full capacity of these sources policy makers will have to invest significant capital in domestic research and deployment efforts to advance new technologies, and increase domestic manufacturing and sourcing of critical materials to build resilience against unreliable global supply chains.

Hydropower: Clean, Renewable, and Still Growth Potential

Globally, hydropower represents a growing segment of the renewable energy production. For some developing countries, it often represents the only solution to satisfy domestic electricity demand. In 2018, reached the world's installed hydropower capacity 1,292 gigawatts (GW), which is about 21 percent of the current water potential. The leading country in using hydropower is China, whose Three Gorges Dam on the Yangtze River is the world's largest (but also most controversial) hydroelectric power plant with a capacity of 22.5 GW.[54]

Hydropower is a renewable, low greenhouse gas emission source of energy. Ecologically, methane that leaks from decomposing organic material below the water surface is the primary source of concern. The most common type of hydropower plants are conventional hydropower plants, where water is stored in the reservoir. Dams play an essential role in surface sweet water retention to prevent floods and as a source of sweet water for agriculture and human use. The

United States commissioned its first hydroelectric plant into operation in 1878. Today, the U.S. hydropower fleet is comprised of 2,198 operational hydropower plants with a total installed capacity of 102,867 megawatts (MW), which represents 322,390 GWh of annual electricity production (in 2017) and provides electricity for about 30 million of U.S. homes. Pumped storage hydropower plants generate around 23 GW of power, which represents 98 percent of the total U.S. energy storage.[55] The U.S. hydropower network supplies about 7 percent of total U.S. energy production.

The importance of hydropower in the energy sector is growing, as confirmed by the recently issued Department of Energy's, "Hydropower Vision: A New Chapter for America's 1st Renewable Electricity Source."[56] This analysis concludes that the U.S. can sustainably increase its installed hydroelectric power generating capacity from 103 GW today up to 153 GW in 2050.[57] DoE plans to retrofit non-powered dams, and install new pumped hydro energy storage. Hydropower plays an essential role as a significant source of generating reserves to respond to peak load capacity, weather changes, transmission grid stability, or to cover energy imbalance and voltage fluctuation. As the largest renewable and reliable energy source, hydropower has considerable potential to meet U.S. energy goals aimed at a gradual shift from fossil fuels and satisfy future energy demand.

Geothermal: Thinking Small, Monumental Opportunities Remain

Though currently a small part of the energy mix globally, the potential of enhanced geothermal systems (EGS) is encouraging, results from the 2019 GeoVision analysis reveal.[58] Market opportunity for geothermal heat-pump technologies equates to supplying heating and cooling solutions for 21.8 percent (21 million) of U.S. households.[59] The deployment potential for non-electric sector geothermal applications is tremendous. Geothermal direct-use district heating can reach 17,500 system installations by 2050. [60] An available 11-fold increase in installed geothermal heat pump capacity is also available.[61] EGS is an easy and long-term value add and resiliency building option as the nation realizes its extreme vulnerability to the energy value chain that fuels society, supplies our grocers, provides water, discards sewage, and provides healthcare, transportation, and gig-economy production.

To build resiliency, the electric power grid's demand side nodes can capitalize on the energy beneath the homes, businesses, and commercial and industrial facilities that allow society to survive, and indeed thrive.[62] Protecting regional populations from chaotic environments that extended power outages will create, no matter the source, is a national security concern.[63] Generating and producing ever more electricity at centralized locations to meet increasing power demand is unnecessary.[64] Full development of locally available, sustainable, and efficient resources at the consumption site reduces base load and eliminates a need for more production plants while also extending active production plant life cycles by decreasing fuel consumption.[65] More generation plants, regardless of type, is an unnecessary, and illogical, next step.

The Office of the Deputy Assistant Secretary of Defense for Operational and Installation Energy reports that the DOD is open to enhanced geothermal systems technology while being technology agnostic.[66] If the technology is a cost-effective means of enabling resilience, the solution will earn consideration.[67] Resilience is found in the ground along the power

transmission and distribution grids, at the production site, and at the consumption site. Geothermal coupled with other sustainable energy solutions, in the form of microgrids, will complement today's power infrastructures around the globe. What will, and continue, to stem progress of EGS are the extensive knowledge and awareness of this technology. Focus on the generation and production side of the value chain, such as wind, photovoltaic, and "Big G" geothermal production, distracts from alternatives on the demand end. Lack of legislative regulation to encourage commercial and residential use, the technology, equipment, and people are readily available in a hemorrhaging oil and gas exploration and extraction industry. Now is the time to repurpose those resources to build regional resiliency around the globe, and in doing so, national security for all countries.

ENERGY'S SUPPLY, DISTRIBUTION & MOBILIZATION CHAINS

Energy's utility is limited without supply, storage, distribution, and conversion systems that transform energy into power. Over the last 20 years, global annual energy consumption increased two percent annually from 390 quadrillion British Thermal Units (QBTUs) to an expected 635 QBTUs in 2020. Based on the EIA's projected annual future growth of 1.2 percent, consumption will rise to 910 QBTUs by 2050.[68] As the world's consumption increases along with standards of living, producing and delivering these BTUs to end users will require improvements in technological solutions, grid capacity, high-tech manufacturing, and even a calming of geopolitical tensions. The next energy transition cannot happen absent these improvements. Though renewables are approaching cost parity with fossil fuels in certain geographical areas looking strictly at capital and input costs, when intermittency issues, physical space requirements, and externalities are included, the results become more mixed. Still, if these technologies will continue to comprise a larger share of the energy universe, advanced conversion and distribution technologies are required.

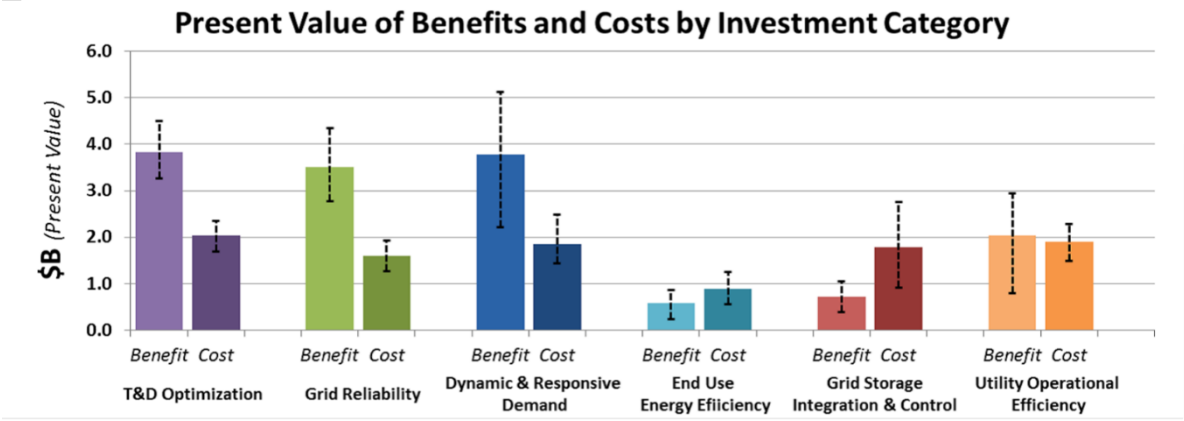
The foundation for 21st century energy mobilization, regardless of threat - diplomatic, informational, military, or economic - is first and foremost a reliable, steady flow of products and services through adaptable and sustainable energy supply chains.[69] Risks to an energy supply chain and logistics strategy (ESCLS) must be identified and mitigated through an ongoing Supply Chain Analysis (SCA) in order to strengthen and advance energy systems. Through careful management and innovative methods, the country can achieve resilient energy supply chains for energy dominance.

This section will explore the often-overlooked areas that stand between energy sources and the end-user. Consumers, be they civilian or military, do not always think of the grid that powers their building and homes, the pipelines that carry oil or natural gas, or the iPhone batteries that seem to last a little longer each year, but these are just as imperative as the sources themselves.

The Electrical Grid

The North American electrical grid is often described as the largest interconnected machine on earth, with more than 7,000 generation stations and 160,000 miles of high-voltage lines connecting the U.S., Canada, and to a lesser extent, Mexico.[70] However, the basic infrastructure that makes up the backbone of the grid is aging and must be upgraded and modernized. The grid was originally designed for steady power from fossil fuel sources but increasing utilization of intermittent renewable generation has created challenges that must be overcome if this trend is to continue. The grid is connected internationally and regionally via two major (East/West) and three minor (Texas, Alaska, and Quebec) grids called "interconnections." Utilities within each interconnection share electricity, but power generally does not flow from one interconnection to another, due to limited Direct Current (DC) ties.[71] If these interconnections were joined in a more robust manner, the U.S. could better take advantage of increasingly dispersed renewable generation, which will reduce bottlenecks, increase redundancy, and link rural areas with high renewable potential to customers along the densely populated coasts.

While the sources of energy have been rapidly changing due to technology, so has the grid that the energy flows across. This transformation is upgrading the "dumb" grid to become truly "smart." Utilities have already begun rolling out "smart meters" to enable 2-way communication, and current U.S. penetration is around 50 percent.[72] This technology enables customers to better track and reduce their peak energy usage, as well as pave the way to incorporate additional battery options, such as electric vehicles, as the cost of energy storage technology decreases. Utilities can also incorporate additional "smart" technologies into transmission and distribution operations. Installing newly inexpensive sensors and remote management technologies will result in more efficient transmission, a reduction of greenhouse gas emissions, and potentially lower electricity rates while increasing reliability and speeding disaster recovery.[73] The costs to do so are high and would be paid upfront by consumers, but ultimately would result in a more stable and reliable grid and ultimately lower energy bills (See Figure 8[74]).



Source: Bonneville Power Administration *Smart Grid Benefits Shown to Outweigh Costs*

Figure 8 Smart Grid Benefits to Shown Outweigh Costs

These and other investments can aid the U.S. strategically by increasing power reliability, reducing costs, and by remaining competitive around the globe in energy grid modernization and technology development. Ultimately, the U.S. should strive to develop a continent-wide smart grid that is able to maximize renewable power generation and utilize consumer and commercial distributed energy storage opportunities throughout the system.

Energy Storage

Energy storage capacity is a primary facet of resiliency and security. As demand for energy increases in future decades, more efficient use of energy is required, and energy storage is necessary to make global energy supply sustainable. There is also increasing global interest and requirements to move towards more environmentally friendly and renewable energy sources. Many of these renewable resources produce energy intermittently and lead to enhanced requirements for energy storage.

There are many different forms of energy storage. Fossil fuels continue to be the most used form of energy, as it is easy to transport and store, and the U.S. Strategic Petroleum Reserve is the world's largest oil supply backup. It was established in 1975 to reduce the impact of interruption in petroleum supplies and as a robust foreign policy tool.[75] It consists of four sites with underground storage caverns along the Gulf of Mexico. The authorized storage capacity is 713.5 million barrels.[76] The current inventory as of April 10, 2020, was 635 million barrels equivalent to around 130 days of import protection.[77] As a comparison, China had oil storage for 80 days as of September last year.[78] The U.S. also has more than 50 percent of the worldwide storage capacity for natural gas, with 380 active underground storage facilities.[79]

When it comes to energy storage for electricity, pumped hydro, batteries, flywheels, and compressed air storages constitute the majority. The leading country for electricity storage in 2018 was Korea. China was number two, and U.S. number three.[80] Global investments in energy storage are expected to grow to US$ 71billion by 2024, and China is expected to account for around 14 percent.[81] Policy incentives and government-sponsored research seem to be important drivers behind this growth."[82] Russia is also starting to focus on energy storage, due to a need to diversify its oil and gas dependent economy.[83]

Beyond enabling sustainable energy in a market with growing demand, energy storage also has other benefits. First, it contributes to economic growth. In 2015, the McKinsey Global Institute identified energy storage as one of the world's top disruptive technologies and estimated that the global economy would see yearly growth of $635 billion by 2025 due to improvements in electricity storage.[84] They also found that, "by making power sources for industrial and residential customers and more reliable, energy storage can also contribute to stronger economic growth in the developing world."[85]

Secondly, energy storage, both for electricity and fossil fuels, ensures the availability of energy when needed, for everyday purposes, as well as during extreme circumstances, including crises and war. Energy storage provides the ability to integrate diverse energy sources and contributes to providing low cost and reliability of energy. Looking at the role of energy storage for national security, energy storage is vital to meet the energy needs for the military and other security organizations for daily operations, crises, and war. The Armed Forces are large consumers of energy. Better technologies for energy storage can increase the endurance for the military, and enhance the performance in several warfare areas, for instance, electronic warfare and the use of high-energy weapons. Additionally, large portions of the U.S. Armed Forces deploy overseas and depend on energy supplies both for operations and facilities. Further, storage in the electric grid makes the system less vulnerable to both physical attacks and cyber-attacks as more resilience is provided through multiple strategies throughout the grid. Lastly, energy storage has the potential to have a geopolitical impact.

Traditionally, countries with limited domestic oil and gas resources have been dependent on petroleum-producing countries for energy, leading to the energy suppliers having leverage over these countries. A shift towards renewable energy and more efficient energy storage means that many countries may become more self-reliant. It also means that the leverage may shift from those who provide fossil fuels to those who can provide technology and material for utilizing and

storing renewable energy.[86] Grid-level battery storage is the most important limiting factor and continues to face physical, economic, and technological hurdles to becoming economically feasible. Cobalt is a primary mineral in today's dominant battery technology - lithium ion batteries – with a supply chain that is functionally controlled by China. Unstable countries like the Democratic Republic of the Congo and Cuba possess the bulk of existing reserves for this critical mineral (see Figure 9), with the U.S. lacking viable mines to meet domestic demand.[87] Though the U.S. and many other countries would like to advance to other battery technologies that rely on fewer scarce minerals, transitioning is proving difficult.

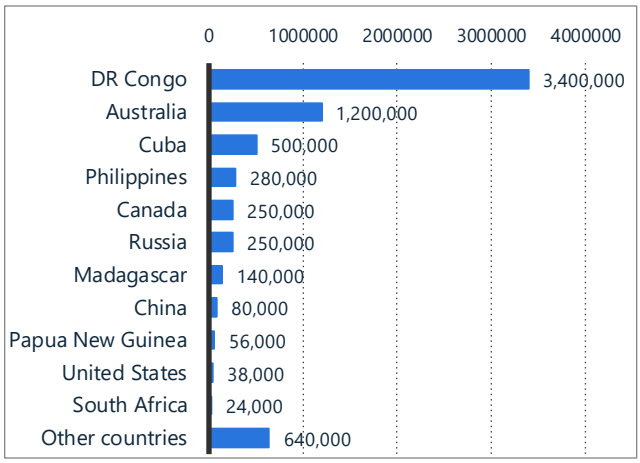


Figure 9 Worldwide Cobalt Reserves (Metric Tons)

Massachusetts Institute of Technology (MIT) Professor Donald Sadoway, one of the leading material scientists and battery researchers in the world, recently stated that current battery research is, "not seeing the disruption at a large enough scale."[88] Just as wind and solar technologies require monumental leaps in technology, so too does battery technology to make these renewable sources cost competitive and widely available. U.S. legislators must understand these realities as they debate and implement policies designed to maintain U.S. energy dominance by balancing economic, security, and environmental concerns. Overall, energy storage is important for society to function and be more resilient. For the U.S. to maintain its influence around the world, it will need to compete in the market for electricity storage just as it does in fossil fuels today.

Oil and Gas Pipelines: An efficient link from sellers to buyers

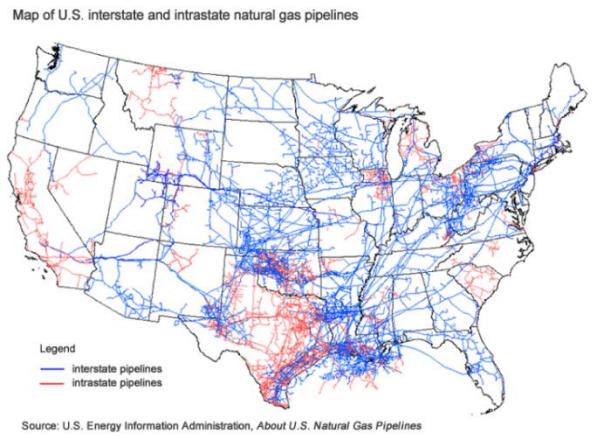


Figure 10 Map of US Natural Gas Pipeline Market

Because oil and gas deposits are often located far from consumers, pipelines are the critical distribution link between fields and processors, utilities, end users, and other consumers of these fuels. U.S. domestic natural gas and oil midstream pipeline transportation companies operate in a highly regulated and fragmented market with high capital startup costs. For natural gas, midstream pipeline companies operate three million miles of pipelines across the U.S. that link natural gas drillers and processors with local distribution system utilities that serve approximately 75 million customers (see Figure 10).[89] Whereas 100 percent of natural gas is moved by pipeline, only about 70 percent of oil is, with the remainder shipped via truck and rail.[90] From an economic and environmental perspective, shipping via rail

and truck are both costlier than shipping by pipelines, even considering the difficult regulatory environment for new pipeline approval.[91] A bevy of State and Federal agencies regulate pipelines throughout the entire lifecycle of operations, which bears significantly on cost and availability. At the national level, FERC, "regulates the rates, terms, and conditions of service of natural gas transportation in interstate commerce."[92] The Natural Gas Policy Act of 1978 also grants FERC authority over certain intrastate pipelines, although almost all states retain their own regulatory agencies and authorities.[93]

As noted earlier, the U.S. only recently became a net energy exporter, primarily due to the starting of LNG exports in 2014 and the lifting of the 40-year ban on oil exports in 2016.[94] Within the U.S., the exponential growth in natural gas supply has come against the backdrop of constrained pipeline capacity, leading many drillers to flare gas since they lack economical methods of storing or transporting it to willing buyers. From 2009-2018, FERC approved ~180,000 miles of new pipeline (an increase of ~6 percent over existing capacity), while the EIA shows that natural gas production rose by 42 percent, or over 30 Bcf per day, over the same period.[95]

Internationally, pipelines are the cause of much geopolitical angst. Nordstream 1 and Nordsteam 2, pipelines that carry natural gas between Russia to mainland Europe through the Baltic Sea, strike at the heart of the debate between cost, energy security, and national security. Russia's "Power of Siberia" pipeline, which opened in December 2019, will satisfy 10 percent of China's natural gas requirements by 2022, providing much needed diversification and economically linking two U.S. competitors.[96] Within the Middle East, pipeline blasts linked to terrorism have occurred on many occasions. In 2017, an oil pipeline blast in Bahrain, home to the U.S. Fifth Fleet, was linked to Iranian-backed Shi'ite militias who frequently seek to sow discord within the country.[97]

Energy in Support of Globally Integrated Operations

As Globally Integrated Operations (GIO) expand and increase demand for energy, the risk for both unarmed and armed conflict increase. For example, between 2001 and 2010, over half of American casualties in Iraq and Afghanistan occurred during land-transport missions, many involving fuel deliveries to remote outposts.[98] Figure 11 depicts the DOD cost structure and demand increases from fiscal years 2010 and 2019.[99] DOD's energy use and cost at both the installation and operational energy levels demonstrate the U.S. military's fiscal and resource challenges toward sustaining the force during routine military exercises and in the event of a national level mobilization.

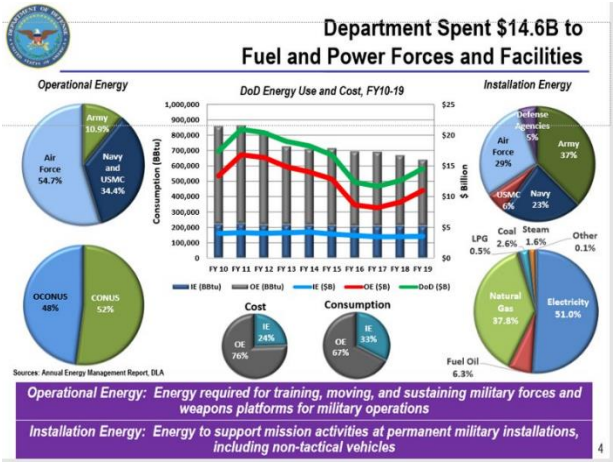


Figure 11 2019 DOD Operational Energy Statistics Chart

Corporations, small-businesses, and even the individual citizen are dependent upon global energy supply chains. Removing as many risks and barriers to resiliency in the supply chain through comprehensive and continuous analysis is the path to operations continuity, regardless of function (industry sector, military, e.g.).[100] Resiliency includes supply continuity, contingency planning and coordination, prioritization, threat assessments, and training for all societal segments.[101] Energy supply resilience is critical for society to operate.

An NSS priority calls for the U.S. to continue diversifying energy sources and creating alternatives to support a whole-of-society mobilization. While collaboration across defense and service research offices attempts to find alternative energy sources, these efforts may not materialize quickly. As research technology matures, mobile reactors could become a resilient source. These small and micro reactors are transportable, cheaper to operate, and provide reliable power wherever it is needed. Portable reactors can complement unreliable power grids and generators dependent upon the fossil fuel supply chain.[102] Three private corporate teams - BWX Technologies, Westinghouse, and X-energy - now have DOD contracts to begin designing mobile nuclear reactor prototypes. This initiative is developing a safe, mobile and advanced nuclear small and micro reactor to support DOD missions abroad and can be deployed domestically as circumstances warrant.[103] U.S. Government leadership recognizes the importance of a reliable, portable, and autonomous energy source for international and domestic DOD missions, and businesses in the country may realize similar benefits, too.

Energy Sector Support for a U.S. Mobilization – Supply Chains Risk

The Energy Sector is a critical center of gravity for any U.S. mobilization. Without constant flow of power supply for all other industries to produce, transport, and deliver basic products and services for society to operate, no mobilization of any kind has any chance of success. The threat that any mobilization effort attempts to counter cannot be fully, or even partially, met without resilient supply chains moving products and services to demand nodes on time and uncompromised with little resistance.

Supply Chain Risk Management (SCRM) requires, at a minimum, steps to identify, assess, and mitigate risks by taking a comprehensive look at all tiers of suppliers, along with the four areas of 1) geographic location, 2) financial and operational stability, 3) cybersecurity posture, and 4) ethical governance. Considering the current global supply chain disruptions resulting from the COVID-19 pandemic, understanding current SCRM is paramount.

First, the geographic location of a component or final product can enable mass production or ease of transfer along the value chain of an item under optimal conditions. However, physical distance between end user and supplier can be catastrophic in times of national disaster, pandemic, or loss of primary transport. An example of this vulnerability is the inability to traverse roads in a natural disaster to deliver fuel for a military installation that has lost primary electrical power and is reliant upon diesel generators to power critical infrastructure such as hospitals.

Second, financial, and operational stability are complementary. A firm's profitability is not only dependent upon efficient management of the company, but also linked to the vertical

alignment of suppliers. For example, in the Houston energy cluster (oil and gas industry) vertical alignment is advantageous for upstream, midstream, and downstream suppliers because this integration guarantees a customer or provides an incentive for finding a customer. However, vertical alignment can also be a key vulnerability if it increases dependency on a single supply chain and lacks redundancy to withstand turbulence to a company's operations, or it expands the source company's (prime vendor) responsibility to monitor key financial indicators of tiered suppliers to ensure solvency through positive cash flow management.

Third, there is the emerging and ever-evolving threat of cyber-attacks. With the evolution of the Internet, smart technologies, AI, and the Internet of things (IoT), the energy industry also increases it vulnerabilities that span the gamut of cyber-security threats from intellectual property (IP) theft, to overmatch capabilities, to complete disablement of a digital platform. China's emphasis on AI/IoT as a central feature of the emerging economics and military-tech revolution further increases this vulnerability.[104] It is only prudent to think of China's declaration from both an offensive and defensive position given its continual IP theft and past cyber intrusions. For the "global" supply chain, this declaration is alarming considering the number of Information Technology/Operational Technology (IT/OT) parts derived from China, the amount of rare earth elements imported from China to make our manufacturing equipment and electronic devices, and the number of IT/OT/IoT platforms integrated into our Industrial Base that might also have a 5G transmission rooted to China. Foreign dependency for the sourcing of baseline technology components introduces risk to the supply chain in the form of counterfeit, defective, and surveillance capabilities that are difficult to detect. Ensuring a stable cybersecurity posture is the most difficult supply chain area to protect and therefore requires domestic manufacturing of the raw materials, parts, equipment, communication lines to hedge against this threat.

Lastly, ethical governance relates to both company and national governance. For instance, in tracing the fuel supply chain for U.S. military installations in Europe, the U.S.' dependence on Russia for fuel introduces a disabling vulnerability. Russian companies have demonstrated a pattern of unethical behavior acting under state authority and they cannot be trusted to fulfill contractual obligations. Therefore, it is counterproductive to U.S. forces stationed abroad to protect against a threat from whom they are reliant upon for a critical class of supply—fuel.

Renewable Energy Industry – Supply Chains Risk Analysis

China, Germany, Japan, Spain, and the U.S. are the current global leaders in the renewable energy industry's research and development, project development, manufacturing, and acquisitions.[105] The renewable energy value supply chain is a complex global system with each source of energy - wind, solar, geothermal, biomass, and hydropower - constricted by its centric manufacturing and technological sophistication. This section will review the supply chain constraints of three emerging technologies – wind, solar, and geothermal - to highlight the challenges to the renewable energy manufacturing supply chain.

Overall, it is the Original Equipment Manufacturers' (OEMs) technical sophistication and the availability of strategic materials that are the greatest challenges towards sustaining a renewable energy manufacturing supply chain. For example, wind power generation is limited to

the technological advances of turbines.[106] A considerable risk to the U.S. wind manufacturing market is construction of the wind blades, which core technology and energy source, iron ore, reside in China. Additionally, other pertinent components such as the shaft system, bearing, and gearbox are specifically customized in Germany and Japan.[107] Additionally, the U.S. market would have to improve its steel processing industry to reduce the barriers of entry into the wind power market.

Regarding solar energy, Asia currently dominates solar energy manufacturing, with over 10,000 manufacturing companies in China and Taiwan producing over 65 percent of the global solar cell production.[108] Additionally, solar tower and heliostat production are currently confined to Chinese manufacturing, limiting the ability for other global renewable energy actors from competing in the market.[109] The U.S. would need to invest in material composite exploration and technical research to compete in the solar energy market. To further illustrate, in the geo-thermal sphere, the manufacturing production of the Polycrystalline Diamond Compact is restricted to few global OEMs. As far as critical materials, neodymium is a critical component to manufacture a geothermal unit's permanent magnets and is currently only mined in China.[110] As illustrated, the renewable energy industry is constrained to geo-commercial limitations and high degree of technological sophistication.

Artificial Intelligence and Energy: Improving Efficiency and Resiliency

Along with smarter grids, the energy sector could significantly benefit from adopting Artificial Intelligence (AI)-based products across the value chain. AI-based products play a key role in modernizing our infrastructure to manage growing demands, diversifying sources of electricity, increasing the use of renewables, and reducing U.S. fossil fuel usage.[111] [112]

Oil and gas companies use AI-based products to improve the safety and efficiency of drilling while improving equipment performance and reliability with predictive maintenance.[113] [114] Electric companies use AI in Smart Grids for grid monitoring and balancing, and solar and wind predictions, and leverage AI-enabled drones for asset inspection to ensure power lines are maintained while minimizing risk to employees.[115] [116] Customers can benefit from using AI-based products to reduce energy consumption, while energy traders can use AI-based products to improve market bids.[117] Since AI in the energy industry is relatively new, competitor-buyer and supplier-competitor-buyer relationships exist to bring the AI technology, combined with the computing power and customer data, to operations.[118]

Government investment is important for developing AI-enabled technology in the energy sector to advance research, development, and adoption.[119] [120] We must ensure supply chain reliability and security for AI-based products used in our critical infrastructure, which is especially important considering China's Made in 2025 goal to lead in Artificial Intelligence and Energy Saving.[121]

NATIONAL SECURITY & ENERGY

National Security Strategy and Energy

In the era of GPC, the U.S. has crafted the NSS around energy dominance.[122] The U.S.'s newfound energy abundance, due to fracked shale oil and gas, is a windfall for the U.S. [123].

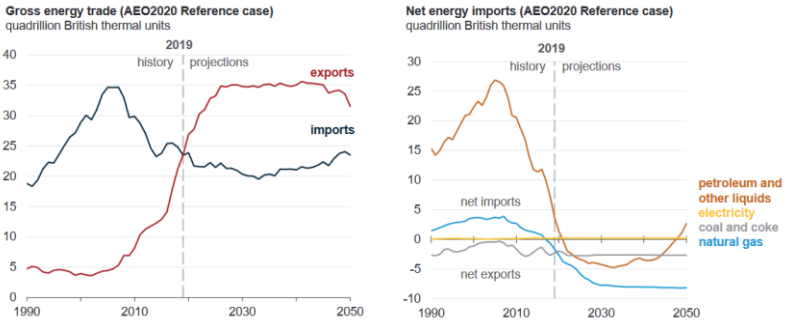


Figure 12 US Net Energy Imports and Exports from EIA.gov Annual Energy Outlook 2020

The phrase hints at U.S. independence or energy security. It infers not just the ability to meet our own energy needs, but to influence energy markets around the world, leveraging oil, gas, nuclear, coal and technology exports to shape the geopolitical landscape and energy markets in our favor. Figure 12, above, shows the U.S. transition from being a net importer of energy to a net exporter in 2019, and how that change was led by a drop in net petroleum imports.[124] Furthermore, the NSS promotes the ability of the U.S. to export energy, which brings with it the power to help our allies diversify their energy sources and confers the power to weaken our adversaries and competitors.[125] The NSS highlights the important role of technology in energy dominance. Most importantly, the technology of fracking demonstrates well the power of the U.S. technology and innovation ecosystem to influence energy exports, energy security, and access.[126]

Though the U.S. enjoys a great wealth of natural energy resources including coal, oil and natural gas, the U.S. government's ability to leverage our technological advantages and continue to incentivize investment in energy technology beyond fossil fuels is our most important resource. Renewable energy technology allows the U.S. to harness underutilized natural resources such as solar, wind, geothermal and hydropower and offers many advantages critical to the GPC: carbon emission reduction; distributed energy production; reduced total energy cost; diversification from fossil energy; jobs; and wealth creation.[127]

Climate change science is politically challenging for the current U.S. administration. However, recognizing the concerns of partner nations around the world is an opportunity to assert U.S. international leadership. U.S. allies and partners in Europe, Asia, Africa, and South America are concerned about climate change, which, in some cases, could impact them more drastically than the U.S. homeland. Venues like the Paris Climate agreement offer critical opportunities where the U.S. should support our allies and punish our adversaries with worldwide energy policies that benefit U.S. national security interests. As one of the world's largest energy producers and consumers, having the U.S. voice at the table of climate change

discussions is exceptionally weighty, allowing it to frame the agenda and possible outcomes in its favor.

The U.S. should be proud of its new oil and gas abundance and leverage this strategic energy coup to its advantage. However, in the context of the GPC, U.S. energy dominance is still more aspirational than reality. Russia will continue to exploit its massive fossil fuel reserves and nuclear industry to influence battleground regions such as Europe, South America, Africa, and the Middle East. At the same time, China's Belt and Road Initiative (BRI) threatens U.S. influence in those same regions. The U.S.'s oil, gas, nuclear and renewable export industries could both temper Russian energy exports and feed the insatiable Chinese hunger for energy. Finally, just as the U.S. is adjusting to the reality of being an energy exporter, COVID-19 has rocked the energy industry, especially oil and gas, to its core. While the short-term impacts are severe, it is not clear that the crisis offers a significant advantage to any of the GPC competitors. For now, it's simply a net-negative for all involved. However, in crisis, there may be opportunity. As the Federal government grapples with how best to support our energy industries, there are tradeoffs between supporting legacy fossil fuel industries and less carbon intensive nuclear and renewable gas industries. The U.S. should balance supporting our legacy fossil fuel energy companies to meet near-term demand, while spurring investment in reduced carbon options to better support our allies and weaken our fossil-fuel dependent competitors. An in-depth discussion of how COVID-19 has impacted U.S. energy markets and national security can be found in Annex B.

Tyranny of Small Spaces in Energy

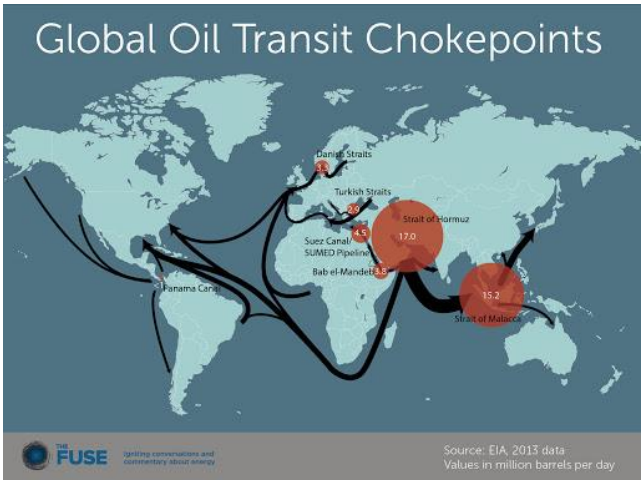


Figure 13 Global Oil Transit Chokepoints

While many geographic locations in the world have significant implications for the global energy fuels market (Figure 13[128]), three that currently cause some of the largest geopolitical stresses are the Strait of Hormuz, the Strait of Malacca, and the Baltic States of Latvia, Lithuania and Estonia. Because of the strategic significance of each of these, they can serve as case studies for regions with similar dilemmas. Instability for both state and non-state actors in the immediate vicinity around the Strait of Hormuz causes tremendous uncertainty in the many places that rely heavily upon Middle Eastern oil for their energy needs. Much of the global tension between China, the U.S. and many other players in the GPC is due to the pressure China feels to gain control over its future energy security, primarily by gaining exclusive domination over passage through the Strait of Malacca. Finally, the Baltic States are highly dependent on Russian oil and gas, leaving them vulnerable to Russia's aspirations to regain control over the region.

DOD's Micro-Grid Concept

Many people often assume that all military installations have microgrids because of its ability to island, or more specifically, provide backup power to critical loads. Although there are a few testbed microgrids on DOD installations, most of the DOD's backup capability is enabled through the disparate operation of small fossil-fuel generators. A microgrid is a local system of distributed energy resources and electrical loads that can operate as a single entity either in parallel to the commercial grid or independently ("island" mode). Microgrids have major advantages over standalone generators for providing energy security: efficient sizing, maintainability, reliability, flexibility, and coverage. Energy security is necessary to powering critical loads for DOD's Continuity of Operations (COOP) when a primary operating location is incapacitated, and operations must relocate with the same level of consistency.

When comparing the costs and benefits of microgrids over backup generators the results vary based on the mix of grid energy and prices in the geographical regions (see Figure 14).[129] Science & Technology Strategy firm Noblis performed a study under two Base Cases (building-tied standalone generators), showing the annual cost to protect a kW of critical load is $80 to $85 and the same in three electricity markets. Under Microgrid Case A (microgrid with large diesel generators only), the comparable all-in energy security cost per kW ranges from $31 (Mid-Atlantic/Northeast) to $61 (California) a substantial cost savings from the base cases. Under Microgrid Case B (microgrid with large diesel and baseload natural gas generators), the annual cost to protect a kW of critical load ranges widely—from negative $80 in California, to $93 in the Mid-Atlantic/Northeast, to $195 in the Southeast. These prices make microgrid integration less cost beneficial in two of the three regions, and not only less expensive but cost negative in one region—California. This example demonstrates the disparate regional energy source mix that impacts the price and feasibility of microgrid integration.[130]

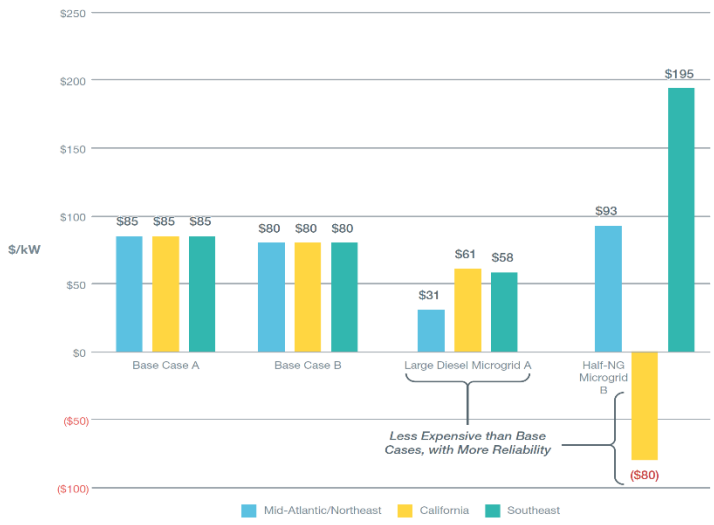


Figure 14 The Annual Net Cost of Protecting each Kilowatt of Critical Load

However, in analyzing three energy sources -generators, batteries, renewables- for DOD microgrids, it is critical to note their costs, resilience, environmental concerns, and inherent challenges. One can conclude that those installations with on-site generation capabilities, coupled with a microgrid and upgrades to the local distribution system, can enhance installation energy security. However, minimizing challenges and constraints are necessary to achieve said energy security. Increasing efficiencies, lowering costs, and enhancing backup power options all have significant impacts on energy security when implemented as part of a comprehensive energy strategy.

Definitively, microgrids enable the energy resilience of installations based on their availability and reliability via the use of generators, batteries, and/or renewables. Analysis of the strategic contextual management dynamics of cost, resilience, environmental considerations, and challenges as a singular adoption has shown the best solution to be batteries, followed by generators, then renewables. However, renewables coupled with batteries is likely the optimal long-term solution if the U.S. can overcome supply chain security issues.

To maximize microgrid integration, the following challenges must be addressed: 1) degraded distribution infrastructure, 2) inadequate federal funding, and 3) legislative constraints. However, the DOD has clearly articulated commitment towards energy management through its $2.9B investment in renewable energy and support of the National Energy Conservation Policy Act (NECPA) and the National Defense Authorization Act (NDAA) 2019 requirements.

Nano Technology and Energy

The development of effective materiel and non-materiel solutions in the energy sector – including using nanotechnology to improve lethality, readiness, and mobilization - will play a vital role in advanced complex systems, the Great Power Competition, and future conflicts. In 2020, research into the "problem of manipulating and controlling things on a small scale,"[131] today known as nanotechnology (nanotech), and applied materials science is producing valuable results in the development of innovative solutions to address gaps in energy diversity, efficiency, resiliency, and security. How the DOD partners with other government agencies, academia, industry, and allies to implement a cohesive strategy that employs advances from nanotech in the energy sector will help ensure collaborative advantage against our adversaries.

Nanotech products that offer resilient, efficient, safe, secure, abundant energy storage capabilities vastly superior to what has traditionally been available are quickly becoming a reality.[132] Still, nanotech markets face several ethical, market and regulatory challenges that are hindering innovation. For the defense sector, leaders should further explore implications of ubiquitous and often imperceptible integration of products into the daily lives of soldiers. This will help frame a conversation about decisive next steps and a path forward to spur innovation and drive acceptance of a fast-approaching reality: nanotech in the energy sector is here and has begun to infiltrate our everyday lives. Ignoring this call to action allows our adversaries to gain an advantage that will put us behind by years, if not decades, in next-generation warfare.

Nanotech applications can transform space, weight, and power (SWaP) considerations for national defense portfolio equipment. Small, light, long-lasting, easily rechargeable batteries, or coatings that manufacturers can easily apply and maintain on equipment to prevent damage, rust, freezing, or overheating will always benefit platform readiness. Other areas of interest to national security address operational energy, fuel efficiency and the resiliency of supply as well as regenerative power,[133] and water purification using nanotubes[134].

Development of next-generation materials is a national imperative. As an ongoing focus, the U.S. needs a deliberate push to support the development and practical use of the proverbial Ubium: employing nano-compound of graphene,[135] nano-milled perovskite, and a conductive

substrate to produce intelligent inks, dyes and coatings that capture, store, transform, generate, and transfer energy (as well as data). A breakthrough in this area will result in the ability to power and find anything (or anyone), anywhere, anytime.

The National Nanotechnology Initiative (NNI) priorities specific to the energy sector are clearly nested in the NSS and proper resourcing by Congress will substantially improve readiness. This includes considerations for surge & mobilization, where our industrial base would be called upon to deliver solutions quickly for a surge (<12 months) and ramp-up substantially (300 percent) over a 24-36-month timeframe. We are very close to answering how we deliver on the potential for advancements in operational energy, to include sensors, hydrogen fuel cells, miniaturized personnel battery packs, small modular reactors, mobile microgrids, and nanotubes for desalinization to replace current large Reverse-Osmosis Water Purification Units (ROWPUs). These innovations should lead quickly and iteratively to the next set of materiel and non-materiel solutions.

Cyber Issues in Energy—Protection of the U.S. Electrical Grid

The U.S. must protect itself from current and future attacks to its electrical grid and critical energy-producing infrastructure. A worst-case scenario, for example, is one involving a state-sponsored Chinese or Russian cyberattack that could lead to country-wide blackouts or blackouts directed at crucial city-centers that last for days or weeks and severely impact the U.S. economy. Chinese military doctrine calls for attacks on an opponent's critical infrastructure in case of conflict.[136] Russia is mapping U.S. critical infrastructure and staging cyberattack assets in order to disrupt or cause substantial damage to civilian and military infrastructure during a crisis.[137] This could come at the least opportune time, one where the nation is in the midst of another crisis such as COVID-19, leading to catastrophic effects for the U.S. economy. Moreover, this could have equally devastating effects on U.S. trading partners and allies connected, in part, to the U.S. grid. Resilient U.S. offensive cybersecurity strategies and public signaling of cyber counterattacks against China and Russia will protect the U.S. grid infrastructure from current grid vulnerabilities.

The government still has much work ahead in mitigating cybersecurity risks facing the electrical grid. Current systems in place show significant gaps in the oversight of cybersecurity vis-a-vis critical infrastructure. For example, FERC reliability standards do not fully address cybersecurity guidance for critical infrastructure.[138] While the National Institute of Standards and Technology (NIST) Framework was established to fill this oversight gap, only FERC standards are enforceable. The NIST Framework, while helpful, provides voluntary guidance only. The U.S. should strengthen and streamline organizations, such as Congress, FERC, North American Electric Reliability Corporation (NERC), NIST, and Department of Energy (DoE) tasked to oversee the nation's electrical grid system cybersecurity with clear and distinct lines of effort to track the progress of cybersecurity resiliency within the U.S. energy grid system.

Energy-Crime-Terrorism Nexus

Energy's significance in the balance of power and the GPC is clear, but energy also plays a role in less existential threats such as crime and terrorism. As the U.S. solidifies its role as a global energy leader and maintains its political, economic, and military influence,

adversaries will try to undermine any potential comparative advantage the U.S. may gain. With an increased dependence on technology, our vulnerabilities to disruption also increases. Terrorists, criminals, and hostile nations are highly determined and adaptive and will exploit these vulnerabilities to further their own objectives.[139] In confronting this threat, energy security and protecting our critical energy infrastructure and supply chains represents an enormous challenge.

Terrorists are patient, opportunistic, and flexible, as evidenced by their persistent targeting and planning of the September 11, 2001 attacks on the World Trade Center. They learn from experience and modify their tactics and targets to capitalize on vulnerabilities.[140] Although U.S. intelligence agencies and law enforcement have made it much more difficult for adversaries to inflict damage on the U.S., probing attacks, both physical and cyber related, have already targeted the energy infrastructure and one should assume these individuals and organizations are planning an event of significant magnitude akin to 9/11. With the growing sophistication of some of these actors, particularly in cyber, the potential for such an attack is not outside the realm of possibility.

Advancements in energy technology enable U.S. efforts to be more energy efficient, but also exposes critical infrastructure to software threats. Malicious actors have the means to deploy a virus that can infiltrate and sabotage industrial control systems, which could result in a pipeline explosion or increase the rotation of a centrifuge to unsustainable levels. The 'Stuxnet' virus, a computer worm that was originally aimed at Iran's nuclear facilities, has since mutated and spread to other industrial and energy-producing facilities. It targeted the programmable logic controllers (PLCs) used to automate machine processes.[141] One would be hard pressed to find one critical infrastructure system not reliant on these control systems.

> "Individual terrorists, terrorist groups and even state-sponsored terrorism are looking for easier and less direct ways to attack the U.S. and its interests. Rather than direct confrontation, these groups will likely employ strategic indirect warfare against powers like the U.S., which can take the form of political and economic manipulation, disruption of infrastructures, intimidation, various forms of economic warfare, etc. This is an area where knowledge and tools are expanding rapidly through the Internet and where the Internet has become the main means for launching the attacks."[142]

Other threats include Electric Magnetic Pulse (EMP) weaponry. Although terrorists and criminals may not currently have the capability to launch such an attack, it is within reach. Since the United States is heavily dependent on electrical systems to provide all basic services, an EMP attack has the potential to have a cascading effect on all aspects of American society.[143]

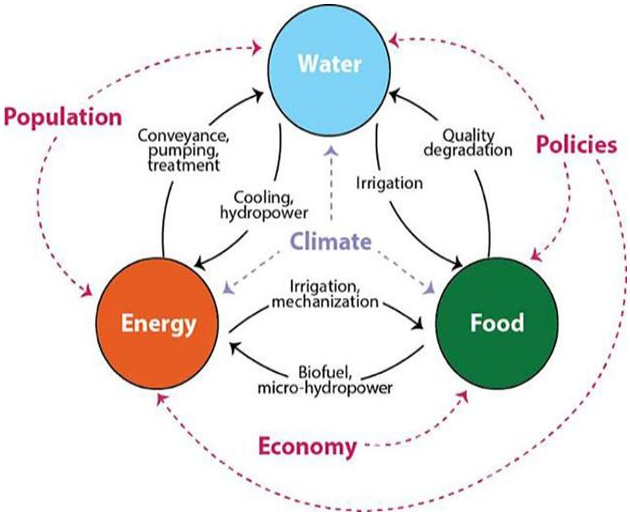
Physical attacks, such as the bomb laden boat used in the 2000 attack against the USS Cole in Yemen,[144] could target oil tankers currently idle off the coast of California. Or, an aircraft-assisted suicide, like 9/11, could target the port of Houston or Corpus Christi, or, any of refineries located there. Either scenario would result in a significant disruption to the broader energy supply chain and the U.S.'s ability to export and import oil and gas.

There are many examples of criminal and state-sponsored attacks on energy systems around the world, such as a recent ransomware attack on a Portuguese European utility giant Energias de Portugal (EDP),[145] the 2019 Houthi claimed attacks on Saudi oil facilities[146], and the on-going Russian cyberwarfare campaign targeting the Ukraine, with power grid attacks in 2015, 2016 and 2017.[147] Amazingly, international terrorists have shown limited interest in attacking the U.S. power grid. However, that should not be a basis for complacency.[148] The U.S. is still considered a significant target and the possibility of an attack involving U.S. critical infrastructure is compelling considering the damage it could cause.

There are numerous U.S. government entities involved in physical and cyber security for critical energy infrastructure, however, it is unclear how all these entities leverage assets, coordinate, and communicate. There are numerous offices and coordination groups within government agencies conducting on-going security assessments, but none appear linked or mapped to a common operating picture or communication network. This silo-ing can lead to a chaotic and dysfunctional environment when a major physical and/or cyber-attack occurs on U.S. critical energy infrastructure. During an ongoing crisis such as COVID-19, managing the impacts of an attack will prove even more difficult.

Water-Energy-Food Nexus

Among U.S. critical infrastructure and resources, energy, water, and food are all essential to U.S. national security, and their primary roles in our survival also make them attractive targets for our adversaries. These resources are also highly reliant on each other, and any disruption to one can have a negative impact on the others. It is these complex interdependencies that is known as the Water-Energy-Food (WEF) Nexus[149] (Figure 15[150]).



While we have access to abundant sources of energy, our use of them is largely dependent on water. Water is used in liquid form to extract and refine fuels and cool power plants. It is also used as a gas (steam) to turn turbines for thermoelectric power which provides 90 percent of the electricity in the U.S.[151] Among the sources of energy, petroleum, natural gas, coal, nuclear, and biomass are the largest consumers of water, and hydropower, wind, solar, and geothermal use the least amount of water.[152] In terms of water use for transportation fuels, it takes three to six gallons of water to produce one gallon of gasoline, and 10 to 324 gallons of water to produce one gallon of ethanol.[153]

In the food and agriculture industry, water irrigates crops and sustains livestock, and is used to process and prepare food.[154] The agriculture sector contributes to the energy industry by providing a source for biofuels, with a key tradeoff being using farmland to grow crops for biofuels versus food for consumption. Either type of crop can in turn have a negative impact on water

quality resulting from the runoff of fertilizers, pesticides, and herbicides into surface and ground water. Additionally, the production and use of both water and food require energy. Energy's roles in the water sector include pumping, treating, and distributing water for use, and then collecting and treating wastewater.[155] Energy also provides the power needed on farms and in food processing industries, as well as transportation fuels to deliver food from farm to market to kitchen tables.

Finally, the WEF Nexus is also influenced by other forces, such as climate, population, and the economy.[156] In fact, how to best manage the WEF Nexus varies among local climates (e.g., arid versus fertile) and can change over time as a local climate becomes more warm, cool, dry or wet. Additionally, as populations and economies expand, the demand for energy, water, and food grow, increasing the stress on the WEF nexus.

Worldwide, an average of 70 percent of freshwater consumption is used for agriculture, varying from 90 percent in low-income countries to 41 percent in high income countries.[157] Conversely, freshwater consumption used in worldwide industry, including the energy industry, averages 19 percent, and is lower in low-income countries and higher in high-income countries.[158] In the U.S., the two largest categories of water withdrawals in 2015 were Thermoelectric Power and Irrigation.[159] Among U.S. government agencies, DOD uses more potable water and more energy than all of the civilian agencies combined.[160]

Given the human dependency on WEF resources, the U.S. government has a myriad of laws and policies regarding their conservation, and they have produced positive results.[161] However, each resource is commonly addressed independently and not as part of an interconnected nexus. This is due in large part to the singular focus of some agencies, and even in cases where interagency coordination is strong, it is often within one or two resources. Incorporating a nexus approach into these programs could greatly increase the effectiveness of our conservation efforts and expand our use of these resources into the future.

Finally, given all the research that has been done globally on the WEF Nexus, no discernable attention has been given to how it should be applied to improving a nation's security. It is time to bring these two fields together. There is a tremendous opportunity for DOD to conduct ground-breaking, applied research on how to integrate WEF Nexus thinking into the U.S. national security and defense strategies. It is only through the sustainable use of our water, energy, and food resources that we will achieve our goal of energy dominance.

GEOPOLITICS OF ENERGY

"Energy security is economic security; economic security is national security."[162] The geopolitics of energy is founded on the global sphere's ability to acquire the necessary natural resources, energy production, and sustainable measures to meet their national interests. Figure 16 depicts the current global energy security risk assessment, an index representing a quantifiable measurement of each country's energy security with respect to sustainable policies, per capita emissions, manufacturing resources, renewable investments, and human capital development.[163] Though energy security does not ensure prosperity - as in the cases of Venezuela or Nigeria - it plays a key role in a country's economic, security, and diplomatic objectives. It is this pursuit- the race for energy independence, economic superiority, and hegemony - that greatly influences the balance of superpower competition and global prosperity.

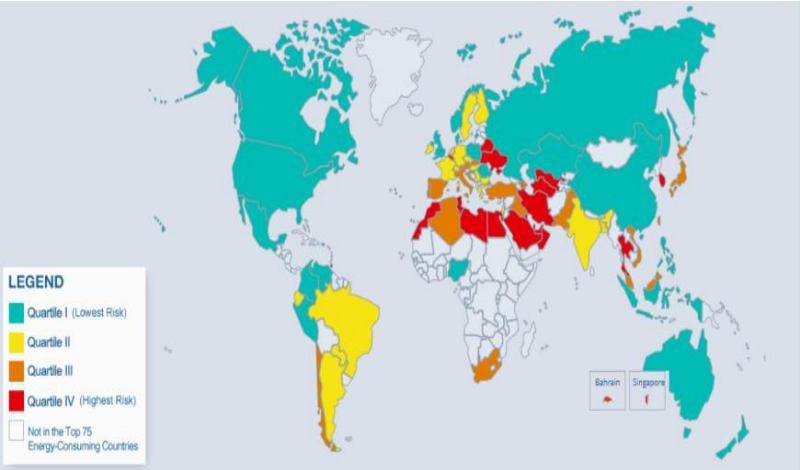


Figure 16 2019 U.S. Commerce Global Energy Institute International Energy Security Index

Energy Diplomacy: An Instrument of Power in the Baltic Nations

Energy diplomacy is a U.S. national interest item that began during the Obama presidential administration and continues today. The Baltic nations and European energy markets are an overlapping area of interest that defines the current era of competition between great powers. Baltic nation sovereignty supports U.S. interests and the liberal democratic world order. As a diplomatic means, the U.S. expansion of Liquid Natural Gas (LNG) export opportunities into the Baltic region will support U.S. economic expansion, strengthen alliances and partnerships and furthers the National Defense Strategy to deter a great power competitor, Russia.

Energy independence is a key interest for the Baltic nations. Today, figures 17 and 18 show that a large amount the EU's energy, which includes the Baltic nations, is provided by Russia through oil and natural gas pipelines.[164] The magnitude of what this meant for the region's security became apparent in 2006 when the "Druzhba" ("friendship" in Russian)

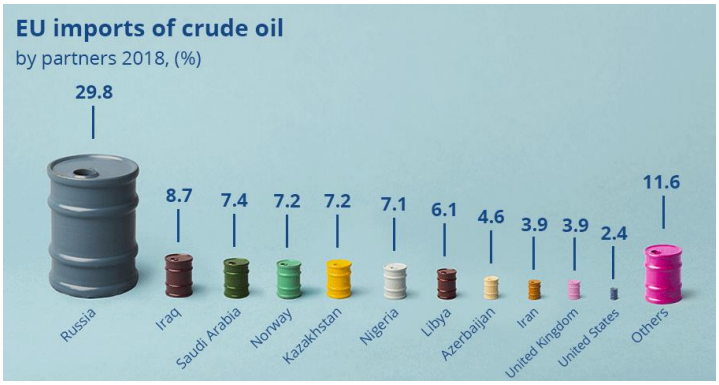


Figure 17: EU Imports of Crude Oil

oil pipeline was shut down by Russia for so-called 'technical repairs' after Lithuania refused to sell their oil refinery to a Russian-led consortium.[165] Because of this, energy independence became key for the Baltic nations to ensure political and economic independence from Russian influence. Since then, the region has been diversifying its[166]

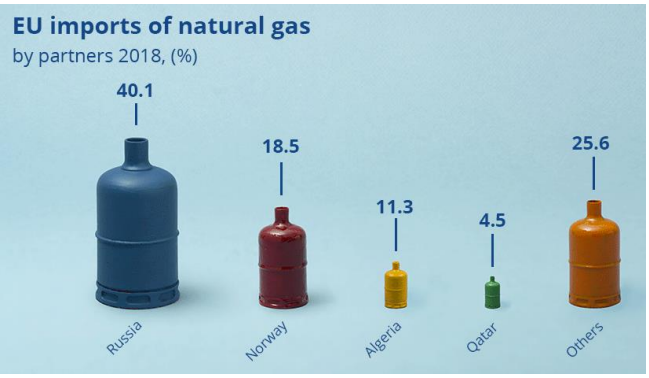


Figure 18: EU Imports of Natural Gas

The Baltic nations have the potential to increase their energy security if they can improve their infrastructure and develop technological advances like the U.S. has. The *Three Seas Initiative* (Figure 19) is an excellent start, as it will work to modernize a north to south infrastructure throughout the Baltic region as opposed to the existing East to West infrastructure that currently exists.[167] Following Lithuania's lead, Latvia and Estonia's expansion of LNG regassification terminals along their port regions increases the region's energy security. The U.S. government, working with industry leaders such as Royal-Dutch Shell, ExxonMobil, and BP should help secure financing that will enable firms to invest in infrastructure projects to store and distribute the re-gasified LNG throughout the region.

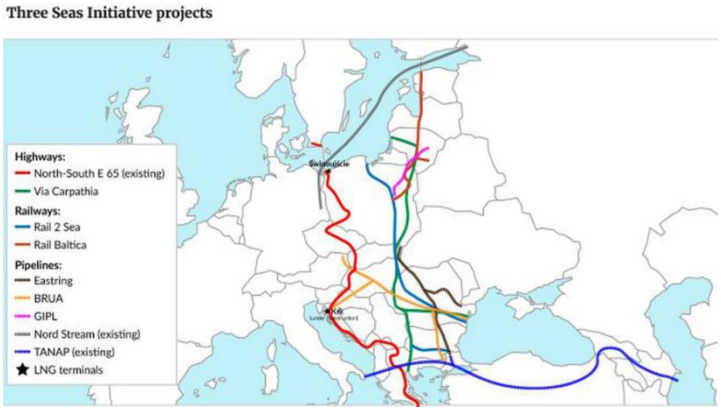


Figure 19: Three Seas Initiative

Markets require a universe of buyers, sellers, competitors, and infrastructure. The Baltic States creating an internal market of firms to operate and extract these resources will help create conditions for regional energy security. However, it will take a deliberate effort between financial institutions, to provide financing, industrial firms to provide technology transfer, and operations and government institutions (U.S. and EU) to create a regulatory framework to establish a robust regional market ecosystem. These actions, if coordinated among allies of the EU, Baltic nations, and the U.S., will support increased energy security and minimize Russian regional influence.

The Baltic nations cannot achieve their sovereign goals without support from the U.S. Diplomatic efforts are critical to support the region as Russia flexes its military muscle in Crimea, Georgia, and Eastern Ukraine. These efforts are energy diplomacy in action and will go far to increase the energy security of the Baltic region as well as advance the interests of the U.S. and the North Atlantic Treaty Organization (NATO) against a great power competitor.

Former Eastern Bloc Countries Energy Diversification

Within the European market, Eastern Bloc Countries (EBCs) lack sufficient domestic natural resources and rely on long-term contracts for natural gas and oil from the leading supplier - Russia. However, dependence on one supplier is a threat to EBCs' energy security and thus is a risk to national economic stability. It is imperative these countries maintain energy stability; they should develop industrial infrastructure, diversify suppliers, and seek new energy alliances to reduce dependence on a single supplier and avoid a serious threat to their respective economies.

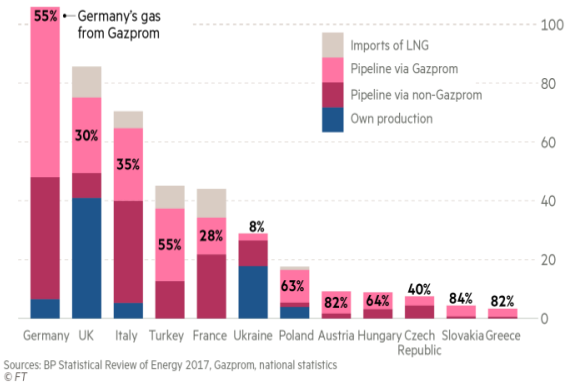


Figure 20 Natural gas statistic in Europe [161]

Until the collapse of the Soviet Union, nearly 100 percent of EBC's imported gas and oil came from Russia, and EBCs did not treat issues affecting energy security as strategic concerns. However, political changes in 1989, the significant increase in gas and oil prices in 2008, conflict in the Middle East, the Russian invasion of Georgia, and the unlawful seizure of Crimea in 2014 by Russia showed how much EBCs' economies depended on Russian energy supply. It became clear that in the event of a conflict, their energy security, and national security, would be endangered.

Today, import statistics continue to confirm that both the EBCs and Western European countries are still heavily dependent on gas supplies from Russia, with many pipelines linking these nations (Figures 20[168] & 21[169]). While the EBCs have taken several actions to become independent of Russian supplies, some Western European countries such as Germany do not see this as a threat. Despite the opposition to Russia's gas infrastructure expansion among most European countries and the sanctions imposed by the U.S. on companies supporting the development of the Nordstream 2 (NS2) Russian gas pipeline, Germany continues to support this investment. Bearing in mind that with the launch of NS2 and the southern pipelines, the transport of gas through the Brotherhood pipeline in Ukraine will be suspended, which will threaten this region of Europe and a key source of income for the Ukrainian government. These activities will increase Russian influence in the European gas market where Gazprom currently exports 243 bcm of natural gas and wants to remain the market leader. Based on Russia's history of using "blackmail" negotiating tactics, such as when it restricted gas transmission during the winter season in 2009 that led to many deaths, none of Russia's Western European customers[170]

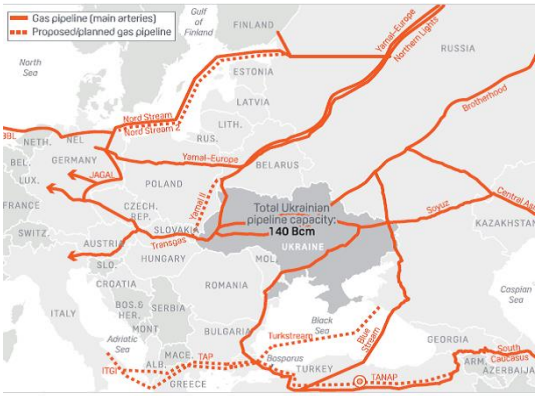


Figure 21: East to West Energy Pipelines [162]

To become independent of the eastern supply of energy resources and increase energy security, EBCs are investing in the development of domestic and international storage and transmission infrastructures. Examples are the gas terminal in Świnoujście (a critical Energy Hub), Naftoport in Gdańsk, and the ongoing investment of the Baltic Pipe, which will supply EBCs with natural gas (Figure 22).[171] Cooperation with Ukraine as a gas storage hub, supplied with gas from different suppliers through Polish pipelines, may pose a benefit in that part of the European market. Also, EBCs continue cooperation within the Visegrad Group V4, searching for new partners, and they develop and increase the use of renewable energy sources contribute to the diversification of the supplies and reduce dependence on other imported sources such as natural gas or oil.

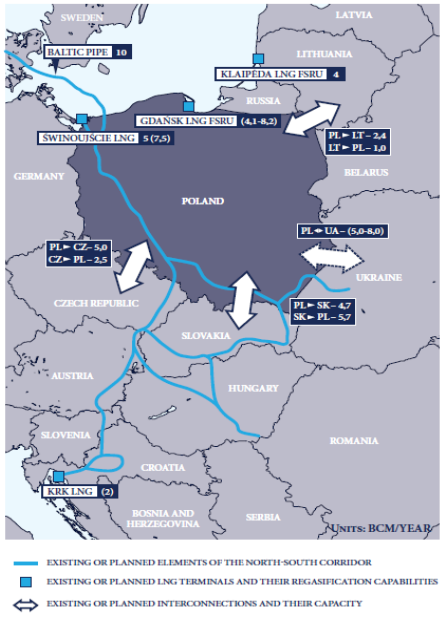


Figure 22 Baltic Pipe, North-South natural gas corridor

For the time being, EBCs remain dependent on Russian energy supplies. But with the right policy, implementation of regulations, new contracts, and ongoing investments, the trend is decreasing. EBCs' ability to implement an appropriate energy strategy, diversify supply directions and providers, develop alternative energy sources, modernize, and develop infrastructure will minimize threats and improve energy security. Strengthening cooperation with the region's partners will undisputedly increase the independence of these partners from Russian supplies.

Conflict Over Natural Gas in the Eastern-Mediterranean Region

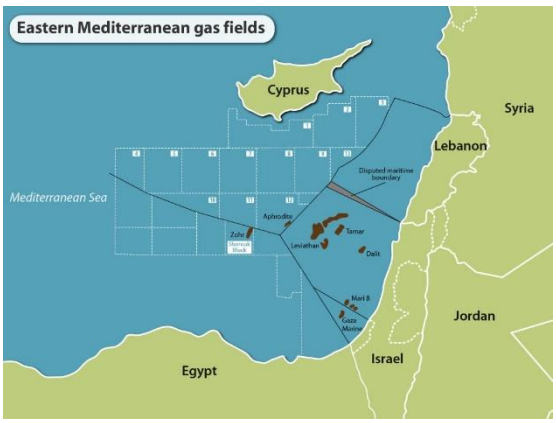


Figure 23 Carole Nakhle, "Politics, economics still stifle Eastern Mediterranean gas"

Whereas Europe has dealt with the geopolitics of natural gas for decades, these issues are more recently prominent in the Eastern Mediterranean region, where the discoveries of natural gas fields has opened the door to a new chapter in the relationships among Egypt, Israel, Cyprus, Lebanon, Syria, and Turkey (Figure 23).[172] Historically, these nations were heavily dependent on energy imports, the development of the discovered gas fields in the Eastern Mediterranean has led to increased energy security and economic gains. Developing a shared, regional energy architecture among these countries has been a challenge as disputes erupt over a unified approach for the construction and distribution of necessary infrastructure. Also, geopolitical issues such as border disputes, the state of war between Lebanon and Israel, the Arab-Israeli conflict, the Cypriot-Turkish conflict, and the civil war in Syria sow additional discord in any intragovernmental energy discussions.[173]

Not only does the interest in natural gas in the East Mediterranean involve the national and regional powers, but it also extends to major powers, including the European Union (EU), Russia, U.S., and China. Natural gas imports from the Eastern Mediterranean would provide the EU with an opportunity to diversify its energy supplies and preserve EU Governments' and companies' interests.[174] Additionally, Russia seeks to be a partner in future gas projects, which would guarantee its oil companies the financial benefit from these projects and secure its presence in the future supply of gas in the global market.[175]

The U.S. has an opportunity to optimize the benefits associated with the natural gas production in the Eastern Mediterranean to support its national military security objectives to include strengthening its allies and partners and reducing the security footprint of its global competitors. U.S. investment in the Eastern Mediterranean natural gas production would weaken Russia's position in Europe and the Middle East and prevent China from investing its BRI foreign direct investment. The U.S. could facilitate the Eastern Mediterranean gas access to Europe, which would further garner political reconciliation among its allies and partners in the region. Conversely, this would undermine the U.S.'s economic interests by reducing shale natural gas exports to the European market as Eastern Mediterranean gas satiates demand.[176]

China's Energy Diplomacy: An Acquisition Strategy based on Deceit

Energy Diplomacy, global natural resources acquisition, and global energy market development may be the determinant factors to shape the GPC victor. As China's industrialization and productivity grows, it will need to gain the necessary natural resources, control the global distribution lines of communication, and rely on its national innovation to meet its projected 2050 Gross Domestic Product (GDP). The People's Republic of China (PRC) is facing the daunting challenge of instituting a more self-reliant energy security policy to overcome the vulnerabilities surrounding its consistent economic growth. Since the 1980's, China has experienced an average of 9-10 percent annual economic growth resulting in an industrial revolution and creation of a 300-million strong middle class.[177] The International Energy Agency projects China will be the largest global energy consumer, oil importer, and coal producer in the world by 2040.[178] China's energy security policy is constrained due to its dependency on imported petroleum to support its total national energy consumption. Key facts affecting China's energy security includes;

- China remained the world's largest energy consumer, accounting for 24 percent of global energy consumption and contributing 34 percent of global energy demand growth in 2018.[179]

- In 2018, among the fossil fuels, consumption growth was led by natural gas (+18 percent) and oil (+5.0 percent), while coal remained the dominant fuel. China's coal consumption as its share of total energy consumption in 2018 (58 percent) hit a historical low importing 54 percent of its coal from Australia, 31 percent from Indonesia, and 17 percent from Russia.[180]

- China is the largest importer of oil and natural gas in the world. The import dependency on oil rose to 72 percent in 2018, the highest in the past half century. The import dependency on gas increased to 43 percent in 2018. [181]

China's national strategic end is to improve its energy security posture by diversifying its natural resources acquisition. China's Energy Diplomacy concentrates on weaponizing the acquisition of natural resources to achieve its vision of becoming the global economic superpower. Through the Chinese Belt & Road Initiative (BRI), foreign aid to energy rich countries, and unique global transportation network to gain control of the world's natural resources, China's diplomatic and economic influence has positioned them to gain control of the acquisition of strategic materials and energy resources in high-debt to GDP countries to support their growing GDP.

China's Energy Diplomacy consists of implementing a national resources acquisition strategy using foreign direct investment, international trade agreements, and national private-public investments to gain the world's energy resources. China's foreign direct investments (FDI) consist not of equity stakes, but rather providing low-interest loans and infrastructure development aid to gain political and economic influence with energy-rich countries. China's debt-trap policy consists of investing in countries with high debt-to-gross domestic product (GDP) ratio or countries who own key global infrastructure by offering interest-bearing loans with onerous terms. China's expectation is that a host country will default on the loan allowing China to restructure the loan with added economic or resource acquisition benefits for China.[182]

China's economic breakthrough consists of signing a trade agreement with an emerging nation predicated on a Chinese national bank financing the partner nation's infrastructure development. As a part of the trade agreement, China exports its workforce to support the project development and uses the host nation's natural resources as collateral to secure the loan and financial settlement. In parallel, China receives concessions in its export goods transaction costs and obtains the natural resources necessary to support its domestic production growth. China's BRI expansion effectively expands its private and public investment growth, resources production capacity, and technology transfer to secure world economic power.

China often strives to expand its energy security by instituting innovative financial transactions to divert the world's natural resources to China. In addition to China's debt-trap policy, China has instituted a "loan-for-oil" program as another diplomatic tool to circumvent current international trade agreements to gain a larger share of the world's resources. This program consists of providing loans to oil-exporting countries with the expectation that loan repayments will come in the form of oil shipments at market prices.[183] More deceivingly, China's aggressive financial negotiation tactic revolves around avoiding mediation in the global market by gaining access to the equity oil or the proportion of oil production that private or state-owned oil companies maintain to meet regulatory requirements. This tactic has been more visible in Sino-Venezuelan and Sino-Brazilian loan-for-oil international negotiations and acquisition strategy.[184]

The U.S. needs to apply a whole-of-government approach to counter China's predatory actions in securing the world's natural resources. The whole-of-government should consider the following policies, programs, and engagement opportunities specific to countering China's economic influence in the natural rich countries and key global points of transportation/ distribution to include,

- Department of the State conducts a vulnerability study of the critical global strategic ports participating in the BRI infrastructure investment to review any transport disruptions of U.S. natural goods.

- Department of State and Department of Commerce partner with U.S. energy industries to increase US competition in global energy development projects, specifically within the BRI international economic zone clusters.

- Department of State and Department of Commerce perform a global supply chain risk analysis for each major U.S. manufacturing industry to determine the supply chain vulnerabilities.

- Increase Nonproliferation, Antiterrorism, Demining, and Related programs (NADR) and Exchange Stabilization Funds investment in countries undergoing bi-lateral negotiations with China to counter the BRI expansion.

Latin America: A Convergence of Energy Sustainability, Security, and Diplomacy

Energy in Latin America could be the balancing factor towards the future state of the global super-power competition. Latin America's natural resources, similar to the strategic graphite and scandium in China, directly impact the global manufacturing and productivity index. Oil in Venezuela directly sustains an aggressive, authoritarian government, and the energy market in Mexico has begun a diversification of its country's market principles from a planned economy to a free market. Latin America's energy relationship within the global sphere has forced a strategic evaluation of the U.S. Monroe Doctrine, considering the strategic placement of our great power competition playing out in our hemisphere.

Mexico. Twenty years ago, Mexico was the 6th largest oil producer in the world and one of the largest suppliers to the U.S., its oil industry was its crown jewel.[185] However, the country's oil sector has been in dramatic decline. President Andres Manuel Lopez Obrador (AMLO) is trying to increase oil production by its state-owned company Pemex.[186] Still, the company is laden with debt, and significant capital investment is required to increase production and improve Mexico's refining capacity.[187] Mexico could become a "global energy powerhouse"[188] with diverse energy sources, including oil, gas, solar, wind, geothermal; it has vast potential for renewable energy development.[189] Mexico banned hydraulic fracturing despite having the fourth-largest shale gas reserves in the world.[190] Mexico's focus remains on oil. For the energy industry to strengthen Mexico's economy, Mexico should consider private investment.[191] Under Lopez Obrador's energy reforms, the focus is on boosting PEMEX. While he has not cancelled existing

contracts, his administration is putting pressure on international companies to show exploration results before opening additional auctions. [192] [193]The reforms are slowing private investments in the upstream market, although mid and downstream investments should continue to grow. [194] [195]

In 2014, through the Sino-Mex Energy Fund, the Chinese invested over $5 billion for energy and infrastructure investment with PEMEX.[196] Earlier this year, China invested $600 million into the Dos Bocas refinery, in the President's home state of Tabasco.[197] While the U.S.-Mexico-Canada Agreement (USMCA) maintains a tariff-free flow of natural gas, oil, and refined products, the U.S. could encourage Mexico to open up to U.S. investments and joint partnerships in its energy sector to increase oil production, distribute natural gas throughout the country, and harness renewables.[198] [199] [200] If the U.S. hesitates to strengthen the relationship with Mexico in the energy sector, Mexico is ripe for additional Chinese investment.

Venezuela. China has invested at least $50 billion in Venezuela massive oil resources since 2007, in which an estimated $20-25 billion remains outstanding as of February 2019.[201] But as Venezuelan oil production declines as seen in Figure 24,[202] and global oil prices drop, Venezuela must commit more oil than anticipated to service loans.[203] [204] Meaning, Venezuela has less crude oil to sell for cash-payments and state revenue.[205] If Venezuela defaults on its loans to China, China could seek to seize assets, as China has done in Tajikistan and Sri Lanka.[206] [207]

Figure 24 Venezuela Oil Production June 2005 – January 2020

Venezuela's debt also affects Citgo, an American subsidiary of the Venezuelan national oil company PDVSA. Citgo could be sold off or broken apart to satisfy PDVSA's debt. The Russian oil company, Rosneft, could acquire Citgo's pieces, since President Maduro placed Citgo shares as collateral for a Russian loan.[208] In March this year, the Russian oil company Rosneft sold its assets in Venezuela to the Russian government, which may be an attempt to avoid U.S. sanctions.[209] Rosneft is selling production, service, and trading assets to a state-owned company, so any U.S. sanctions elevate to Moscow.[210] Venezuela fits into a geopolitical battle between the U.S. and Russia in the energy sector, in addition to the Russia-Saudi Arabia price war, which may be a strategy to weaken the U.S. shale industry.[211]

Finally, Spain has a considerable investment in Venezuela. [212] Spain's oil company, Repsol, manages several crude and gas assets there.[213] Repsol has an oil-for-loan program with Venezuela. Due to the financial constraints of the Maduro government, Venezuela is increasing its oil shipments to Spain to pay down the debt.[214] [215]While the U.S. expands its sanctions, the EU continues to receive Venezuelan oil.[216] As of April 2020, the U.S. pressured Repsol to stop

its oil-for-gasoline swap with Venezuela, stating the swaps were sanctionable.[217] The recent rise in Venezuelan oil exports, 9% in February 2020, was likely due to buyers trying to get oil before the new U.S. sanctions on PDVSA and its trade partners.218 The U.S. Treasury gave buyers until the end of May to finish purchases.[219]

Chile. After facing energy-related difficulties through a dependency on fossil fuel imports and mainly coal-fired power plants, Chile is striving to become carbon-neutral by 2050.[220] [221]Chile is working to increase liquefied natural gas to replace diesel and boost sustainable hydroelectric and non-conventional renewable energy, such as geothermal, wind, solar, tidal, biomass, and hydroelectric plans.[222] Chile's renewable market has become one of the hottest in Latin America with a reported growth rate of 31.5% for non-hydro renewables (from 2000-2018).[223] Chile has some of the best solar resources on the planet, making it a perfect consumer for China's lower-cost solar panels. Just last year, the U.S. power company Sempra Energy sold its Chilean business to State Grid Corporation of China for $2.23 billion.[224] China is Chile's biggest trading partner, and its influence has been growing. From 2016 to 2018, Chinese investment rose dramatically in the lithium market and energy infrastructure, rising from $350 million to $6.6 billion.[225] Unlike what we've seen in Venezuela with its debt to China, Chile is mostly a traditional trade partner to China with a long-time relationship, so Chinese influence is likely to be more subtle, depending on its soft power.[226]

RECOMMENDATIONS TO POLICYMAKERS

Legislative Proposals; U.S National Policy Recommendations

- The U.S. Government must strengthen and streamline organizations tasked with overseeing the nation's electrical grid cybersecurity to increase resiliency. Giving institutions such as the Federal Energy Regulatory Commission, North American Electric Reliability Corporation, National Institute of Standards and Technology, and Department of Energy clear and distinct lines of effort and authorities to impose measurable and enforceable standards to track cybersecurity resiliency for the U.S. energy network and the U.S. power grid.
- Rejoin the Paris Climate Agreement to assert U.S. leadership and shape world energy policy in favor of U.S. interests.
- Continue and deepen engagements with resource-rich allies, such as Canada and Australia.
- Require resource conservation laws and regulations to address the Water-Energy-Food (WEF) Nexus.
- Support and expand the U.S. renewable technology industry with research grants, tax credits, and other incentives.
- Expand section 123 language of the U.S. Atomic Energy Act to shape the small modular reactors market and reduce export barriers to gain a competitive advantage in the global market against Russia and China state owned enterprises.
- Mature our use of Artificial Intelligence (AI) in the energy sector through federal incentives and the investment in AI-related science and technology education initiatives.

Recommendations to the Executive Office of the President

- Establish a WEF Nexus lead at the National Security Council (NSC) to incorporate WEF Nexus thinking into national security decision-making.
- Identify a national coordinator to streamline the existing security and communication authorities surrounding critical energy infrastructure

Recommendations to the Department of Defense

- Monitor Chinese state-owned companies, such as the Poly Group, Inc. who have been accused of illegal military arms sales and are operating in BRI participating countries as energy project development advisors.
- Facilitate accelerated research, development, and deployment of micro-reactors as secure and reliable operational energy sources internationally and domestically.
- Achieve power resiliency on installations, nationally and internationally, more quickly using shallow geothermal solutions through direct use ground sources to decrease the power generation base load requirements in conjunction with rollout of other renewable technology.
- Incorporate the WEF Nexus framework in DOD energy management and operational plans.
- Provide research and development funds for WEF Nexus research for each service and incentivize each service to adopt the WEF Nexus approach in their resource management.

- Increase the North American Electric Reliability Corporation (NERC) Electricity enforcement authority to include the Information Sharing and Analysis Center by requiring all power entities to report physical security incidents
- Allow for Military construction funds to be combined with third-party financing to improve our military installation grid reliability.

Recommendations to the Department of State

- Conduct a critical global strategic vulnerability study for ports participating in the BRI infrastructure investment to identify U.S. transport disruptions.
- Counter China's BRI, by investing BUILD Act resources and expanding initiatives such as America Crece to compete in global development programs in BRI international economic zones and Increase Nonproliferation, Antiterrorism, Demining, and Related programs investment in countries undergoing bi-lateral negotiations with China.
- Perform a global supply chain risk analysis for each major U.S. manufacturing industry to determine the supply chain vulnerabilities
- Facilitate border disputes agreements among the Eastern Mediterranean nations through bilateral negotiations or the United Nations to resolve Natural Gas exploration and energy market development issues.
- Support the *Three Seas Initiative* by facilitating the rapid processing of U.S. firms' export licenses competing for LNG construction projects in the global market.
- Increase coordination with the EU to update key pillars of the energy strategy to include market liberalization and integration, strengthening the legislative and regulatory framework, supporting market functionality and supply diversification.

Recommendations for the Department of Energy

- Prioritize a national electrical grid interconnect that ties all the individual interconnects together, allowing increased renewable penetration and improved grid redundancy.

Recommendations for the National Nanotechnology Initiative (NNI)

- Update the 2016 nanotechnology strategy to institutionalize gains and provide development priorities, frameworks, and timelines as a signal to industry and our allies.
- Increase support for common accepted nomenclature, definitions, and measurement standards as part of program component area 4, defined by the NNI as "Research Infrastructure and Instrumentation."[227]
- Codify in law the need to shift from nanotechnology funding research and development to production to mature the technology in both the military-industrial complex and the commercial marketplace, and incentivize broad adoption, refinement, and innovation.
- Explicitly nest NNI priorities specific to the energy sector into the NSS and provide funding through appropriations acts.

APPENDIX A

City of Houston's Energy Cluster ~ A Diamond of National Advantage

The city of Houston, Texas serves as the global energy industry's beacon for innovation, research, and sustainability practices, poised to bolster the world's future energy growth. Houston is home to the premier energy cluster interlocking the capabilities of its golden triangle - Government, Universities, and Industry - to generate the world's leading science and business practices. Houston is home to over 4,600 energy-related firms, one-third of the U.S. jobs in oil and gas extraction, new technologies such as hydraulic fracturing and deep-water offshore, and leading university research.[228] Through mere chance and through the deliberate exploitation of its geographical, geological, human capital, and industrial resources, Houston has become one of the primary energy capitals of the world.

Michael Porter's Diamond Model demonstrates how Houston has exploited its physical, governmental, and institutional attributes to become the global cluster of energy innovation (Figure 25).[229] This study seeks to evaluate the how the interconnected model elements of firm structure, demand conditions, factor conditions, and supporting industries emerged to create Houston's competitive advantage in the international energy market.

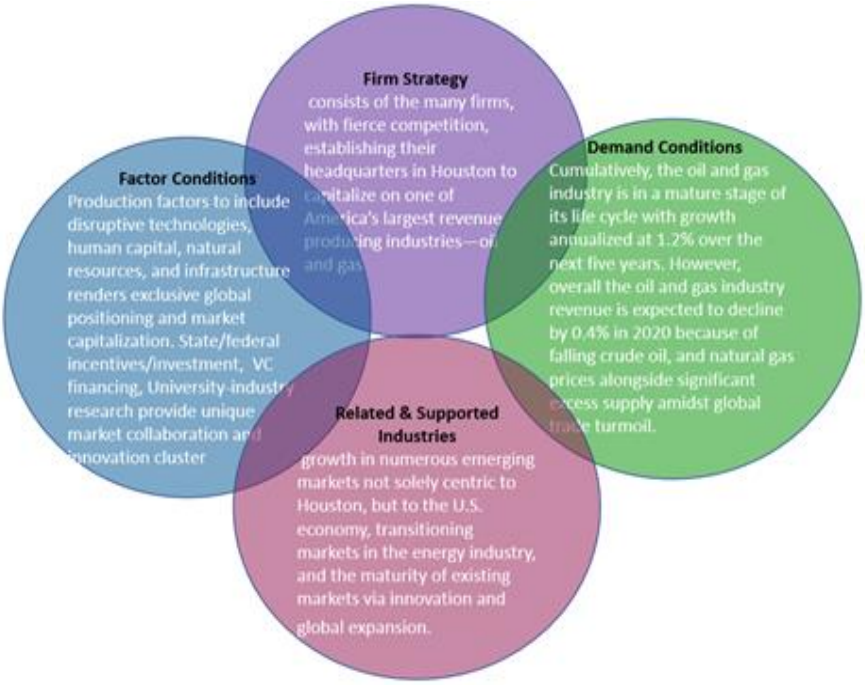


Figure 25: Houston's Energy Cluster Diamond Overview

Factor Conditions

The city of Houston's energy cluster derived from three interlacing historical events: the first oil discovery in 1901 in Spindletop, Texas, construction of the Houston Deepwater port in 1914, and 40 oil companies supporting the World War II petrochemical demand.[230] These input factors, along with other resource, legal, cultural, and educational inputs helped establish Houston as an energy cluster. Though Beaumont, Texas was initially a center of production for oil and gas, Houston's "superior communications, transportation and infrastructure" proved decisive as equipment manufacturing ramped up, and local families that formed the first large companies like Texas Oil Co., Gulf Oil, and Humble Oil relocated headquarters to the city starting in 1904.[231] Houston's history of geological oil exploration, deep-water port operations, and supply of oil and petrochemical products during World War II were also integral to the city's emergence as an energy leader.[232]

Oil and gas firms require experts across a range of disciplines. Figure 26 depicts the Houston area industrial complex and its conglomeration of industries within the concentrated cluster.[233] This wide range of knowledge lends itself to clustering of experts in a small area, as demand for expertise grows among firms. It also leads to the growth in educational institutions. With dedicated energy programs, Rice University and the University of Houston are critical to the industry's training, research, and development efforts. These university-industry partnerships, along with venture capital, global distribution infrastructure, and community and civic partnerships help facilitate the premier business and disruptive technologies in the energy industry. Houston's large foreign-born population share, 23.5 percent, enables workforce diversification and new ideas that are critical for increased innovation.[234]

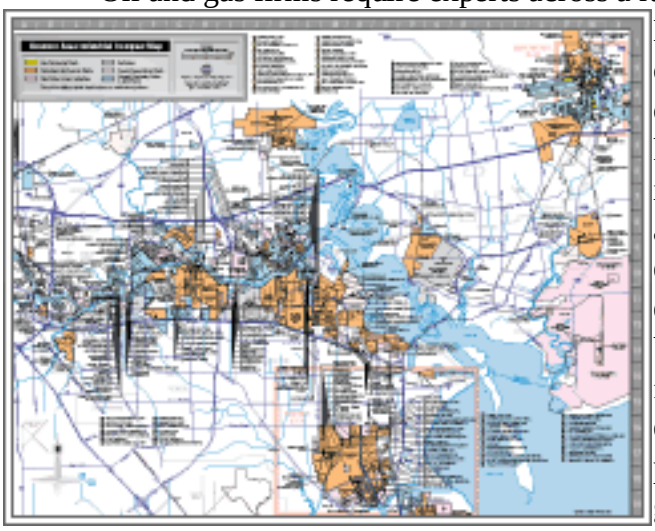


Figure 26 2019 Houston Area Industrial Complex Map

Federal, state, and local regulations were key factors that allowed Houston to flourish as the world's center of oil and gas development over the last century. The Railway Commission of Texas was arguably the most important regulatory body in the oil and gas space. Given authority over oil rates and "common carrier" access in 1917 and later expanded to natural gas, the commission's history of setting quotas, rates, and other regulatory functions was a model for the world.[235] This helped cement Texas, and by extension Houston, as world leaders in the regulatory approach to the industry. Local Houston culture has also had an impact, with "a broadly shared societal consensus among a majority of the population, rich and poor, favored oil development largely unrestrained by pollution controls."[236]

Houston's energy cluster relies on the continuous interaction of three major efforts: the City of Houston's trade associations, public-private partnerships (PPP), and community [237]

Houston is host to one of the largest trade associations in the nation to include the Greater Houston Partnership, Texas Board of Professional Engineers, Greater Houston Builders Association, ISM-Houston, Houston Bar Association, and AFP Greater Houston[238] These trade associations and PPPs provide a professional network forum for its members, who are predominately drawn from the Houston energy cluster to share knowledge and innovation.

Houston's often overlooked PPPs also help sustain the energy cluster. Center for Houston's Future (CHF) recognizes the changing demands across the energy sector and the implications for Houston. The non-profit Young Professionals in Energy (YPE) Houston provides a forum for networking and career development through social, educational, and civic service opportunities, promoting synergy outside of work. Other non-profits like United Way, local food banks, and disaster relief organizations allow the energy industry to re-invest in the local communities and build positive reputations that also help sustain the cluster. In 2018, ExxonMobil donated $211M worldwide ($74M U.S., $97M other countries, $41M gift sharing). They are also directly involved in the local community and they donated more than 443 thousand volunteer hours in 2018 to almost 3,600 charitable organizations.[239]

These factors not only helped Houston dominate oil and gas, but it also helped more recent expansion into other energy industry sectors. Once Houston came to dominate oil and gas, other related energy sectors soon followed. Across the upstream, midstream, and downstream production, oil and gas is heavy on energy requirements. Large utilities like CenterPoint Energy, Calpine, and NRG (dual-headquartered with Princeton, NJ) are headquartered in Houston. As utilities continue to branch into renewable generation sources, Texas as whole is uniquely positioned to manage its own energy as the Texas Interconnection functions as one of only three grids within the U.S.[240] This has led Texas as a whole and Houston in particular, to lead among renewable energy companies.

The city of Houston was one of the first cities to implement renewable energy standards, and it leads the U.S. with 92 percent of its energy coming from renewable sources.[241] Texas is well endowed with wind and solar sources of energy, and Texas is now number one in the U.S. in Wind and Biofuel production.[242] The Houston Technology Center has helped foster the development of over 300 technology companies, including many in the sustainable energy sector.[243]

Firm Structure and Rivalry

Houston's energy cluster encourages fierce competition and synergy that allows these local industries to leverage each other's expertise to continually improve the epicenter of America's oil and gas industry. Houston has endured many industry booms and bust cycles, but the city continues to endure with a large percentage of oil and gas company corporate headquarters,

"Houston is home to 44 of the nation's 128 publicly traded oil and gas exploration and production firms, including eight of the top 25 as ranked by 2017 total assets. Seven more among the top 25 have subsidiaries, major divisions or other significant operations in Houston, including ExxonMobil, Chevron, Hess and Murphy Oil".[244]

Houston is a headquarters city and the chief technical center for a global oil industry which has complementary compensation rates.[245] Phillips 66, ConocoPhillips, and Enterprise Product Partners are currently the largest U.S. oil and gas companies by market cap to locate their headquarters in Houston. Additionally, major international firms such as Royal Dutch Shell (RDS), British Petroleum (BP), and Saudi Aramco have their U.S. headquarters in Houston.[246] In 2017, Exxon Mobil Corp relocated employees of its subsidiary, XTO Energy, to the Houston cluster. Because of high real estate and capital start-up costs, consolidation within the energy industry is extremely high. With so many of oil and gas companies clustered in Houston, it is common to witness mergers and acquisitions involving Houston firms. For example, French-based oil explorer Schlumberger Ltd became the fourth largest employer in the city after acquiring Houston-based Cameron International Corp in 2016.

With so many corporate decision-makers, technical experts, and supporting industries in one location, the oil and gas cluster benefits from the effects of agglomeration, which enhances economies and scale and network effects. The cyclical nature of the industry and high-demand signal for low-cost energy necessitates constant innovation, such as in hydraulic fracturing, or fracking. Houston/Woodlands-based Mitchell Energy, whose founder, George Mitchell, became "the father of fracking," utilized local experienced geologists and engineers to develop and commercialize this technology, which re-vitalized Houston over the last decade.[247] Other firms within the cluster and industry soon followed, and the vast untapped shale reserves of the U.S. suddenly became accessible.

Companies inside the cluster have a competitive advantage in three areas: access to other companies specializing in energy, large numbers of skilled and specialized employees, and access to company-specific intelligence on oil markets.[248] ConocoPhillips' bottoms-up innovation leverages the ideas and expertise of their operational employees to gain market share and improve business operations.[249]

Within the renewables space, stalwart international oil and gas companies like Royal Dutch Shell (RDS) and British Petroleum (BP) not only maintain U.S. headquarters in Houston but also have large research facilities in the city dedicated to sustainable energy.[250] Though some cities in the U.S. have more renewable energy startups, Houston's niche is "businesses focused on implementing technology in large-scale projects."[251] This has often proven more profitable and sustainable from a business perspective, which will help industry during inevitable downturns and increase the number of firms competing in this space.

Demand Conditions

Houston's energy cluster benefited greatly from timing. Just as oil's discovery, refining, and distribution ramped up over a century ago, the automobile was gaining traction as an affordable and primary means of transportation. Population density in the U.S. was less also than other rich countries, leading to fewer public transportation options. Houston especially fits this mold as, "90 percent of all commuters in the city ride in cars."[252]

Gas taxes directed toward the construction of roads, most notably the Interstate Highway System in the 1950's, served to further the penetration of the car culture throughout the country

and especially in Texas. Houston is one of the largest cities by population, but also by land area. The Municipal Tax Act of 1963 helped the city annex cheap land around the city, expanding[253]

Development of the petrochemicals industry provided an additional growth driver for Houston's energy cluster. Petrochemicals are not only derived from fossil fuels, they also require a significant amount of energy to produce. With petrochemical feedstock in abundance, utilities needed vast and inexpensive sources of energy to help it compete. Growth in utilities and multiple sources of energy aside from fossil fuels allowed the renewables space to thrive. Also, with millions of miles of roads needed across the country, alternatives to concrete boomed. Demand for inexpensive asphalt derived from oil was a direct beneficiary of this requirement.

Related and Supporting Industries

Supporting industries initially surrounded oil and gas extraction but have expanded to other markets in the energy industry (Figure 27). Within the mature fossil fuel industry, there has been an increase in oilfield manufacturing and services companies that support energy extraction. Firms such as National Oilwell Varco, Schlumberger and Halliburton have developed a market that specializes in machinery and special metals fabrication.[254]

The petrochemical industry has initiated steps to become independent from the oil feedstock market by instituting a flexible commodity trading and risk-management system to source material predictive analysis and inventory reserves controls.[255] This also allowed the petrochemical sector to transcend oil and gas into its own independent energy-related cluster. Leading companies such as Dow Chemical and Exxon Mobil are developing advanced additive materials and byproducts to improve energy emissions efficiencies and ethane additives.

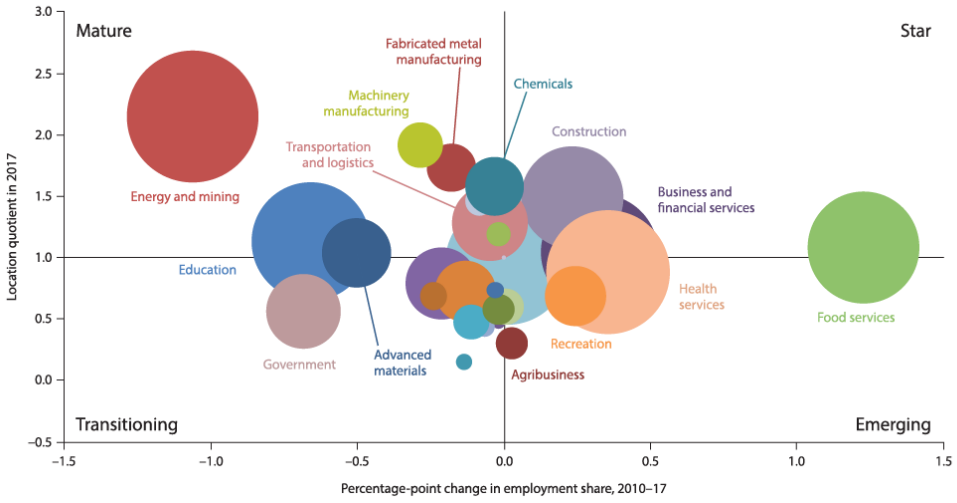


Figure 27: Houston's Energy Cluster Supporting Industries

Houston's transportation sector and healthcare services are two additional market clusters that emerged from the oil industry. Houston's sea commercial lines of communication and Houston Intercontinental airport are two major hubs in gross product export/ import transport [256] [257]

Additionally, the Houston energy cluster has led to the rise of auxiliary services such as the finance, banking, and merger and acquisition markets.[258] Houston has 23 companies from the Fortune 500 list to include all major financial entities supporting the Houston energy cluster.[259] The New York-based JPMorgan Chase & Company owns approximately 42 percent of the Houston banking's deposit market share, with over $109.97 billion, followed by San Francisco-based Wells Fargo & Co. holding about 11 percent of the deposit share, and Charlotte, North Carolina-based Bank of America Corps holding 10 percent of the deposit share equal to $23.7 billion.[260] The Houston cluster's financial auxiliary services are instrumental in providing the cluster's energy companies with the necessary capital, project financing, tax equity, and mergers & acquisitions for major exploration projects, upstream & downstream projects integration, and infrastructure development.[261]

APPENDIX B

Energy and Pandemics

The U.S. energy sector has been one of the largest economic casualties in the fight against the Coronavirus Disease 2019 (COVID-19). However, this is not the first time our energy sector has experienced a dramatic rise or fall in supply and demand. In the early 1970s, oil prices quadrupled during the oil embargo of the Arab-Israeli War.[262] Between 2005 and 2008, the price per barrel grew from $25 to $147 due to tensions in the Middle East, the value of the U.S. dollar, and increased Chinese demand.[263] The energy sector has also seen dramatic drops in energy use. During the 2008 financial crisis, the price of oil dropped from $150/barrel to $35/barrel,[264] caused by shrinking demand. During the COVID-19 pandemic, the price of oil dropped to negative $37/barrel, a historic low, based on an extreme supply surplus, estimated at 30 million barrels per day in excess oil, and a significant decline in demand due to travel restrictions impacting the automotive, airline, and cruise line industries.[265] The EIA also projects that prices for West Texas Intermediate (WTI) will remain below the five-year average (Figure 28).[266]

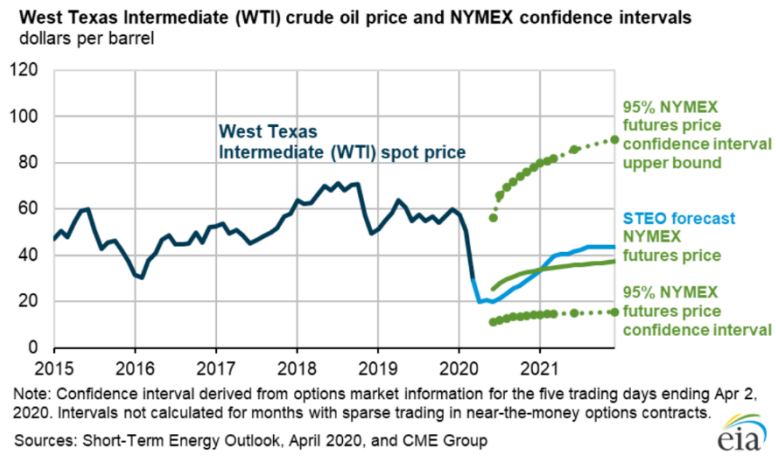


Figure 25: West Texas Intermediate (WTI) Crude Oil Price from EIA.gov Short Term Energy Outlook [245]

Oil and gas are not the only elements within the energy sector to experience pandemic disruption. Statista estimates residential use of electricity will have increased between 6-8 percent, while electricity demand from commercial and educational buildings will have decreased by 25-30 percent after final tabulations.[267] The coal industry had marginal impacts based on the reduced workforce caused by coronavirus outbreaks.[268] The solar and wind energy markets have experienced disruptions to the supply chain of renewables and likely maintenance delays due to travel bans.[269] [270] Nuclear power, as a baseload supplier, is likely the least affected energy source so far.[271]

The global crisis of energy over-supply and unprecedented decrease in demand caused by the COVID-19 pandemic, compounded by market flooding in an economic oil war between Russia and Saudi Arabia have caused competing opinions about where stimulus funds for COVID-19 relief should best be spent. Stimulus spending packages have become highly politicized with conservative and liberal sides arguing which energy industries, fossil fuel or renewables, are deserving of "bail-outs."[272] As of the beginning of May 2020, the initial three stimulus packages have not included funds for either renewable energy tax credits or legacy

fossil industries.[273] This politicization is unfortunate as it tends to over-simplify the ramifications of investing in one while neglecting the other, as well as over-emphasizing the significance of stimulus funds when market forces are likely to be the larger driving force in the ultimate outcome for the energy industry.

Prior to the COVID-19 crisis, the market trajectory for both renewables and fossil fuel industries was moving in a direction that was surprisingly acceptable to both. The high potential for loss of this positive momentum is causing each camp to circle its wagons. The development of U.S. horizontal drilling and fracking technologies for natural gas had the effect of dropping the global price for natural gas to historically low levels which, in turn, created a U.S. export market for LNG. The ability of the U.S. to export natural gas at reasonable prices made conversion from coal to cleaner burning natural gas economically feasible for many countries. It also provided a stable alternative source of energy for U.S. allies and partners to counter predatory pricing practices by Russian state-owned gas companies. This, in turn, forced Russia to make its gas prices transparent to compete on the global exchange.

In the U.S., the externality from exporting natural gas was that gas prices stayed low enough to compete with coal, but high enough to make renewable energy sources attractive for investment, even by traditional fossil fuel generating companies. This led to the reduction of global carbon emissions while allowing for sufficient time to develop additional renewable technologies that do not marginalize vulnerable people or disproportionately extract scarce resources. The COVID-19 crisis has shown us the importance and fragility of this balance. However, it is important to note that spreading stimulus investment over both fossil fuel and renewable industries is far more likely to return us to a path of decarbonization and global security than allowing either to decay.[274]

There are several potential geopolitical effects of the COVID-19 crisis related to the fossil, renewable energy balance. First, the global power balance during the last century has largely been decided by the availability of fossil fuels, something that has provided oil-rich countries tremendous influence.[275] A transition away from fossil fuels towards renewable energy sources could shift the power from the petroleum-producing countries to countries with the technology and materials to exploit and store renewable energy. China is well-positioned to become the world's main provider of renewable energy products and technology, heavily subsidizing these key industries.[276] The U.S. is also among the leading countries in renewables. However, government incentives must be sustained to compete with China. It is unclear whether the ongoing crisis is going to delay the world's energy transition, as many countries currently seem more focused on recovering their economies than pursuing low carbon and renewable goals. It may be tempting for the U.S. to prioritize the oil and gas industry as this could be beneficial in the short-term. However, it may be detrimental to U.S. global influence in the long run. The current situation could represent an opportunity for the U.S. to pursue energy dominance by utilizing the window of opportunity and implementing policies to pursue technological advantage in the renewable sector while maintaining its position in the oil and gas industry.

As described earlier, the pandemic has led to a decrease in energy demand and plummeting oil prices. Several fossil fuel dependent countries, including Iran, Iraq, and

Venezuela, are highly vulnerable to low oil prices and may have difficulties funding their government budgets, including their budgets for national security.[277] Hence, there is a danger of increased instability in these countries. This situation also represents an opportunity for other actors such as China, Russia, or the U.S. to increase their influence over these governments. Furthermore, reduced [278] Energy policy decisions in the wake of COVID-19 are likely to have large and lasting geopolitical impacts. Therefore, it is essential that the U.S. takes advantage of this situation to continue its influential global role post-COVID-19.

In summary, as COVID-19 ravages the world, the long-term impact to energy markets as it relates to national security is still uncertain. In the near-term, demand for worldwide energy has fallen dramatically, suppressing prices for nearly all energy commodities, and hurting energy producers. Low-oil prices may temporarily cause U.S. shale oil and gas producers to slow their production or in some cases to go out of business. However, these may be short-term impacts. Looking further out to the five to ten-year horizon, it is not clear that the pandemic by itself will significantly change the balance of power between the U.S., China, and Russia as it relates to energy. Furthermore, COVID-19 does not change the long-term macro-trends of decarbonization, renewable technology adoption, climate change, American energy abundance, or growing Asian demand. However, the U.S. could leverage this opportunity to reshape future energy markets with a strategic investment in renewable technology while doing what is necessary to keep current fossil fuel producers solvent to meet near term demand. Only through balanced post-COVID-19 investment choices will the U.S. fulfill its destiny of energy dominance and ensure energy security for the nation.

APPENDIX C

Energy Industry Five Forces Analysis

In 1979, Dr. Michael Porter published "How Competitive Forces Shape Strategy" in the Harvard Business Review.[279] These competitive forces (Bargaining Power of Buyers, Bargaining Power of Suppliers, Threat of New Entrants, Threat of Substitutes, and Rivalry among Competitors) have become the standard for conducting analysis of industry profitability and performance. Understanding the basic business context of the U.S. energy industry is an important initial step prior to evaluating it in the economic, security and diplomatic realms. Though typically used to evaluate a firm's strategic position at the microeconomic level, applying Michael Porter's Five Forces Framework (Figure 29) to the U.S. energy industry provides several key insights into its structure, strengths, and vulnerabilities. The industry is extremely diverse with upstream and downstream impacts touching every corner of the domestic and worldwide economy. For purposes of this analysis, the industry will be segmented into three end-use consumption categories: residential/commercial, transportation, and industrial. Understanding the competitive forces, and their underlying causes, reveals the roots of an industry's current profitability while providing a framework for anticipating and influencing competition (and profitability) over time.[280] The energy industry consists of many firms operating across multiple industries, sectors, markets and countries. This appendix provides an overview of the competitive forces that drive some of the most prominent sectors of the energy industry.

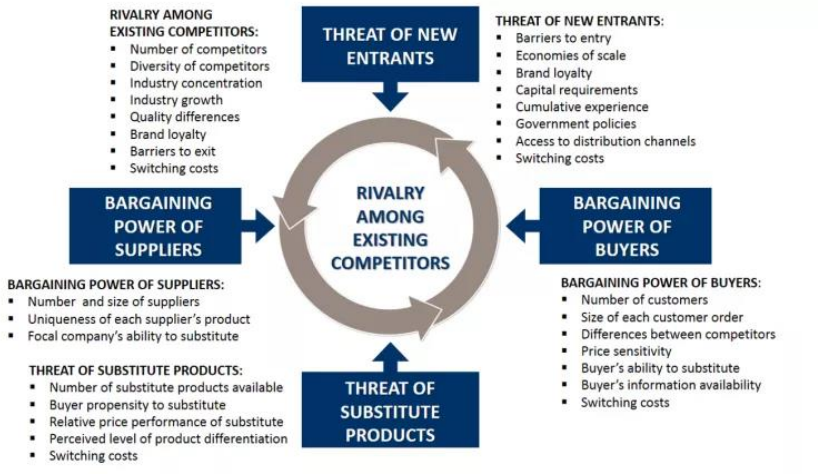


Figure 29: Porter's Five Forces Framework

Residential/Commercial: The U.S. residential and commercial sectors used 28 percent of U.S. energy consumption in 2018, most of which was sourced from electricity (45 percent) and natural gas/heat (40 percent). Natural gas as a source comprises over 50 percent of this end-use when considering it makes up 35 percent of electricity production.

1) Rivalry Among Existing Competitors is generally low and dominated by large electric utilities who are often regionally based and act as quasi-governmental entities. Electricity and heat are public goods, so government oversight and regulations limit profit potential.
2) Threat of New Entrants is low since economies of scale are paramount, limiting the ability of new entrants to overcome bureaucratic hurdles and established providers' advantages. Mergers and acquisitions are the primary means by which energy providers expand across regions.
3) Bargaining Power of Buyers is low to moderate depending on consumption volume. Even

with more options and information available for distributed renewable power over the past decade, monopolistic or duopolistic energy providers dominate this market due to high fixed costs and economies of scale. Switching providers is usually not possible in most markets, leading to significant government intervention and regulatory oversight.
4) Bargaining Power of Suppliers ranges from low to high for this end-use. Electricity is generated from diverse sources, many using highly specialized materials, equipment, and supply chains to generate and transport electricity to end users. Vendors of items as distinct as transformers to uranium are required, each with varying levels of market power. Natural gas suppliers have low power, but some renewable energy suppliers are gaining power as state and federal mandates increase required generation using this method.
5) Threat of Substitutes is low but growing quickly as renewable sources such as wind and solar enjoy subsidization as well as a reputation as cleaner and better for the environment than traditional sources. Distributed, on-site generation from individual homes to large commercial facilities provides a growing threat to utilities and traditional providers.

Transportation: The transportation security consumed 28.3 quadrillion British Thermal Units (QBTUs) (37 percent of total energy) in the U.S. in 2018. Transportation is almost entirely powered by oil, with 92 percent of energy inputs derived from it. U.S. transportation costs have benefited from the near tripling of oil production over the past 15 years, along with increased production from border countries.

1) Rivalry Among Existing Competitors is moderate to strong. The market is oligopolistic with increasing rivalry. The Organization of Petroleum Exporting Countries (OPEC) cartel has weakened and fractured in recent years as large multi-national firms leverage new technology and superior business management skills to keep the world awash in oil.
2) Threat of New Entrants is moderate, as fracking, and other technological improvements enable firms to recover reserves from uneconomical locations. Equipment, regulatory, and real estate costs are prohibitive allowing only well-capitalized countries/ firms to compete
3) Bargaining Power of Buyers is low due to the domination of oil as a feedstock. Consumers are generally price takers with commoditized fossil fuel prices set on the world market. U.S. fracking has upended the traditional domination of OPEC nations, providing lower prices.
4) Bargaining Power of Suppliers is also low, mostly due to increased globalization and the commoditization in key supplier markets like construction, steel, and manufacturing. Water scarcity has recently been subjected to the market forces.
5)Threat of Substitutes for oil's use in transportation is growing, but still comprises just a small portion of the overall market. Not likely feasible for air and seaborne transportation soon, alternatives are growing in the ground market. Natural gas vehicles lack a nationwide infrastructure to support refueling. Electric vehicles have improved greatly over the last decade, but still lack key features like quick recharging, secure supply chains, and infrastructure to penetrate the market quickly. Environmental regulations continue to be a key driver

Industrial: Per the Energy Information Administration (EIA), the industrial sector uses more energy worldwide (54 percent) than the other end uses combined, but within the U.S. it comprises only 26.3 QBTUs (35 percent) of end use. This is a testament to both the relative energy efficiency of U.S. industrial users and the outsourcing of certain energy-intensive

industries to other countries. Industrial use experiences slightly more balanced input from sources, but oil (34 percent) and natural gas (40 percent) provide the lion's share.
1) Rivalry Among Existing Competitors is higher than other sectors as providers compete for large contracts with high-volume users. Industrial users like steel producers use millions of dollars' worth of energy per year, and require stable, consistent supply.
2) Threat of New Entrants is extremely low as industrial users typically have specific needs that require economies of scale to deliver reliability and cost-effectiveness. Like other end-uses, large established players are well-capitalized with supporting infrastructure and supply-chains.
3) Bargaining Power of Buyers is moderate depending on consumption levels of users. Large farming consortiums and steel smelters have high power due to volume, but smaller players are likely price takers.
4) Bargaining Power of Suppliers is generally low. As oil and natural gas supplies in the U.S. have proliferated across the country, suppliers of equipment and land ownership have less power to raise prices.
5) Threat of Substitutes is low and increasing less than other sectors. Renewables already comprise around 10 percent of feedstock, but increased penetration is more difficult due to concentrated power requirements.

Global Exploration of Oil and Gas Market

The oil and natural gas exploration market is a commercial market that is tightly coupled with the production market because successful exploration leads into production. It involves global players and encompasses many regions throughout the world. However, the market is mainly dominated by countries in three main regions: Saudi Arabia in the Middle East, Russia in Europe, and the United States in North America—which is due in large part to the accessibility of oil and gas reserves in these areas.[281]

Countries that participate within the universe of **sellers** in this market offer varying degrees of exploration opportunities depending on several factors, including a country's needs, the size of their reserves, regulations, and ability for exploring companies to meet these. While some countries such as Saudi Arabia, Iran, and Venezuela have chosen to nationalize their markets and maintain tight controls, limiting investment by outside corporations, others are more open to outside investment.[282] The power of sellers in the exploration market is strong since they hold the power to approve or disapprove a company's ability to explore in their country by the granting of exploration licenses.[283] This relationship between the selling countries and the exploration companies can be a win-win for both parties when they agree to partner by establishing contracts.

The universe of buyers is vast for oil or gas and is also made up of international players across the globe. The **power of buyers** is strong. For example, China is expected to be Russia's main growth market for oil and gas exports.[284] As such, it is focusing on exploration in the East Siberian region.[285] Demand from buyers in Europe is strong as evidenced in the agreement between Germany and Russia to build the Nord Stream 2 pipeline, which has a potential to double capacity.[286]

Unusual or significant rules, under which the market operates includes license requirement for oil and gas exploration activities already mentioned as well as environmental requirements imposed by sellers.[287] These factors signal the up-front risks that exploration companies must take into consideration before they can potentially reap the benefits of the extraction of resources. **Substitutes** have to do with the type of exploration that a company chooses to invest. Browning exploration is exploration conducted close to or adjacent to a field that has already been productive, thereby lowering the risk of discovering no resources.[288] This type of exploration significantly reduces the need for large amounts of additional capital, since equipment and facilities needed for these efforts are already near the new site.[289] Greenfield exploration, however, focuses on finding resource deposits in previously unexplored areas.[290]

The nature of **competition** in the market is one with a significant number of competitors in this world-wide market, the current global market is heavily saturated with a handful of well-established companies which have long-held relationships with customers.[291] On a global scale, domination by a few companies, significant barriers to entry, and a mostly undifferentiated product—signal that this form of competition most resembles an oligopoly. Four large companies bring in 20 percent of total revenues in the oil and gas exploration and production market; these are ExxonMobil, Chevron Corporation, BP, and Royal Dutch Shell.[292]

Gas exploration is considered a risky business because the initial investment is high. For example, substantial capital, expertise, and time are required to locate potential oil and gas fields. Further, there are no guarantees that once a potential source is discovered, the company will recoup all its costs—let alone make a profit.[293] Thus, **threat of new entrants** is low in the exploration market. Additionally, as previously discussed, a company must be able to meet all regulations imposed by governments in the countries of exploration.

Oil Drilling and Gas Extraction Market in the U.S.

The Oil Drilling and Gas Extraction market in the U.S. is a segment of the larger market of global oil drilling and gas extraction. According to IBIS Energy Advisors, "Companies in this industry operate and develop oil and gas field properties."[294] This market is segmented from the larger global oil market by only including firms that explore, develop and extract oil and natural gas fields in the U.S and territorial waters. This market includes the drilling and extraction and sale of oil and natural gas. Oil and natural gas can be found at the same locations; however, recent technologies have opened locations that were exclusively natural gas.

The major **competitors** in this market compete are in an oligopoly competition. Although there are 7,633 firms operating in this market, six firms represent 23 percent of the total market share.[295] The top competitors by market share include Chevron Corp (6.5 percent of the market), ExxonMobil (5.2 percent), BP (4.8 percent), Conoco Phillips (4.5 percent) and Devon Energy Corp (2.4 percent). Firms in this market produce revenue by selling the oil and gas extracted from the ground.

The force of competitors on market profitability is high. Competitors must develop brand and quality recognition to operate effectively and expand market share. Additionally, firms such as ExxonMobil are well postured to compete in this market because they are vertically integrated

throughout all aspects of the oil and gas industry (exploration, upstream, downstream, and chemical refinement operations).

This market has a low-level threat of **new entrants**. Participation in this market is capital intensive and requires economies of scale to offset high start-up costs.[296] **Buyers** have moderate power in this market. Current buyers include firms that generate electricity (utilities), countries (exports), industrial companies, and refinement industry companies, many of which are integrated in the oil and gas extraction market. Buyers in this market generally purchase large amounts of oil and gas using robust, long-term contract agreements, the contract lengths (long term) and large purchase quantity embolden buyer power.[297]

Suppliers have a large amount of power over market revenue and the participating firms' profit. Suppliers include landowners, governments, service providers, hardware manufacturers, pipeline operators and global supply commodity markets. The extreme variance of supplier participants creates challenges for market participants, which provide supplier power over this market. Access to land, government regulations and taxation as well as global supply speculation can cause increases in costs for extraction firms.[298]

The threat of **substitutes** in this market is moderate. Substitutes include alternate sources of energy (solar, wind, water, geothermal, etc.). Overtime, alternate sources of energy are expected to increase global energy production market share and create downward pressure for oil and natural gas. However, this is not anticipated to offset the global demand for productivity expansion, so long-term demand for oil and gas is forecasted to increase through 2040.[299] Social environmental activism is expected to contribute to the increase in alternative energy sources. This may lead to further competition of substitutes.[300]

The overall assessment of Porter's Five Forces challenges profitability due to the power of competitors and buyers. Large, integrated firms that operate in multiple sectors of the industry achieve higher profits by controlling the extraction, shipment, and refinement of the products, thereby increasing firm profitability.

Global Trade in Liquefied Natural Gas Market

Liquefied natural gas (LNG) is, "natural gas that has been cooled to a liquid state, at about -260° Fahrenheit, for shipping and storage."[301] LNG can be safely transported by ship or truck, therefore increasing access to natural gas around the world.[302] By greatly expanding the reach of natural gas, global trade for LNG is a growing commercial market. LNG trade increased for five consecutive years, from 2014 – 2018, and experienced 9.8 percent growth from 2017 to 2018.[303] The boom in the global market for LNG has significant drivers, on both the demand side and the supply side.

The nature of LNG trade **competition** is an oligopoly with high rivalry among competitors. This structure causes LNG producers to capture more of the economic surplus than [304]. Out of the 19 countries that exported LNG in 2018, the top LNG exporting countries are: Qatar, Australia, United States, Malaysia, and Russia. There is a mix of private and state-owned companies. For example, Qatar has a state-owned company; Australia and U.S. have private

companies. The leading U.S. companies in LNG are: Shell, Cheniere, ExxonMobil, Total, and Chevron. With proposed projects around the world exceeding forecasted demand, early movers in adding liquefaction capacity have an advantage.

The threat of **new entrants** is low due to high cost of entering the market, however, there is a low ease of market entry because there are few firms and the product is identical.[305] Increased global demand for natural gas makes LNG trade an attractive market. Entering the LNG market is capital intensive, and there is a high cost for infrastructure and heavy regulations. Major energy corporations have greater access to markets due to name recognition/longer operating histories, greater financial, technical and marketing resources.

Threat of Substitute products is medium due to the increasing use of renewables. Additionally, product differentiation of substitutes is significant: natural gas is cleaner than coal and can be paired with other renewable forms of energy. There is a high cost of switching from one energy source to another, the cost to build new or expand capacity at natural gas plants is high, as is the cost to convert existing coal plants to gas. The development of renewals is occurring but not at a rapid pace.

The bargaining power of **suppliers** is low due to a robust supply of LNG available due to hydraulic fracking. There is a current over supply of natural gas which leads to market price drops. The glut in the market giving suppliers no negotiating power, and if the price continues to fall, it could halt drilling to decrease supply. There are long term supply agreements tied to spot LNG prices which helps stabilize the market. Additionally, in some cases supplier flair export-sized quantities of gas because it is cheaper to discard the resource than it is to transport it.

The bargaining power of **buyers** is high due to excess supply, which creates lower prices. Although LNG demand has been growing, supply is growing faster, significantly reducing prices world-wide. Buyer power has increased throughout the market; buyers are not willing to lock in current "high" rates as prices are expected to fall. Buyers are then seeking short term contracts and avoiding "take or pay" agreements.

Despite the increasing number of LNG exporters, the market is still dominated by a few, with the top two being Australia and Qatar. LNG exporting countries comprising almost half of the market share, and the ongoing dominance of large energy companies.[306] Another barrier to entry is the environmental and trade regulations specific to natural gas in each country. These regulations address negative externalities such as environmental and safety concerns, as well as the trade relationships between countries. For example, U.S. LNG regulators include the Department of Energy, the Federal Energy Regulatory Commission, the Department of Transportation, the U.S. Coast Guard and the Department of Homeland Security.[307]

Electricity Distribution in the U.S.

Electricity is readily accessible and mostly reliable. According to the World Bank in 2017, 100 percent of American households had access to electricity.[308] However, electricity is a complex necessity that navigates three separate steps before a customer consumes it. Step one is generating electricity from primary sources. Step two is transmitting high-voltage electricity

long distances from the generation source. Step three is distribution. During distribution, transformers step-down high-voltage electricity onto local power lines. These low-voltage lines deliver electricity to the end-user.

The electricity distribution market is part of a complex web and characterized by multiple interdependencies. Physically, utilities are dependent on poles, wires, transformers, and many other supply chain items to erect the local distribution network. As previously stated, electricity distribution is the last step in delivering electricity to the customer. Therefore, it is dependent on primary energy sources. It is dependent on power plants to convert the primary energy into electricity. It is also dependent on the transmission market to send high-voltage electricity to local substations. The market is also dependent on Independent Service Operators and Regional Transmission Organizations. Simply put, these entities control and monitor the three regional electric grids within the United States.[309] Finally, the North American Electric Reliability Corporation (NERC) and Federal Energy Regulations Commission (FERC) are key participants as well. They do not regulate the distribution market directly, but their upstream actions certainly have an impact downstream.

Electricity is unique since consumers are dependent on local distribution lines to provide electricity, that is, unless they decide to go "off the grid" and generate their own electricity. Additionally, electricity distribution is a dual-use market.

Electricity distribution has numerous **sellers**. According to the Department of Energy, more than 3,200 electric utilities distribute electricity to 145 million households.[310] These utilities come in many forms, ranging from traditional for-profit investor owned utilities like Exelon or Dominion, non-profit municipal power companies, non-profit co-ops, federal power programs such as the Tennessee Valley Authority, and independent power producers that sell to utilities or directly to the end-user.

Electricity distribution has several **buyers** as well. According to IBISWorld, the largest group of buyers is residential customers representing roughly 46 percent of the customer base. Additional buyers consist of the commercial sector (37 percent), industrial sector (17 percent), and the transportation sector at a miniscule percentage.[311]

The **threat of substitutes** is low due to the heavy regulations surrounding the electricity distribution market. The federal and state levels regulate the overall energy industry and electricity sector. The electricity distribution market is regulated at the state level by a public utility commission (PUC).[312] PUCs set utility rates to account for operating expense, depreciation and amortization, taxes and return on invested capital.

Competition within the electricity sector is a complicated topic; the electricity transmission market is an oligopoly dominated by a few major companies; electricity distribution is on the other end of the spectrum. It is essentially a natural monopoly at the local level. One utility owns the power lines and residential customers are dependent on those local distribution lines to consume electricity.[313] Paradoxically, most customers today have the choice to purchase electricity from another transmission source, or even another utility company, but they must still use local distribution lines owned by a single company. Additionally, since most utilities operate

in local and regional markets, market concentration is low.[314] The four largest utilities dominate regional markets, but only account for about 20 percent of total revenue.[315] Finally, there is a remarkably high **barrier to enter** the market due to infrastructure cost.

Across the energy universe, Porter's Five Forces framework provides a useful lens through which to view market participants' actions. However, as previous sections in this paper highlighted, business interests are only one aspect of energy's many considerations.

APPENDIX D

Individual Energy Industry Study Papers

"China's Energy Diplomacy: Weaponizing its Natural Resource Acquisition Strategy"
Lieutenant Colonel Gerard Acosta, US Army

"The Duality of Coal: Dirty, But Potential For a Long and Bright Future"
Lieutenant Colonel Stephen G. Anderson, U.S. Air Force

"Energy Crime Terrorism - Nexus"
Ms. Kathleen M. Donahue, U.S. Department of State

"Department of Defense Microgrids"
Colonel Crystal M. Hills, U.S. Army

"U.S. Electrical Grid"
Colonel Christopher A Jarratt, U.S. Air Force

"Energy Considerations for US National Security Strategy in an Era of Great Powers Competition"
Lieutenant Colonel Mason Edwin MacGarvey, US Air Force

"The U.S. Energy Transition - Not So Fast"
Lieutenant Colonel Michael Mai, U.S. Army

"The U.S. Nuclear Chess Game: Leveraging Small Modular Reactor (SMR) Technology to Enhance U.S. National Security and Diplomacy"
Captain JaJa Joe Everton Marshall, U.S. Navy

"Nanotechnology in the Energy Sector"
Mr. Daniel S. Martinez, U.S. Department of Defense, CIV

"Energy Diplomacy: An Instrument of Power in the Baltics"
Lieutenant Colonel Phillip Radzikowski, U.S. Army

"The Water-Energy-Food Nexus and U.S. National Security"
Ms. Diane E. Ray, U.S. Agency for International Development.

"Cyber Issues in Energy—Protection of the U.S. Electrical Grid"
Lieutenant Colonel Edna Rodriguez, US Marine Corps

“Paradigm Change: What is Mobilization Now? 21st Century Freedom Can't Be Shaped Using the 20th Century Forge”
Commander Jarrod H. Smith, U.S. Navy

“Artificial Intelligence in the Energy Sector”
Ms. Brena M. Starr, U.S. Department of Defense, CIV

“Natural Gas – The Potential to Provide Energy Security to Allies and Partners”
Colonel James M. Swartz, U.S. Army

“Dire Straits - The Tyranny of Geography - Small Spaces, Small Countries”
Dr. Lesley Wilhelm, U.S. Department of Defense, CIV

“Hydropower”
Colonel Karel Navratil, Land Forces Command of the Czech Armed Forces

“The Dependence of the Polish Economy on Natural Resources and the Russian Energy Transport Infrastructure”
Colonel Krzysztof Kociuba, General Command of Polish Armed Forces

“The Conflict over Natural Gas in the East Mediterranean region”
Colonel Georges Rizkallah, Lebanese Armed Forces

“Energy Storage”
Captain Connie Stien, Royal Norwegian Navy

APPENDIX E

Acronyms

AI:	Artificial Intelligence
ANG:	Air National Guard
ARPA-E:	Advanced Research Projects Agency-Energy
BP:	British Petroleum
BRI:	Belt and Road Initiative
BUILD Act:	Better Utilization of Investments Leading to Development Act of 2018
CAPT:	Captain
CBA:	Cost-Benefit Analysis
CCUS:	Carbon Capture Usage and Storage
CDR:	Commander
CHF:	Center for Houston's Future
COL:	Colonel
COOP:	Continuity of Operations
COVID-19:	Coronovirus Disease 2019
DA:	Department of the Army
DC:	Direct Current
DIA:	Defense Intelligence Agency
DIME:	Diplomacy, Information, Military, and Economics
DLA:	Defense Logistics Agency
DON:	Department of the Navy
DOD:	Department of Defense
DOE:	Department of Energy
DOS:	Department of State
EBC:	Eastern Bloc Countries
EGS:	Enhanced Geothermal System
EI:	Energy Industry
EIA:	Energy Information Administration

EMP:	Electric Magnetic Pulse
ES	Eisenhower School
ESCLS	Energy Supply Chains and Logistics Strategy
EU	European Union
EX-IM	U.S. Export-Import Bank
FDI	Foreign Direct Investment
FERC	Federal Energy Regulatory Commission
GDP	Gross Domestic Product
GG	Government Grade
GIO	Globally Integrated Operations
GPC	Great Power Competition
GS	General Schedule
GW	Gigawatt
IGCC	Integrated Gasification Combined Cycle
IoT	Internet of Things
IP	Intellectual Property
IT/OT	Information Technology/Operational Technology
LNG	Liquefied Natural Gas
LTC	Lieutenant Colonel
LtCOL	Lieutenant Colonel
MIT	Massachusetts Institute of Technology
MW	Megawatt
NADR	Nonproliferation, Antiterrorism, Demining, and Related programs
NATO	North Atlantic Treaty Organization
NDAA	National Defense Authorization Act
NDS	National Defense Strategy
NDU	National Defense University
NECPA	National Energy Conservation Policy Act
NERC	North American Electric Reliability Corporation
NIST	National Institute of Standards and Technology

NNI	National Nanotechnology Initiative
NRECA	National Rural Electrical Cooperative Association
NSC	National Security Council
NSS	National Security Strategy
OEM	Original Equipment Manufacturer
OPEC	Organization of Petroleum Exporting Countries
PPE	Personal Protective Equipment
PPP	Public-Private Partnerships
PUC	Public Utility Commission
QBTU	Quadrillion British Thermal Unit
RDS	Royal Dutch Shell
ROWPU	Reverse-Osmosis Water Purification Unit
SCA	Supply Chain Analysis
SCRM	Supply Chain Risk Management
SMR	Small Modular Reactor
SWaP	Space, Weight, and Power
Tcf	Trillion Cubic Feet
U.S.	United States
USA	United States Army
USAF	United States Air Force
USMC	United States Marine Corps
USN	United States Navy
USAID	United States Agency for International Development
WEF	Water-Energy-Food
YPE	Young Professionals in Energy

APPENDIX F

List of Figures with Sources

Figure 1: U.S. Primary Energy Overview, 1950-2019
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Figure 3: Energy Consumption by Source, World 1965-2018
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