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Industry Study Report

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 2017

Abstract: Recent developments and advancements in the domestic energy sector have greatly enhanced U.S. energy security. Newfound access to vast oil and natural gas reserves made possible by advances in hydraulic fracturing technology, the rapid expansion of power generation from renewable energy sources, and improvements in energy efficiency are providing American's with unprecedented access to abundant, reliable, and affordable energy. Nevertheless, the lack of a coherent national energy strategy, flawed energy markets, and aging infrastructure pose an acute risk to future U.S. energy security. To address these risks, the U.S. must pursue four key imperatives to preserve U.S. long-term energy security.

The United States must…

- ***Imperative 1:*** Employ diverse energy solutions
- ***Imperative 2:*** Modernize and expand its energy infrastructure and distribution system
- ***Imperative 3:*** Maintain a competitive advantage in technological innovation
- ***Imperative 4:*** Develop a new energy strategy that increases energy security, bolsters foreign relations, and strengthens its economic base

Colonel Nasser Alqahtani, Saudi Arabia National Guard
Mr. Louis Crishock, Department of State
Colonel Brian Gross, U.S. Air Force
Commander Matthew Holman, U.S. Navy
Colonel John Hudson, U.S. Army
Lieutenant Colonel Matthew Ketchum, U.S. Army
Ms. Michelle Kim, Department of Justice
Ms. Jessica Kirk, Department of Defense
Colonel Stephen MacDonald, Canadian Army
Mr. Gregory Moritz, Department of Defense
Mr. Peter Neville, Department of Homeland Security
Mr. Christopher Robinson, Defense Acquisition University
Lieutenant Colonel Robert Sherwood, U.S. Marine Corps
Lieutenant Colonel John Stratton, U.S. Air Force
Mr. Timothy Watts, Department of State

Captain Bill Johns, U.S. Navy, Faculty Lead
Dr. Paul Sullivan, National Defense University, Faculty
Ms. Susan Norwood, National Defense University, Faculty
Lieutenant Colonel Eric Weis, U.S. Army, PhD, Faculty

Industry Study Outreach and Field Studies

On Campus Presenters:
Advanced Projects Research Agency – Energy, Washington, DC
American Petroleum Institute, Washington, DC
American Wind Energy Association, Washington, DC
Citizens for Affordable Energy, Washington, DC
Geothermal Energy Association, Washington, DC
National Hydropower Association, Washington, DC
National Mining Association, Washington, DC
National Nuclear Security Administration, Washington, DC
Peabody Energy, Inc., Washington, DC
Strategic Marketing Innovations, Inc., Washington, DC
The Institute of Energy Economics – Japan, Tokyo, Japan
The Stella Group, Ltd., Washington, DC
U.S. Congressman, U.S. House of Representatives, Washington, DC
U.S. Energy Information Agency, Washington, DC
Veeco Instruments, Inc., Plainview, NY

Field Studies – Domestic:
Alpha Omega Winery and Microgrid, St. Helena, CA
Alveo Energy, Santa Clara, CA
Atlantic Council, Washington, DC
Congressional Research Service of the Library of Congress, Washington, DC
CONSOL Energy Marine Terminal, Inc., Baltimore, MD
Dominion Power North Anna Nuclear Power Plant, Mineral, VA
Embassy of Canada, Washington, DC
Embassy of Japan, Washington, DC
Embassy of Mongolia, Washington, DC
Exelon Conowingo Hydroelectric Generating Station, Darlington, MD
Exelon Perryman Oil & Gas Generating Station, Perryman, MD
Exelon Perryman Solar Farm, Perryman, MD
Exelon Trading Floor, Baltimore, MD
Facebook, Menlo Park, CA
Kinder Morgan Rail Terminal, Baltimore, MD
Lawrence Livermore National Laboratory, Livermore, CA
Maryland Energy Administration, Baltimore, MD
National Security Council, Washington, DC
Northern California Power Agency Geothermal Power Plant Facility, Middletown, CA
PJM Interconnection, Audubon, PA
Stanford University Structures and Composites Laboratory, Stanford, CA
University of California, Berkeley, Institute of Asian Studies, Berkeley, CA
U.S. Department of State, Washington, DC
U.S. National Security Council, Washington, DC
Wheelabrator Technologies, Inc., Waste-to-Energy Facility, Baltimore, MD

Field Studies – International:

Fujisawa Sustainable Smart Town, Kanagawa, Japan
Hamaoka Nuclear Power Station, Shizuoka, Japan
Idemitsu Bulk Terminal, Chiba, Japan
Isogo Clean Coal Power Plant, Kanagawa, Japan
Iwatani Corporation Hydrogen Station and Toyota Showroom, Tokyo, Japan
Kawasaki Eco Life Museum and Mega Solar Plant, Tokyo, Japan
Meeting with Graduate of Colorado School of Mines on Refinery Projects in Mongolia, Ulaanbaatar, Mongolia
Meeting with Representatives from Clean Energy Company and Engie Company, Ulaanbaatar, Mongolia
Meeting with Senior Researcher at Institute of Strategic Studies on Mongolia's Foreign Policy, Ulaanbaatar, Mongolia
Ministry of Economy, Trade and Industry, Tokyo, Japan
Ministry of Energy, Ulaanbaatar, Mongolia
Ministry of Mining, Ulaanbaatar, Mongolia
Mongolian National Defense University, Ulaanbaatar, Mongolia
Tokyo Gas LNG Terminal, Chiba, Japan

But of one thing we can be pretty certain: The world's appetite for energy in the years ahead will grow enormously. The absolute numbers are staggering. Whatever the mix in the years ahead, energy and its challenges will be defining for our future.

–Daniel Yergin, *The Quest: Energy, Security, and the Remaking of the Modern World*

Introduction

The global energy industry is beset with paradoxes which make constructing a national energy policy problematic. In the industrialized world, the development and sustainment of energy resources for agriculture, transportation, electricity generation, and both industrial and residential use are inextricably linked to the development of a modern society and prerequisites for status as a developed nation. To an ever-increasing extent, the quest to provide an adequate supply of energy to meet a growing global demand "is the lifeblood of the global economy."[1] Yet, despite the benefits, comforts, and wealth manifest through the development and maturation of energy resources, the production and use of our global reserves can also have negative impacts.

> Changes in price can tip economies into recession or bolster economic growth. Revenue windfalls can enrich nations or be a curse that feeds corruption and weakens economies. Energy is a source of geopolitical influence, but also vulnerability. It can motivate conflict or cooperation. Energy keeps food and medicine refrigerated; illuminates the night for study, safety, and work; enables global transportation and communications. Yet it can also despoil the air we breathe and the water we drink, as well as harm our lands and oceans.[2]

The ability to move society and civilization forward through the responsible development and use of globally shared, finite, and precious energy commodities requires trade-offs. It requires asking tough questions, and making even tougher choices, while navigating a dynamic and volatile geostrategic environment as well as uncertain political and regulatory environments.

As a highly developed and industrialized nation, the U.S. is a global leader in the production and supply of energy. Surpassed by China in 2009, the U.S. is currently the second largest producer of energy, producing 2.20 thousand Mtoe (Million Tonnes of Oil Equivalent – See Glossary) per year (Reference Figure 1). Similarly, it is no surprise the U.S. is also a voracious consumer of energy. Behind only China in this category as well, the U.S. consumes around 1.54 thousand Mtoe per year (Reference Figure 2). Described in different terms, in 2014 the International Energy Agency (IEA) estimated the "world total primary energy consumption was about 539 quadrillion British thermal units (Btu), and U.S. primary consumption was about 98 quadrillion Btu, equal to 18% of world total primary energy consumption" (Reference Figure 3).[3]

Recent developments and advancements in the domestic energy sector have greatly enhanced U.S. energy security. Newfound access to vast oil and natural gas reserves made possible by advances in hydraulic fracturing technology, the rapid expansion of power generation from renewable energy sources, and improvements in energy efficiency are providing American's with unprecedented access to abundant, reliable, and affordable energy. Nevertheless, the lack of a coherent national energy strategy, flawed energy markets, and aging infrastructure pose an acute risk to future U.S. energy security. To address these risks, the U.S. must pursue four key imperatives to preserve U.S. long-term energy security.

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To achieve these four imperatives, the U.S. must implement a series of associated policy recommendations discussed in depth throughout the last half of this report.

To arrive at these conclusions and recommendations, this report will first provide context by defining the energy industry and explaining the importance and components of energy security. Next, it will provide a broad overview of the landscape and current condition of the energy industry by looking at domestic nonrenewable fuel sources, domestic renewable fuel sources, key domestic enablers for the energy industry, and vital international partnerships and opportunities the U.S. must preserve. After establishing a firm foundation in the basics of the energy industry, the report articulates the results of a Force Field analysis conducted on the four imperatives using a STEEP (Social, Technological, Economic, Environmental, and Political) methodology to derive specific policy recommendations the U.S. must implement to ensure its long-term energy security.

Energy Industry and Energy Security Triad Defined

Energy Industry Defined

At a macro level, the energy industry represents the totality of all industries involved in the exploration, extraction, production, refining, distribution, and sale of energy. Energy comes in many different forms such as heat (thermal), light (radiant), motion (kinetic), electrical, chemical, or nuclear energy, and can be used for many different purposes.[4] In general, energy sources are divided into two groups:

- Renewable (an energy source that can be easily replenished)
- Nonrenewable (an energy source that cannot be easily replenished)[5]

Within the U.S., over 90% of our energy is produced from nonrenewable, or fossil fuel sources, like petroleum, natural gas, and coal. Once produced, the energy is then consumed by five major energy sectors, with the majority going to service our transportation sector as well as generate electricity (Reference Figures 4, 5, & 6). However, the production of energy from renewable energy sources such as wind, solar, and biomass is increasing rapidly due to a growing need to reduce global greenhouse gas (GHG) emissions and create a more sustainable long-term consumption profile. Overall, "growing consumer demand and world class innovation…make the U.S. one of the world's most attractive markets with total investment in the U.S. energy sector at $280 billion in 2015."[6]

Energy Security Defined

Energy Security. Energy security is the ability to meet domestic energy demand with a diverse, reliable, affordable, sustainable, and secure energy supply. An important distinction to note is energy security ***does not*** require or imply energy independence. While there is value in a country having a relatively high degree of energy self-sufficiency, the idea of energy independence "does not reflect the highly integrated global energy market in which we now live."[7] In most cases, a higher degree of energy self-sufficiency reduces the dependency on foreign sources of supply and the vulnerability associated with disruptions to changes in the access, price, and quantity of that supply. However, as Japan learned following the Fukushima Daiichi nuclear disaster, and the U.S. experienced during events such as Hurricanes Rita and

Katrina, the ability to import supplies quickly from global markets to meet domestic energy demands is an important safeguard against disruptions in energy supply. In the end, "we are more secure, not less, when energy markets are interdependent," and the U.S. must continue to pursue policy options which secure access to efficient global markets.[8]

Energy Security Triad. To foster our energy security and build interdependence, the energy security of the U.S. rests on three specific pillars: national security, economic development and prosperity, and environmental responsibility. Viewing policy recommendations and choices through any one of these lenses individually results in a higher potential to create regulatory stovepipes and erect barriers to growth, development, and innovation within the energy industry. Therefore, U.S. energy policy must focus on areas where these pillars overlap and leverage America's competitive advantages in technological innovation and abundant energy resources toward achieving and sustaining long-term energy security.

Energy Security – National Security Nexus. The responsibility to preserve and protect the people, property, and resources within sovereign territory is not unique to the U.S. All nations face the same duties and their citizens desire the same basic human needs. Naturally, the quest to fulfill the energy needs of both developed and developing nations can also lead to conflict and competition over scarce and finite resources. Until recently, a dependence on oil "contributed to U.S. involvement in regions of the world that are often unstable and sometimes hostile to American interests."[9] Further exacerbating the potential for conflict, geopolitical rivalry and instability can also "impact energy markets when they disrupt production, disrupt transportation flows, raise insurance rates, or reduce demand" (Reference Figure 7).[10] With this in mind, the Trump Administration is "committed to achieving energy independence from the OPEC cartel and any nations hostile to our interests."[11] The Administration also recognizes "boosting domestic energy production," and increasing our own oil and gas exports, are good for the American economy and in our national security interests.[12]

Energy Security – Economic Development and Prosperity Nexus. Energy is an indispensable driver of the world economy. The energy industry is both a means to economic development and prosperity unto itself, as well as the underlying catalyst for economic development and prosperity for the global economy writ large. Energy security "is improved not by 'independence,' but by being integrated into a global energy market, allowing more optionality, interconnectedness, competition, supply diversity, and interdependence."[13] Energy security requires strong governance with a business and regulatory climate that promotes investment, development, and innovation to ensure adequate supplies and infrastructure will be available both now, and in the future.[14] The efficient functioning of integrated energy markets, at both the domestic and international level, "is the best guarantee against physical energy supply disruptions."[15] At this point, the Trump Administration has advertised a commitment to eliminating harmful and burdensome regulations on the U.S. energy industry, vowing to implement energy policies "that lower costs for hardworking Americans to maximize the use of American resources."[16] Through prosperity, we can also develop the technology and infrastructure required to move closer to a reduced carbon future as economic prosperity and environmental responsibility are inextricably linked.

Energy Security – Environmental Responsibility Nexus. Despite a polarizing climate change debate, there is widespread consensus on the need to reduce global GHG emissions. Agreements such as the Paris Accord, the Kyoto Protocol, and numerous other international commitments represent opportunities for countries to contemplate the decisions they make with respect to the energy sources and methods they use for power generation and transportation. A renewed emphasis on environmental responsibility becomes a forcing function for countries to critically evaluate decisions between time (how fast they bring on generation capabilities to meet demand requirements versus the long-term environmental impact) and money (pay now for more expensive infrastructure and technology to reduce environmental impact versus the long-term health and environmental impact on populations). In many areas of the world, however, the cost of energy is so cheap and abundant (such as natural gas in the U.S. or coal in Mongolia), it becomes difficult, both economically and environmentally, to incentivize people to conserve resources and/or increase energy efficiency. While environmental and climate policies are often conflated, the Trump Administration recognizes America's "need for energy must go hand-in-hand with responsible stewardship of the environment [and] protecting clean air and clean water, conserving our natural habitats, and preserving our natural reserves and resources will remain a high priority."[17]

Landscape & Current Condition of Energy Industry

Domestic Nonrenewable Energy Sources

The four major nonrenewable energy sources are crude oil, natural gas, coal, and uranium (nuclear energy).[18] An important distinction for reference is "all fossil fuels are nonrenewable, but not all nonrenewable energy sources are fossil fuels."[19] Crude oil, natural gas, and coal are considered fossil fuels because they were formed from the buried remains of plants and animals that lived millions of years ago. Conversely, uranium ore, which is mined and converted to a fuel used in nuclear power plants, is not a fossil fuel but is classified as a nonrenewable fuel.[20] As of 2015, nonrenewable energy sources accounted for 90% of U.S. domestic energy consumption (Reference Figure 8).[21] While it is still too early to know with certainty how the Trump Administration will articulate nonrenewable energy policies, it is clear President Trump "aims to increase the United States energy supply" by pledging to open federal lands for coal leasing as well as expanding oil and gas leasing.[22] By embracing the shale oil and gas revolution, the Trump Administration hopes to "bring jobs and prosperity to millions of Americans" and "take advantage of the estimated $50 trillion in untapped shale, oil, and natural gas reserves, especially those on federal lands that the American people own."[23]

Crude Oil. Crude oil is a complex global market that creates challenges for domestic energy security since events around the world impact the supply, as well as the domestic prices, of crude oil and its derivative petroleum products.[24] Taking those factors into consideration, the "America First Energy Plan" is a commitment to "maximize the use of American resources, freeing us from dependence on foreign oil."[25] Recent breakthroughs in drilling and extraction technology have unleashed the potential of shale oil making the U.S. a swing crude oil producer. In the final months of 2013, "American domestic crude oil production surpassed imports, and the United States overtook Russia as the world's second largest oil producer."[26] Furthermore, the IEA estimates by 2020, the U.S. will be the largest oil producer in the world.[27] Given that trajectory, it is unlikely other sources will displace oil as a critical source of energy, despite significant advances in renewable energy as well as advances in hybrid and electric vehicle technology. With negative externalities almost insurmountable to overcome in the near-term, such as high switching costs for alternative fuel vehicles and infrastructure, the IEA and the U.S. Energy Information Administration both forecast the U.S. will remain dependent on oil to meet domestic needs.[28] That said, "the outlook for the U.S. oil supply has shifted from one of scarcity and insecurity to one of domestic abundance" with clear economic and national security benefits.[29]

Natural Gas. It is difficult to overestimate the importance of natural gas as a fuel source, both for global economic growth and for its ability to aid in global efforts to control climate change. According to IEA, production of natural gas has tripled over the last forty years from roughly 1100 billion cubic meters (Bcm) per year to roughly 3500 Bcm per year.[30] While the U.S. and Australia are the focus of most of the recent growth, gas production has grown over much of the world, including Asia and Africa.[31] U.S. production of natural gas has grown significantly due to production in the Marcellus Shale of the Eastern U.S., and the Bakken Formation of the Great Plains, with Marcellus Shale production expected to lead continuing gains in the coming decades.[32] This production, combined with an investment in liquefied natural gas (LNG) technology, should permit the U.S. to move from a net importer of gas to a net exporter of gas in the immediate future.[33] As such, the strategic importance of natural gas is growing, not only due to its abundance and relative ubiquity, but also because it burns more cleanly than other fossil fuels. Natural gas burned in efficient modern power plants can emit from 50%-60% less carbon dioxide than coal burned in a modern power plant, and vehicles powered by natural gas can emit 15%-20% less green house gas emissions compared to gasoline-powered engines.[34] For this reason, some energy experts view natural gas a *bridge fuel*, one which can help countries cut emissions in the short term, while offering time to prepare a transition to a future where zero emission renewables play a greater role.

Coal - Coal's history in the U.S. is undeniably significant as it powered unmatched industrial development and the rise of the American superpower between the late 1880's until the 1950's. Today, coal represents about 33% of all electricity generated in the U.S.[35] It is an inexpensive, abundant, and reliable source of energy for the U.S., and known coal reserves are estimated to last another 283 years (at the current rate of consumption and with today's technology).[36] However, despite coal's abundance and affordability, the outlook for the industry is bleak due to its impact on the environment. Over the past four years, U.S. coal producers experienced deep financial trouble, and even with the recent support of the new administration, coal-fired power plants are continuing to retire. Since 2011, the U.S. coal market declined by an average of 10.3 % annually,[37] and the number of businesses declined by an average of 5% annually down to 1,147.[38] In 2015, the number of actual producing mines decreased by 13%, and the labor force reduced by 12% yielding the lowest number of employees since 1870.[39] Overall, more environmentally-friendly and economically attractive sources of energy are taking center stage. In the U.S., for example, the shale revolution, combined with improved technological innovations and economies of scale in the renewable energy market, are continuing to shift investment capital away from coal to more affordable and environmentally responsible sources of energy.[40]

Nuclear. The U.S. nuclear industry also faces significant risk. Nuclear power's key strength as a reliable source of low carbon baseload electricity could offer a viable path to achieving meaningful reductions in GHG emissions while meeting growing global demand for energy. However, factors such as high capital costs of construction and overhaul, low natural gas prices, the impact of subsidized renewables, lack of progress on a solution for the long-term storage of nuclear waste, fall-out from the Fukushima accident in Japan, proliferation concerns, and many other factors are eroding the economic and political viability of the nuclear fleet and portend an uncertain future for U.S. nuclear suppliers. While some estimate global nuclear power capacity will have to double by 2050 for the world to meet emissions goals,[41] a thirtyyear hiatus in major nuclear construction has caused the atrophy of U.S. nuclear expertise and erosion of U.S. manufacturing capacity for critical components.[42] Despite these developments, there is an emerging industry in the U.S. and Canada focused on advanced reactor designs that show promise in mitigating nuclear power's critical shortcomings.[43] Yet, it is unclear whether this new generation of advanced reactor technology will find a path to large scale deployment without national level action on energy policy that addresses the failure of electricity markets to effectively impute value to the positive economic externalities of nuclear power.

Domestic Renewable Energy Sources

Although renewable energy sources account for only 10% of current domestic energy production, the International Renewable Energy Agency projects the share of renewables in the total U.S. energy mix could reach 27% by 2030.[44] Renewable energy plays an important role in decreasing GHG emissions, as well as providing diversity to our energy supply. Unlike fossil fuels, which are finite, renewable energy sources regenerate offering near limitless energy potential. The five commonly used renewable energy sources are solar, wind, hydropower, geothermal, and biomass (to include wood and wood waste, municipal solid waste, landfill gas and biogas, ethanol, and biodiesel).[45] While the Trump Administration appears to be bullish on nonrenewable energy, wind and solar costs continue to decline precipitously due to "state and federal government mandates and incentives for renewable energy," thereby encouraging continued growth in investment and development of renewable energy resources in the U.S.[46]

Solar. Compared to power generated using fossil fuels, solar power generation is clean—emitting no pollutants or greenhouse gases. Power is generated using multiple technologies including photovoltaic (PV), which converts light to electricity using semi-conductor material, and concentrating solar power, which uses thermal energy focused by concentrating lenses or mirrors to drive utility-scale turbines.[47] While solar power is extremely reliable, the main obstacles to widespread PV implementation are intermittent, non-peak load energy production and the adverse effect large midday PV generation can have on grid stability (Reference Figure 9).[48] These obstacles can be overcome through more effective power scheduling and dispatch, load shifting, and by adding energy storage to the grid such as through pumped hydro facilities or utility scale batteries.[49] Notwithstanding reductions in the federal Solar Investment Tax Credit (ITC) in the coming years, PV growth should continue due to further improvements in PV efficiency. In 2016, solar represented the largest new source of electricity generating capacity exceeding both wind and natural gas new additions.[50] Over 14 MWdc of solar PV was installed in 2016 representing 39% of all new capacity.[51] If present trends in PV efficiency continue in spite of subsidies going away, PV will be cost competitive with traditional forms of electricity by the early 2020s in many parts of the U.S.[52]

Hydro. The hydroelectric power industry also enjoys a positive outlook well into the future. The industry is mature with more than 400 firms currently competing for business, and in 2016, the industry generated $3.7B in revenue and raked in $580M in profits.[53] Due to the shale gas boom and resultant low prices, gas-generated power plants are more cost effective and ultimately threaten hydroelectric power firms. Additional barriers to entry include: potential drought conditions, large amounts of capital to build infrastructure, limited suitable sites, community resistance, and state and federal regulations on damming resources. Despite these challenges, opportunities exist for hydroelectric power including infrastructure improvements on existing facilities that can yield capacity and efficiency gains. Approximately 90%, or 80,000, of dams in the U.S. do not currently produce electricity, although they can be converted to do so.[54]

Furthermore, the ocean waters off the coast of the U.S. (and to a lesser extent inland rivers) offer a tremendous, untapped energy source that is clean, renewable, and reliable. The advancement of marine and hydrokinetic (MHK) technologies can be used to draw power from ocean and river currents, tides, surface waves, and differences in ocean water temperature. Considering nearly 50% of the U.S. population lives near the ocean, tapping into just 5% of the technically extractable energy would provide power to 6-8 million homes.[55] Both traditional hydroelectric power and MHK technologies offer a consistent source of power that can be used for baseload generation, demonstrating a significant advantage over other renewable sources.

Wind. Today, wind power accounts for approximately 5% of domestic electricity production in the U.S. and wind is poised to surpass hydroelectric as the predominant source of American renewable energy (Reference Figure 10). [56] The U.S. Department of Energy estimates wind has the potential to provide 20% of all U.S. electricity by 2030, and 35% of U.S. electricity by 2050.[57] Increased wind production would bolster U.S. energy security by enhancing the diversity, accessibility, and reliability of our domestic power supply, and augmenting the mixture of existing power sources such as natural gas, nuclear, coal, and other renewables. Such a diversified mix of power sources is essential to our technology-based society, in which consistent access to electricity is a national security imperative.[58] The growth trend in U.S. wind power also corresponds with global trends where some estimates predict renewables will account for more than half of the growth in global energy supply over the next 20 years.[59] Although the federal production tax credit (PTC) begins a gradual phase-down in 2017, 29 states have renewable portfolio standards (RPS) mandating the prioritization of renewable energy sources such as wind.[60] Over the long-term, wind energy has the potential to increase the diversity, accessibility, and reliability of our domestic power supply enabling the U.S. to maintain consistent access to electricity in the future.

Hydrogen. As the most abundant element in the universe, hydrogen offers intriguing possibilities for supplying the world's energy needs. Hydrogen is a safe and highly versatile energy storage and transportation medium without environmental degradation or adverse geopolitical implications. While hydrogen may be combusted directly, energy is typically extracted from hydrogen electrochemically via a fuel cell, which works by combining hydrogen and oxygen across an electrolyte. The process generates an electrical current by conveying electrons from anode to cathode, via a circuit much like a battery (but with a continuous supply of fuel), producing only water and heat as byproducts.[61] The Department of Energy is leading a fuel cell implementation strategy to drive market transformation and foster a domestic manufacturing base, promote green job growth in manufacturing, maintenance and support, and enhance hydrogen production capability.[62] However, the successful use of hydrogen depends heavily on large government investments across all facets of the hydrogen supply chain, power generation, and vehicle refueling infrastructure to enable global economies of scale. Greater hydrogen utilization will greatly enhance the versatility and range of applications for virtually all other aspects of energy generation, storage, and transportation. Most notable among these applications is the opportunity for a reduced carbon footprint through either direct fuel cell carbon capture applications or 100% carbon free generation of hydrogen via renewable sources.[63]

Biomass & Biofuels. Energy derived from biomass fuel has grown substantially in recent years and the future outlook remains bright. Energy is produced by burning certain types of waste or using methane gas captured from landfills. Firms in this industry can be categorized into those firms that produce electricity from biomass fuels, and firms that are primarily engaged in operating trash disposal incinerators which also generate electricity. The annual growth rate for firms dedicated to producing energy is expected to grow 1.3% annually until 2022 with revenue reaching $840 million and profits slightly over $105 million.[64] Much of the growth in this area can be attributed to the focus on climate change and renewable energy production tax credits as used with other renewable energy sources. However, like other renewable sources, the primary barrier for entry is the capital cost and expertise required to build a power generation facility. Despite these challenges, the focus remains on climate change and the push for renewable energy which will include biomass solutions. Furthermore, most states enacted RPS which require local utilities to generate electricity from renewable power as a percentage of their total energy portfolio.[65] Biomass also has a distinct advantage over other intermittent renewables, including wind and solar, as biomass energy is continuous and can be used for baseload power. As such, biomass energy will continue to grow in the coming years.

Domestic Enablers

Smart & Micro Grids. While today's electric generation, transmission, and distribution industry is still reliant on infrastructure developed and installed decades ago, the landscape is changing dramatically. New technologies are challenging traditional norms and providing electricity consumers with incredible new capabilities, better reliability, lower prices, and increasingly diverse energy generation options. As the electric system becomes more complex and microgrids, and other unregulated private generation and storage entities continue to rise, new communications technologies and system methodologies are being developed to provide real-time situational awareness tools to balance electricity system supply and demand.[66] A new approach to smart grids will require a large-scale adoption of smart grid information and communication technology, advanced metering technology, and increased control requirements, with the ultimate outcome of increased flexibility, reliability, and resiliency in the electric system. Least-cost methodologies will likely give way to demand-response programs bolstering competition, lowering energy prices, encouraging changes in customer demand, and giving consumers a better understanding of the costs of renewable energy generation.[67]

Infrastructure Security & Cyber Security. Overall, the U.S. energy sector is subject to more cyber-attacks than any other area of critical infrastructure.[68] A staggering sixty-eight percent of firms were successfully hacked in 2015.[69] Within this sector, the largest vulnerability are the 435,000 miles of pipelines moving oil, natural gas, and refined products throughout America.[70] This is the definition of critical infrastructure. Any extensive incapacitation or destruction of our pipelines would have a debilitating effect on national security, economic security, and public health and safety.[71] Though pipelines are the safest mode of transport, they are at risk of consequential cyber-attack due to the linkage of Supervisory Control and Data Acquisition (SCADA) systems to the internet.[72] Following the September 11, 2001 terrorist attacks, the Department of Homeland Security's (DHS) Transportation Security Administration (TSA) was granted the authority to regulate bulk pipeline industries but chose to take a more collaborative and guiding approach with voluntary industry compliance. Given the absence of standardized periodic industry reporting to TSA, we don't have a data-driven understanding as to whether these guidelines are being implemented or if they have made our pipeline infrastructure safer.[73] Congress, DHS, and the pipeline industries themselves, do not have the information needed to make sound policy decisions.

Pipelines. The pipeline transportation industry is a vital part of the U.S.'s national security and critical infrastructure, connecting natural gas and oil producers, refiners, and consumers across the country. The pipeline industry operates more than 207,800 miles of liquid pipelines,[74] 301,177 miles of natural gas transmission pipelines, and 1,276,844 miles of natural gas distribution lines across the U.S. [75] In 2014, liquid pipelines transported in excess of 9.3 billion barrels of crude oil to refiners (75% of the nation's crude oil) and 6.9 billion barrels of refined product (60% of refined production) to market. Over the last five years, there has been significant expansion in crude oil pipelines due to the substantial increases in production of oil in Canada, North Dakota, and West Texas. The industry responded by increasing its capacity and building more than 12,000 miles of crude oil pipelines between 2009-2014.[76] Despite rising demand in natural gas, this same growth has not been experienced in natural gas transmission and gathering pipelines, remaining in a relatively constant range between 310,000 miles and 333,000 miles since the mid 1980's. Congress and the President must continue to support the expansion and upgrade of the existing crude oil, nature gas, and refined product pipelines to ensure the nation can safely and economically leverage our vast petroleum and natural gas reservoirs.

Energy Storage & Batteries. The current trend toward the growing use of renewable energy for power generation must also be supported with commensurate growth in energy storage. Whether power is generated using renewable or nonrenewable sources, in the current system, there is very little storage capability once the power is produced. Therefore, if the power is not consumed after transmission, that power is lost. To maximize the use of renewable energy sources, a policy change that incorporates grid storage capacity needs to be incorporated into all new transmission, distribution lines, and renewable energy generating locations. The system needs a way to regulate the times and amounts that energy is being passed through to the consumer. One of the most efficient ways to accomplish this is to store energy for later use when demand is greater using, for example, a battery or pumped storage technology which pumps water to a higher elevation and then release the stored energy when the demand is greater. The future of battery manufacturing within the U.S. lies in forward-thinking research and development (R&D) to increase battery storage capacity, decrease their size and weight, increase their structural integrity, reduce the overall cost of manufacturing, and ultimately increase the overall efficiency of energy storage.

Efficiency. As "the only energy resource possessed by all countries," energy efficiency (EE) significantly influences energy security, economic security, and national security. [77] Previously known as the *fifth fuel*, EE's invisible, domestic, affordable, and environmentally-friendly characteristics have earned it the title of *first fuel*. [78] Defined as consumption avoidance, EE is "doing the same amount of work—often in a better, cleaner and cheaper way – with less energy."[79] Domestically, "U.S. energy use is approximately half of what it would have been if we had not improved our [EE] over the past 40 years."[80] While the *America First Energy Renaissance Policy* does not specifically mention EE, its position that "boosting domestic energy production is in America's national security interest" can be interpreted as referencing the virtual energy production that EE affords.[81] Internationally, EE has resulted in $4 trillion of "cumulative savings on energy expenditure" for IEA nations,[82] improving their trade balances by lessening import demand since 2000.[83] Such implementation lowers infrastructure lifecycle costs, prevents environmental degradation, cuts operating costs, eases taxpayer burdens, ameliorates health concerns, and enhances sustainability. While room exists for the U.S. and other nations to increase consumption avoidance, incorporating EE strategies is a critical part of ensuring energy, economic, and national security.

International Partnerships & Opportunities

Opportunities in U.S.-Japan Energy Relations. With little or no fossil fuel resources of its own, Japan's energy policies are primarily driven by their need for energy security and improved self-sufficiency. For years, Japan has relied on a combination of a large fleet of nuclear reactors and imported oil and gas to meet its energy needs. However, the devastating earthquake and tsunami of 2011 turned the energy industry of Japan on its head. Before 2011, nuclear power accounted for approximately 30% of Japan's electrical power generation. Following the Triple Disaster of 2011—the East Japan earthquake, tsunami, and the Fukushima-Daiichi nuclear power plant failure—Japan's nuclear fleet was taken offline indefinitely; a limited number of nuclear facilities have returned to production, under enhanced safety procedures, starting in 2015. As outlined in the government's Strategic Energy Plan, issued in 2014, Japan aims to replace the power once generated by nuclear plants through a combination of measures including increased efficiency, called "setsuden," promotion of renewables, and power generation from thermal power plants fueled by imported coal and natural gas (imported as liquefied natural gas, LNG).[84] According to the U.S. Energy Information Administration, Japan remains the world's largest importer of LNG, importing 4.4 trillion cubic feet per year (Tcf/Y) in 2015, accounting for almost one-third of the global market for LNG.[85] Overall, Japan has shown tremendous resilience in the face of enormous national hardship and is willing to share the lessons in safe nuclear operations it learned through the tragedy while simultaneously aspiring to be a world leader in renewable energy technology and use.

Opportunities in U.S.-Mongolia Energy Relations. For centuries, the grasslands of Mongolia have nourished and provided for its people. Now, what lies beneath the ground is bringing Mongolia into a new age of prosperity, driving industrial development, and raising the standard of living. Despite the significant geostrategic challenge of being landlocked between Russia and China, "the Mongolian people sit atop massive combined and mostly untapped reserves of coal, uranium, rare earths, copper, gold, zinc, oil, silver and more."[86] Some estimates believe the value of these reserves could be well over $1 trillion.[87] This kind of revenue and wealth could be a game-changer for a country with only 3 million people and an annual GDP of roughly $12 billion. Mongolia is taking many steps toward diversifying their energy portfolio with clean coal, renewables, and realizing the full potential of their energy and mineral reserves. However, they cannot do it alone, and struggle to maintain a balance of attracting foreign investors with the technical ability and financial backing to help them build national wealth without being exploited and their resources striped out from under them. Through their '3rd Neighbor Policy,' Mongolia hopes to expand their partnerships and cooperation with other highly developed and democratic nations to diversify their economy, encourage investment in Mongolia, and grow their young democracy.

Opportunities in U.S.-Canada Energy Relations. Canada and the U.S. have a deep economic, social, and security relationship. Energy is a key component of the bilateral trade relationship as Canada is the largest external supplier of energy to the U.S. including electricity, uranium, natural gas, and oil. The provisions of two trade agreements facilitate this energy trade: the bilateral Free Trade Agreement (FTA) between the U.S. and Canada and the trilateral North American Free Trade Agreement (NAFTA) between the U.S., Canada, and Mexico. Both of these free trade agreements prohibit the imposition of minimal export prices or export taxes and restrict enacting supply limits.[88] One critical energy source covered under these provisions is crude oil of which Canada is a significant supplier to the U.S. Due to its vast supply of oil contained in the Alberta oil sands, Canada has 171 billion barrels of proven oil reserves placing it third behind Saudi Arabia and Venezuela, and it is the only non-OPEC member in the top five.[89] Canada is also the fourth largest crude oil exporter in the world.[90] Ninety-four percent of those exports went to the U.S. in 2015 making it the largest foreign supplier of crude oil to the U.S. with a 43% share of total oil imports to the U.S. and 20% of U.S. refineries' crude oil intake.[91] In 2016, Canada provided more oil to the U.S. than the next four oil importing countries combined.[92] Further, the Keystone XL pipeline, with a capacity of 830,000 barrels per day, may make Canada an even more important supplier of crude oil to the U.S. In January 2017, President Trump gave his de facto approval of the pipeline by signing an order inviting TransCanada to resubmit a request for a Presidential permit, which President Obama previously refused.[93] TransCanada resubmitted its permit request two days following the signature of the Presidential Memorandum.[94] Overall, Canada is a secure and reliable supplier of crude oil that must be considered as part of America's energy policy formulation.

Imperative Analysis & Policy Recommendations to Ensure Continued Energy Security

Methodology

As asserted in the report's thesis, in order for the U.S. to maintain a competitive advantage in the energy industry and preserve its energy security, the U.S. must meet four key imperatives. The individual imperatives were developed through multiple group discussions, by conducting a SWOT analysis (Strengths, Weaknesses, Opportunities, and Threats), and by drawing upon the information received, and observations made, throughout the past five months of the industry study classroom, outreach, and field study sessions. Once the four imperatives were established, we conducted a Force Field analysis on each imperative. A Force Field analysis is a decision-making tool used to analyze the forces for and against change, and represent them in a clear way to more effectively communicate the reasoning behind the decision.[95] In our analysis, we used the terms tailwinds (or support) and headwinds (or resistance) to describe the amount of support or resistance there was toward the specific imperative. Providing an additional layer of analysis, we used the STEEP methodology (Social, Technological, Economic, Environmental, and Political) to provide different lenses to evaluate the support and resistance. A color code of green, yellow, and red was then used to provide a weighting system to the framework to show the severity of the support or resistance. Based on the magnitude of the support or resistance, specific policy recommendations were derived to either increase support, or minimize resistance, toward the U.S. implementing energy policies to ensure its long-term energy security. (Reference complete set of diagrams in the Diagrams for Force Field & STEEP Analysis section).

Imperative #1: The United States must employ diverse energy solutions

To maintain its security and economic prosperity, and preserve the well-being of the American people, it is imperative the U.S. employ diverse energy solutions. History provides stark examples of economic disruption caused by over reliance on a specific energy source. Two such examples are the experience of the U.S. during the Arab oil embargo of 1973 and current energy insecurity faced by Japan due to its decision to take nuclear power facilities offline following the Fukushima-Daiichi disaster. A diverse energy mix will ensure the U.S. can continue to withstand supply scarcity, geopolitical instability, and market volatility affecting any specific energy source.

See Diagrams for Force Field & STEEP Analysis: Imperative #1

Tailwinds (Support). Analysis of the U.S. energy sector identified several key forces that promote near-term U.S. energy diversity. Although growth in domestic energy consumption is expected to remain modest over the next 20 years, Americans have come to expect, and the economy has come to depend on, ready access to affordable energy.[96] This motivates continued efforts to secure new resources and identify new energy solutions. Low fossil fuel prices, and incentives implemented through current laws and regulations, are driving growing shares of natural gas and renewables in the electricity generation mix.[97] The widespread deployment of advanced horizontal drilling and hydraulic fracturing have greatly increased the availability of domestically produced oil and natural gas. This has also reduced U.S. dependence on oil imports and led to growing U.S. influence in international energy trade. At the same time, environmental concerns have resulted in policy initiatives at the federal, state, and local levels that have spurred rapid growth and decreased cost of renewable energy production (wind, solar, biomass, etc.). Additionally, there are a broad range of new and emerging energy technologies supporting a diverse U.S. energy portfolio. Moving forward, the Trump Administration's "America First Energy Plan" promises to reduce regulation that constrains development and use of abundant fossil fuel resources, further adding to the diversity of U.S. energy options.[98]

Headwinds (Resistance). In contrast, the analysis of the U.S. energy sector also identified key forces that pose risk to energy diversity in the long-term. Foremost among these forces is the lack of a federal energy strategy. This, combined with fragmented federal and state level mandates and incentives that favor specific technologies or sources rather than a broad range of energy solutions, creates an uncertain environment for energy innovation and capital investment. Without a coherent national energy strategy, the domestic abundance of cheap oil and natural gas, supported by a vast existing infrastructure, increase their probability of entrenchment in the U.S. energy system. Though this entrenchment has near-term economic benefits, it undermines the future viability of reliable, low-carbon energy sources. For example, the rapid expansion of natural gas-fired electric power generation plants has driven down electricity prices and threatens the financial health of nuclear plants. In turn, this threatens the ability of the U.S. to meet future energy demand, while substantially reducing GHG emissions. Furthermore, bureaucratic roadblocks, resistance to unwanted development ("not in my backyard" syndrome), and a lack of coherent planning and investment for modernization of U.S. energy infrastructure is limiting the expansion of renewables and impeding the efficient exploitation of oil and natural gas resources.[99]

Overall Assessment. Although the U.S. currently enjoys the security of a robust energy mix because of abundant domestic resources and an expanding and commercially viable renewable energy sector, the headwinds discussed above pose a risk to maintaining a balanced energy portfolio in the long-term.

Policy Recommendations

Policy Recommendation #1: Develop a national energy market standard that provides performance benchmarks for establishing stable and predictable price signals that incentivize development of reliable, low-carbon energy solutions, to hedge against displacement of key

energy sources by short-term availability of inexpensive oil and natural gas. The aim is to facilitate long-term planning and investment in variety of sustainable energy sources and supporting infrastructure.

Electricity generation. Although natural gas and coal dominate the market, electricity is currently generated from several different sources: natural gas - 33.8%; coal - 30.4%; nuclear - 19.7%; renewables - 14.9%.[100] Many states introduced RPS, which mandate generation from non-fossil fuel sources. This approach is one mechanism to achieve the goal of energy diversity. However, mandate and incentive programs should be expanded and generalized to include all sources of clean, low carbon energy. This includes market mechanisms that account for negative externalities associated with all forms of waste.

Transportation. Gasoline and diesel fuel dominate the U.S. transportation energy sector. Oil is a global commodity of which the price and availability are subject to global market fluctuation and geopolitical circumstances. Consequently, increasing the adoption of advanced fuels technology (e.g., natural gas, hydrogen, flex-fuel, and electric) will reduce reliance on oil as a single source, thereby increasing U.S. energy security. As such, federal and state governments must facilitate wider adoption of alternative transportation fuels through initiatives such as expanding the current tax credit for advanced fuel vehicle purchases; incentivizing the establishment of advanced fuel infrastructure such as fueling stations and electrical grid improvements; and mandating expanded procurement of advanced fuel vehicles in lieu of petroleum vehicles for government fleets.

Policy Recommendation #2: Expand existing R&D efforts and initiatives to support long-term viability of coal and nuclear power generation as a clean source of energy.

Coal. Power generation from coal as a percentage of overall energy production is steadily declining due to the low price of natural gas and concern over GHG emissions. Steps to curb an over reliance on natural gas are discussed in policy recommendation #1 above. However, in light of domestic climate change concerns in many U.S. states, the trend toward reduced coal power generation will continue unless affordable, clean coal power technology becomes available. Initiatives to include expanded R&D of clean power technology must be pursued to ensure coal remains a substantial component of the U.S. energy mix.

Nuclear. As discussed earlier, nuclear is a reliable source of low carbon electric power generation. Nevertheless, the high capital expenditures needed to ensure safety and reliability in large nuclear plants are proving to be an untenable financial challenge. Accordingly, a critical element to consider in the future of nuclear power is the progress being made in advanced reactor designs that have the potential to mitigate economic challenges while improving safety, reliability, nuclear waste management, and security. In fact, a new industry is emerging in the U.S. around development of advanced reactor technologies. The Nuclear Regulatory Commission (NRC) is expected to issue the first licenses for Small Modular Reactors (SMR), the most mature new nuclear reactor technology, within the next decade. SMRs create an opportunity to implement a more feasible financing model than is available for conventional nuclear plant construction.[101] The small size of SMRs (ten to 300 megawatts) allows their use in many different applications from generating electricity to providing heat for industrial applications. The modular design allows them to be manufactured in a factory and installed on site in an incremental fashion as power demands increase. This provides opportunities to greatly reduce construction costs.[102] Moreover, development of advanced nuclear fuel reprocessing will be an important complement to advanced reactor designs while helping to mitigate the nuclear waste problem. Thus, to keep nuclear as an option in the future U.S. energy mix, the U.S. must increase its R&D investment in advance reactor designs and nuclear fuel reprocessing.

International Collaboration. The U.S. must seek to expand international collaboration opportunities as part of its efforts to ensure the viability of coal and nuclear. Japan faces acute energy challenges and their future energy security will be shaped by the long-term viability of coal and nuclear. Consequently, Japan is making progress with clean coal technology and working to reconstitute its nuclear sector. The U.S. could benefit from closer collaboration with Japan and other trusted international partners in these areas.

Imperative #2: The United States must modernize and expand its energy infrastructure and distribution system

The US energy infrastructure is aging and in need of significant upgrade and expansion to meet current demand and support future economic growth.

See Diagrams for Force Field & STEEP Analysis: Imperative #2

Tailwinds (Support). The energy industry is benefiting from a variety of recent technical advancements and positive trends in energy diversification which offer opportunities for modernization and expansion of the energy system. The boom in hydraulic fracturing has resulted in a significant increase in availability of affordable natural gas and shale oil. In addition, the growing presence and acceptance of distributed generation, as well as advancements in renewable energy options and smart grid technology, have led to a more diverse national energy portfolio.

Public attitudes and expectations reflect a growing awareness of emerging technologies capable of meeting an ever-evolving and increasingly diverse set of energy needs. Foremost among social priorities is an expectation of accessible, reliable energy with environmental considerations also playing a significant role in these social trends. Additionally, the cost and associated profitability of renewable energy, and the growing role of natural gas as a relatively clean and responsive fossil fuel, support infrastructure improvements for both natural gas and electricity.

Cyber and physical vulnerabilities necessitate technological improvements and investment in modern, more efficient control systems. In addition, private sector investment in R&D is driving rapid advances in technologies such as solar, wind, biofuel, battery storage, hydrogen fuel cells, and smart grids.

Positive political momentum within the federal government in support of fossil fuel development, reducing over-burdensome regulations, and expanding opportunities for job growth through infrastructure development offers significant economic growth opportunities.

Government support of a broad "all of the above" energy approach coupled with a drive to reduce regulatory hurdles should lead to significant increases in the volume of energy produced and exported while reducing the overall cost of energy for the consumers.

Headwinds (Resistance). Economic and political forces are the primary headwinds to energy infrastructure improvements. Among the economic headwinds are slow or stagnant growth in domestic electricity demand resulting in reduced investment due to high capital costs with low returns on investment. In addition, affordable and abundant natural gas has reduced investment in renewables, clean coal technology and nuclear.

Politically, the climate change and environmental lobby supports expansion of renewable energy initiatives, but often strongly resists the fossil fuel infrastructure upgrades needed to balance the renewable portfolio. Well-established energy lobbies, meanwhile, drive political resistance to change. These forces, together with reliance on private industry for transformation, prevent establishment of a national energy strategy. The inconsistent and fragmented energy strategies that do exist are difficult to implement in the face of significant fiscal constraints, divergent priorities, and political gridlock.

Environmental concerns and active resistance to fossil fuel energy resource development often delay projects and increase project cost. Nearly all new pipeline proposals submitted to the Federal Energy Regulatory Commission (FERC) face obstruction from organized activist groups and other detractors.[103]

The intermittent nature of sun and wind generation adds strain to electrical transmission and distribution networks, and prevents a more dramatic shift from fossil fuels to renewables. Future battery technology or other solutions such as implementation of hydrogen supply chains may resolve this issue, but sufficiently large systems are not yet economically viable to integrate renewables into the grid on a broad scale.[104]

The outdated and aging electric grid does not incorporate the technology necessary to communicate and integrate distributed sources and provide customers with accurate pricing models that reflect the actual costs of generation. Smart grid technological solutions are currently available, but require significant capital expenditure to implement.

The economic incentives for adding and maintaining transmission and distribution infrastructure is reduced as the U.S. transitions from the traditional system of centralized electricity generation and monopolistic transmission and distribution. The traditional model, where public utilities have incentive to maintain and expand infrastructure through guaranteed profitability, has become problematic as distributed generation methods and microgrids expand, and capital requirements for utilities increase.[105]

Overall Assessment. The American Society of Civil Engineers' annual US Infrastructure Report Card grades the energy infrastructure as a "D+".[106] Significant portions of the U.S. energy infrastructure were built more than 50 years ago, have exceeded their design life, and require significant upgrades. In addition, the aging infrastructure presents multiple cyber and physical security vulnerabilities. The electrical transmission and distribution system, and the natural gas pipeline systems in particular, require significant direct investment to ensure the reliable and stable delivery of energy to meet current demand and support economic growth.

Planning the energy infrastructure of the future must consider transitioning renewable energy from a source of supplementary power to a baseload resource. Hydropower has traditionally been the primary renewable energy source and, along with nuclear, they are extremely capital intensive, controversial with respect to environmental safety, and unlikely to see further expansion. As such, these traditional resources show little prospect for growth. Improving technologies in wind and solar coincide with increasing public interest in renewable clean energy, but also require new connections to the grid from their predominately remote locations. Innovations in battery storage technology, hydrogen production and fuel cell generation, pumped storage, and other areas provide options for large scale energy storage and distributed generation of renewable energy sources.

The U.S. must establish and adhere to a viable national energy policy in conjunction with state governments, industry, and global partners to build this new energy industry infrastructure while responding to the urgent need to repair and upgrade our long-neglected existing infrastructure. It can do so by leveraging technological and environmentally responsive social trends to create the necessary economic and political environments to effect this change. The following two recommendations are essential to begin this necessary task.

Policy Recommendations

Policy Recommendation #1: The U.S. must pass legislation to allow export of natural gas without a requirement of an export license to America's mutual defense pact partners (Japan and NATO). The implementation of such legislation will incentivize the private sector to invest in natural gas pipeline expansion and upgrades to meet increased demand in Asia and Europe. This legislation will support the economics of U.S. domestic natural gas pipelines and export capacity expansion. To this point, exports have been hindered by the 1938 Natural Gas Act which requires the Department of Energy to grant export licenses to nations with which the U.S. does not have free trade agreements.[107] Rising demand for LNG and coal, particularly in Asia, creates opportunities for the U.S. to significantly increase its export of energy. A greater U.S. influence in global energy markets will counter the associated geopolitical leverage Russia and the Middle East have in Asia and Europe. Domestic LNG export volumes are expected to double in 2017 with the U.S. becoming the fifth or sixth largest exporter in the world.[108]

Policy Recommendation #2: Congress and the administration must establish a National Grid Modernization Strategy to increase efficiency, resiliency, reliability, and security of the electrical grid. Any new strategy must include the implementation of smart grid technology, which will also enable improved pricing models and encourage distributed energy generation and green energy options through market forces. Much of the newly built renewable energy generation capacity is intermittent, low capacity, non-synchronous, and location-specific.[109] This creates significant challenges for grid operators who must precisely balance generation and demand through complex transmission and distribution networks.[110] The existing electric grid does not incorporate the technology necessary to communicate and integrate distributed sources and provide customers with accurate pricing models that reflect actual costs of generation. Significant capital expenditures will be required to implement the required smart grid technological solutions. Smart grids enable demand-response programs which encourage changes in consumer demand by providing visibility of actual costs of generation from different sources.[111] As least-cost methodologies currently used give way to demand-response programs, grid transformation becomes more economically advantageous.

Imperative #3: The United States must maintain a competitive advantage in technological innovation

Growing innovation domestically is essential to preserving the technological advantage that underpins U.S. national security. The U.S. "national security science, technology, and innovation enterprise must be able to meet the rapidly evolving threats of today's world while also establishing and maintaining strategic partnerships, employing swiftly changing technologies, coping with diminishing resources, and finding ways to benefit from accelerating globalization."[112] Innovation across the energy sector is essential as "technologies that exist today, or are likely to be developed in the near future, could save considerable money […and…] lower projected U.S. energy use by 17% to 20% by 2020, and 25% to 31% by 2030."[113] While the market must be receptive to cultivating and maintaining domestic advantage of investments and innovation, such innovation is necessary to contribute to both energy and national security.

See Diagrams for Force Field & STEEP Analysis: Imperative #3

Tailwinds (Support). Because the economy is the foundation of U.S. national security, the strongest tailwind is that innovation gives birth to technology, and technology presents global market opportunities. The 2017 creation of the White House Office of American Innovation, whose goal is to "develop innovative solutions to many problems [the U.S.] faces," signals federal-level dedication to promoting innovation across government and industry thought leaders.[114] Meanwhile, the President's proposed budget cuts seek to prevent USG funding from crowding out private investment placing a greater emphasis on market-driven forces to bring innovation to fruition.[115] Moreover, strong public support for innovative technologies related to energy efficiency and clean energy result in positive investment returns.[116, 117] The public's desire for affordable energy is a tailwind in support of innovation that will enable the U.S. to pursue economic prosperity and energy security, both foundational for national security.

Headwinds (Resistance). Historically, the USG has provided direct funding for R&D projects to help industry develop, prototype, and introduce innovative technologies to market. However, shrinking budgets pose a significant challenge to the energy industry and innovation, as evidenced by President's proposal to eliminate the Advanced Research Projects Agency – Energy (ARPA-E),[118, 119] the Department of Energy's (DOE) innovation incubator whose FY17 budget request was $500 million.[120] The elimination of USG-funded innovative outlets will reduce the innovative scope, diversity, and commercialization potential upon which industry previously relied. Further, international theft of U.S. intellectual property (IP) underscores the criticality of information and presents a strategic challenge costing the U.S. economy an estimated $225 to $600 billion annually (a total of over $1.2 trillion in economic damage since 2013).[121] While an "estimated 80% of the value of U.S. corporations lies in their IP portfolios,"[122] this IP is at-risk if other countries lift and commercialize it first, depriving the U.S. of innovations and market share that could contribute to national security, discourages investment, alters competitive advantage, and stymies innovation.[123] This grave threat undermines the U.S. innovation ecosystem, productivity, prosperity, and global competitiveness, and yet to-date, the community has not executed sanctions for international IP theft.[124]

Overall Assessment. Current tailwinds and headwinds afford the U.S. a prime opportunity to promote an environment allowing innovation to prosper. Doing so will not only strengthen U.S. energy security, but provide an avenue for the nation to exert soft power, a necessary complement to hard power mechanisms (e.g. sanctions, industrial base) the U.S. leverages to ensure national security. Nuanced soft power projects national values and "provide[s] economic security in the form of income and business opportunities for individuals. Economic growth depends on… science, technology, and innovation,"[125] as these factors form a foundation for national security. Lack of economic certainty and IP theft, however, threaten the U.S.'s ability to cultivate and maintain energy-related innovation domestically.

Policy Recommendations

The U.S. must encourage an innovation-friendly climate by mitigating "market risks [that] inhibit innovation," to include uncertain economic investment climate, the risk that others will copy IP and R&D initiatives, and market infeasibility.[126] To maintain a technological advantage, "it is essential the U.S. do all in its power to ensure the continued competitive strength and dominance of American firms and their technologies."[127] The following policy recommendations focus on incentivizing innovation and preserving IP to ensure those investments produce domestic benefit.

Policy Recommendation #1: Incentivize Innovation

1a. ***Reduce fossil fuel subsidies and narrow the subsidies' scope to efforts that address fossil fuel efficiency gains and clean fossil fuel energy solutions (such as carbon capture).*** USG incentives must be redirected away from fossil fuels and toward gaining efficiencies and clean energy solutions. The U.S. annually spends approximately $21 billion on fossil fuel exploration and production subsidies,[128] though DOE estimates that the U.S. has enough natural gas to last 90 years,[129] a discovery USG subsidies made possible. Note that this policy does not eliminate fossil fuel subsidies, rather, it focuses funding on activities that will sustain the fossil fuel industry in the out-years, ensuring its place in the U.S.'s diverse energy portfolio.

1b. Incentivize technology development and innovation through federal tax credits, subsidies, and direct funding (e.g. DOE). Investors need confidence their investments will reap a meaningful return on investment (ROI). To mitigate "barriers and unforeseen transaction costs" associated with investments,[130] the USG must offer federal tax credits, subsidies, and in some cases direct funding for R&D projects as incentives to increase demand for innovation. These actions will minimize uncertainty, which will build investors' confidence and perseverance to pursue financially-beneficial ROI via the market and commercialization. While states offer tax incentives for energy initiatives, implementing federal-level tax credits, subsidies, and direct funding will integrate "incentives early in the commercialization process and across the national market that can be highly leveraged for maximum impact."[131] Reducing fossil fuel federal fund subsidies will make funding available to support these efforts. The resultant multiplier effect will grow the nation's GDP, which will strengthen the economy and in-turn enhance U.S. national security. The U.S. must assess indicators (e.g. GDP growth, use of diverse energy technologies) over time to evaluate the efficacy of this policy.

Policy Recommendation #2: ***Preserve intellectual property by keeping U.S.-funded innovation in the U.S. and establishing international norms to prevent IP theft.*** The USG must develop an innovation-focused governance structure akin to the Committee on Foreign Investment in the U.S. (CFIUS), "an inter-agency committee authorized to review transactions that could result in control of a U.S. business by a foreign person".[132] This structure must fuse risk assessments across disparate entities to assess national security implications and propose mitigations resulting from illegitimate movement of innovation from the U.S. Lessons learned from this endeavor must then be used to contribute to the creation of international norms aimed at preventing IP theft. While launching an innovation-focused CFIUS grows bureaucracy and requires resources (e.g. time, personnel) to institute, such governance contributes a deliberative robustness to preserve and force-multiply innovation, the protection of which otherwise lacks the rigor necessary to grow U.S. energy security and thus national security. IP theft also fosters the erosion of international norms and world order which must be addressed through more direct international engagement and the enforcement of existing legislation. Members of the World Trade Organization (WTO) are held to international agreements regarding the criminalization of IP theft, which have largely been ignored by many countries, to include China which accounts for 80% of U.S. IP theft.[133] Working with the WTO to prioritize IP theft issues, the U.S. must restrict academic, commercial, and governmental cooperation with countries in violation of WTO IP agreements. The U.S. must require any international trade agreements/treaties be modified to contain specific enforceable provisions against IP rights violations. In cases of severe or persistent violation of U.S. IP rights, the U.S. could also employ the International Emergency Economic Powers Act which allows for sanctions denying the use of the U.S.

banking system to individuals or organizations participating or benefiting from the theft of U.S. IP.[134]

Imperative #4: The U.S. must develop a new energy strategy to increase energy security

The U.S. must develop a new energy strategy to leverage its abundant energy resources to increase overall energy security, strengthen the U.S. economic base, and bolster U.S. leadership abroad. The desired end state of this strategy would be to increase the diversity, accessibility, and reliability of U.S. domestic energy supply. With the U.S. rising among the world's top energy-producers, this is an opportune time to maximize U.S. energy resources through a genuine, "all-of-the-above" energy strategy.[135] Such policies have been pursued by past administrations, but today's energy abundance makes such a strategy more likely to succeed.[136]

See Diagrams for Force Field & STEEP Analysis: Imperative #4

Tailwinds (Support). An analysis of the forces impacting this imperative suggest that social, technological, and environmental tailwinds would provide strong support for a truly diversified energy strategy. From the social perspective, the strongest tailwinds would be derived from public interests centering on the potential economic benefits, particularly domestic employment growth and increased energy exports. There would also be public support for renewable energy that addresses environmental concerns and the risk of climate change. The bolstering of U.S. leadership via energy diplomacy and increased energy exports would also generate social support. Finally, U.S. technical expertise and established R&D in the energy industry would sustain the new strategy.

Headwinds (Resistance). The most significant headwinds to a more diversified energy strategy would originate from well-established fossil fuel companies in the U.S., based largely on economic concerns. Petroleum and other energy companies would be reluctant to support an energy policy that could change operating paradigms or influence global energy markets. These companies would also be impacted by capital costs associated with modernizing or building new energy systems and infrastructure in response to new policy, such as energy efficient and clean power generation options that include carbon capture technologies. Energy companies in the U.S. create a significant political force and would require the greatest effort to offset in developing a new, diversified energy strategy that would be politically viable.

Overall Assessment. An analysis of the above variables suggests that while significant headwinds exist, the U.S. is in a unique position to establish itself as a global energy leader and also possesses the means to generate a new energy strategy to enhance national security. To do so, the U.S. must develop its strategy accounting for the global trend that "the economics of traditional fossil fuels and renewables are in the process of converging."[137] In fact, the U.S. should pursue a genuine, all-of-the-above strategy that continues to incentivize many of its fossil fuel and conventional power resources, as they are critical components of the U.S. energy mix. This complimentary, all-of-the-above approach has long-standing, bi-partisan support in the U.S., even if it has not always succeeded.[138]

Policy Recommendations:

Policy Recommendation #1: The U.S. must maximize the effective use of its newfound abundance of energy resources, to include all fossil fuels, nuclear, and renewables in order to increase its energy security, foreign diplomacy, and bolster the U.S. economic base.

This strategy and supporting policies will focus specifically on ensuring stable and transparent energy markets and would include measures to expand the export of both crude oil and LNG.[139] It would also include a measure to replace portions of the proposed Trans-Pacific Partnership (TPP) to boost energy trade with Asia, and it would leverage U.S. energy diplomacy as well as existing U.S. technical expertise and energy R&D.[140]

Per the new administration's *America First Energy Plan*, the U.S. should embrace its existing resources in untapped shale, oil, and natural gas reserves, while also investing in new technologies such as clean coal.[141] However, an all-of-the-above energy strategy must likewise embrace renewable sources. To gain support for this type of fully diversified energy strategy, the administration must be convinced that the strategy will gain the support of oil companies, congress, and voters. This would be accomplished by emphasizing the mutually beneficial aspects of the strategy. Specifically, the strategy would generate increased opportunities to export oil and gas and it would include new opportunities to explore untapped resources on select federal lands. The strategy would also garner congressional and voter support due to new employment opportunities and infrastructure upgrades associated with renewable and fossil fuel expansion, by addressing risks associated with climate change, and because an all-of-the-above energy concept has enjoyed bi-partisan support for many years.[142]

To initiate this policy internationally, the U.S. should start by focusing on energy relationships in North America and with our European allies.[143] Canada has long been an important energy partner to the U.S. and "increased energy trade between the U.S. and Canada is viewed by many as a major contributor to U.S. energy security."[144] Canada is the largest foreign supplier of petroleum products, natural gas, and electric power to the U.S., and it is also the primary destination for U.S. energy exports.[145] Similarly, cooperative energy relations with Mexico will enhance energy security and help to sustain the U.S. economic base, partly due to the trade surplus as the U.S. sells more energy to Mexico than it imports.[146]

By becoming an increasingly important exporter of LNG, the U.S. can reduce the reliance of our European and NATO partners on Russian natural gas, enhancing our own energy security, as well as our national security and prosperity and that of our European allies.[147] While the U.S. faces near-term challenges, mainly because of the lack of LNG terminals in Europe, a new energy strategy would drive the U.S. toward this end.[148] Again, this approach would enable the U.S. to capitalize on its energy resources, increase net U.S. exports of energy, and would ultimately enhance energy security at home while ensuring leadership and energy diplomacy abroad. The U.S. should develop this new energy strategy during its period of relative energy abundance, rather than waiting for a crisis to necessitate change.

Conclusion

This is a time of consequence, not only for our country but for the energy industry writ large. Newfound access to vast oil and natural gas reserves in the U.S., coupled with the rapid expansion of renewable energy power generation and improvements in efficiency, are providing American's with unprecedented access to abundant, reliable, and affordable energy. While the conjunction of so many events and the rapid pace of change signals a time of historic opportunity, it also "creates major uncertainties and challenges for decision makers [making] the search for answers—and clarity—all the more urgent."[149] For this reason, the U.S. must remain resolute in its pursuit of the four key imperatives, covered herein, to maintain a competitive advantage in the energy industry and preserve its long-term energy security.

Figures

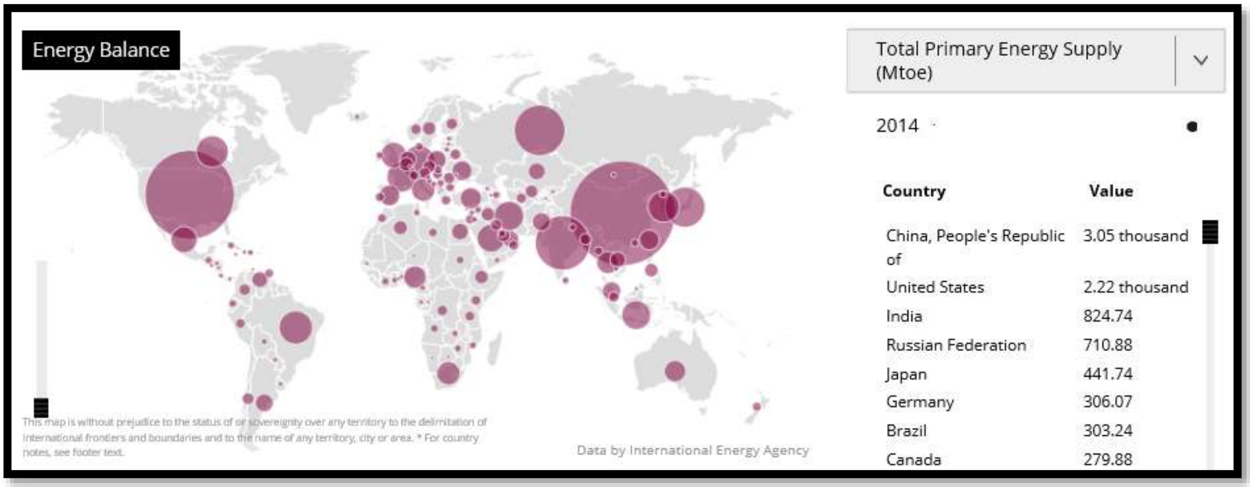


Figure 1: World Energy Balance: Total Primary Energy Supply (Mtoe)[150]

Figure 2: World Energy Balance: Total Final Consumption (Mtoe)[151]

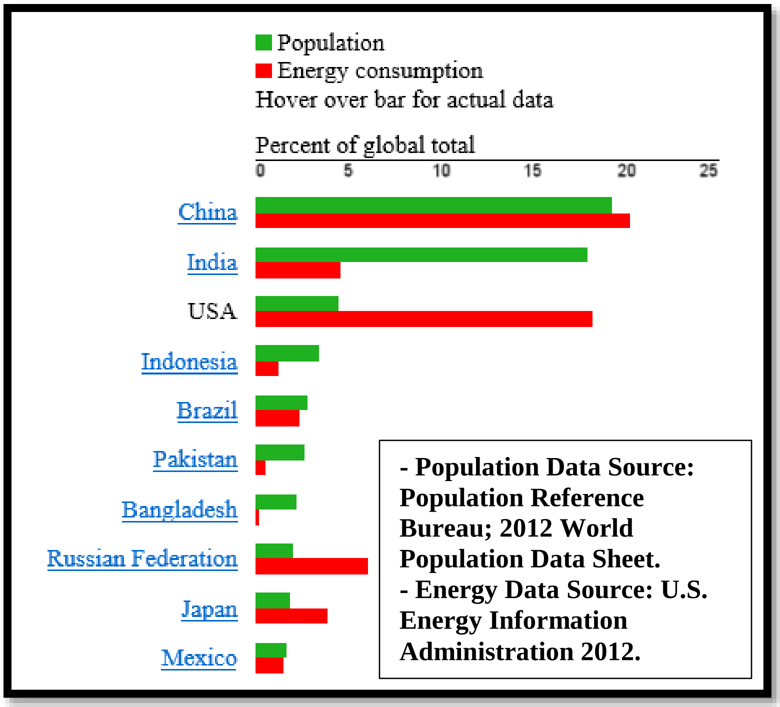


Figure 3: Population and Energy Consumption by Country (Top 10)[152]

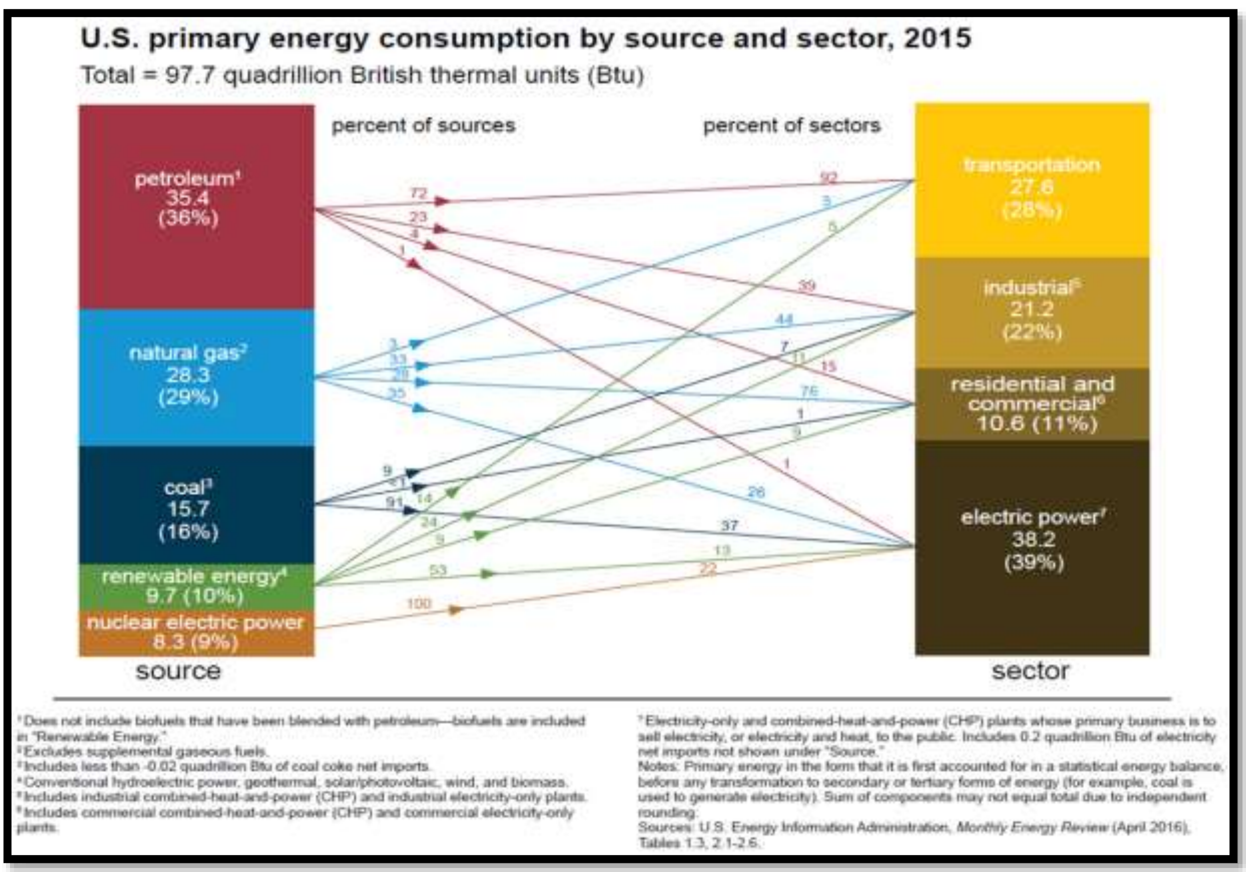


Figure 4: U.S. Primary Energy Consumption by Source and Sector, 2015[153]

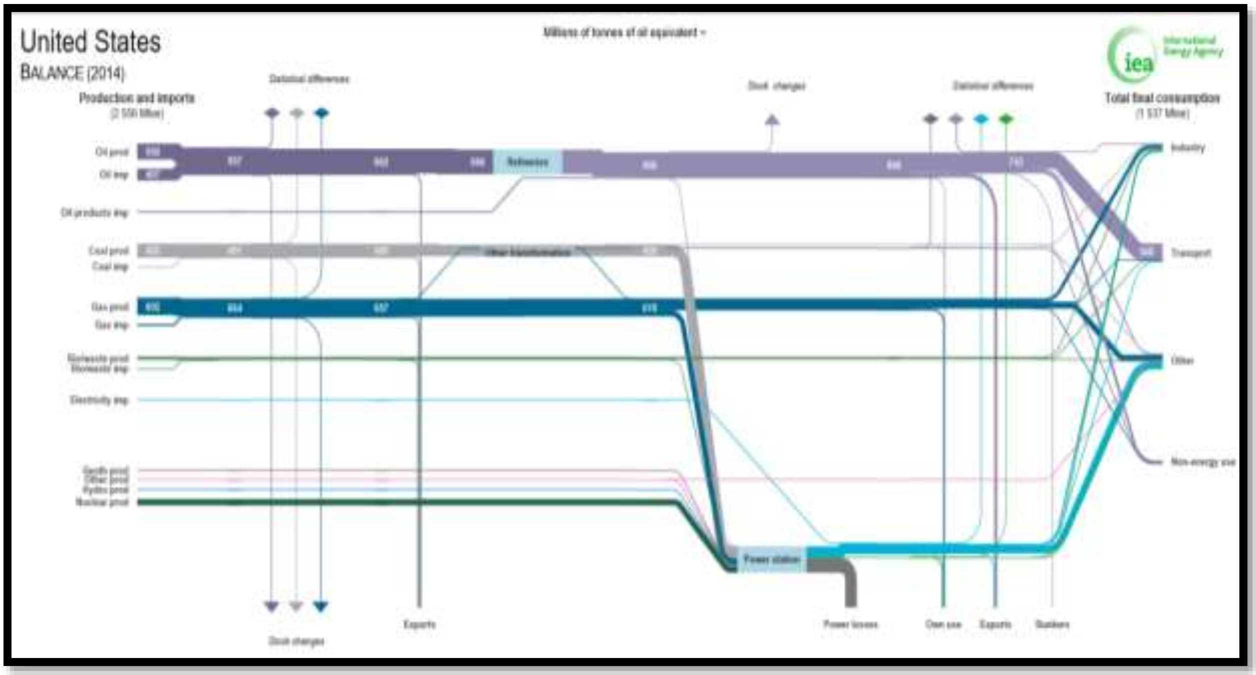


Figure 5: United States Energy Balance (2014)[154]

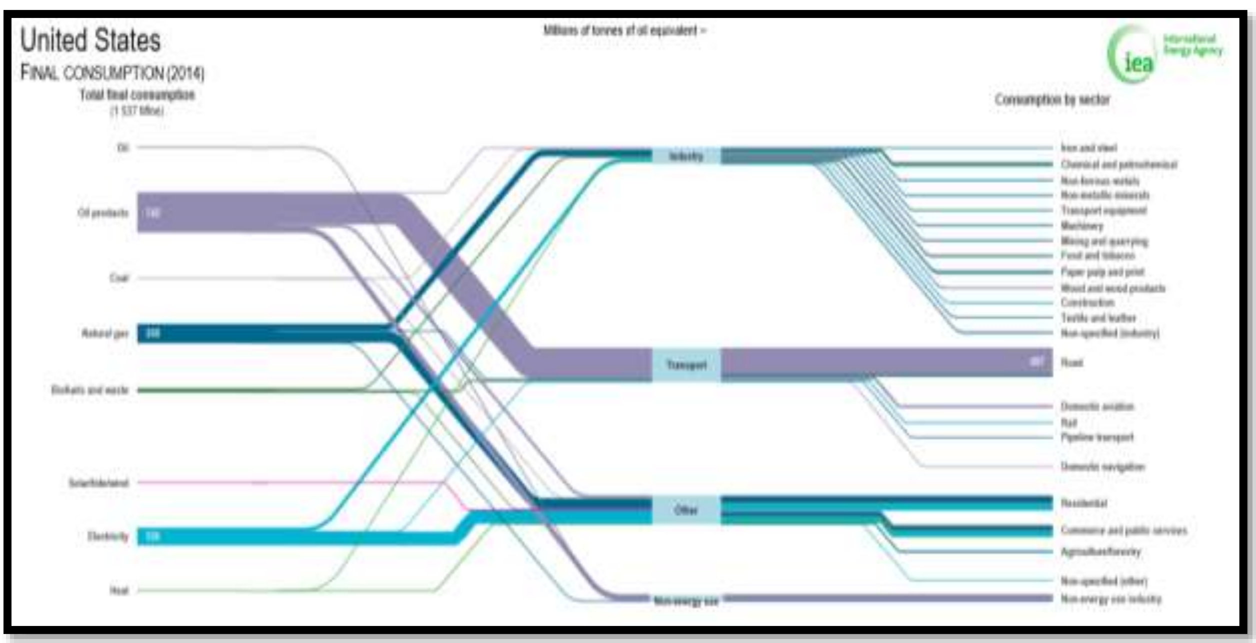


Figure 6: United States Energy Final Consumption (2014)[155]

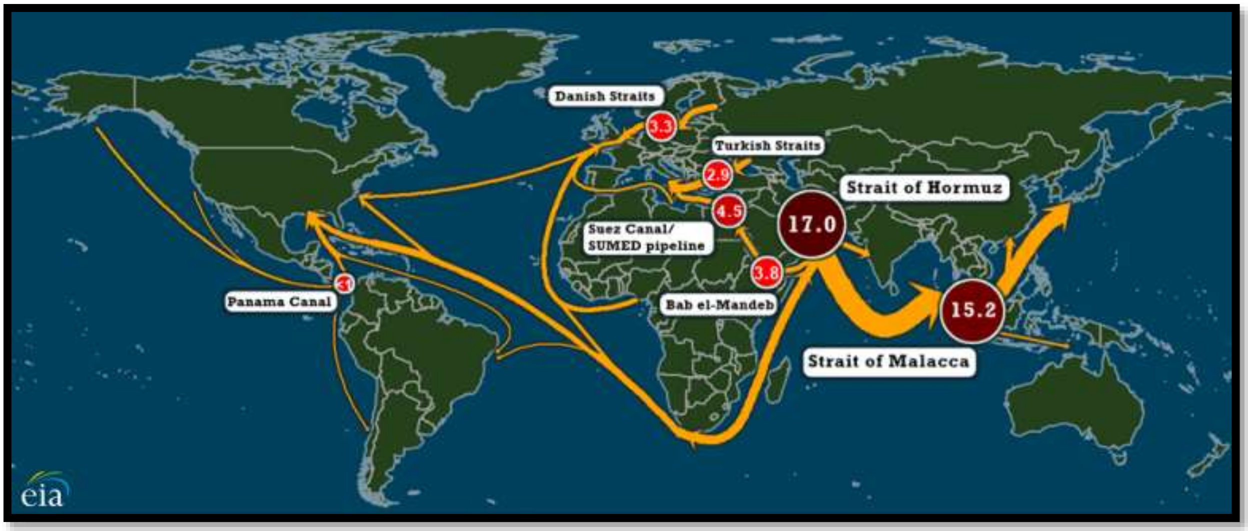


Figure 7: Daily Transit Volumes Through World Maritime Oil Chokepoints[156]

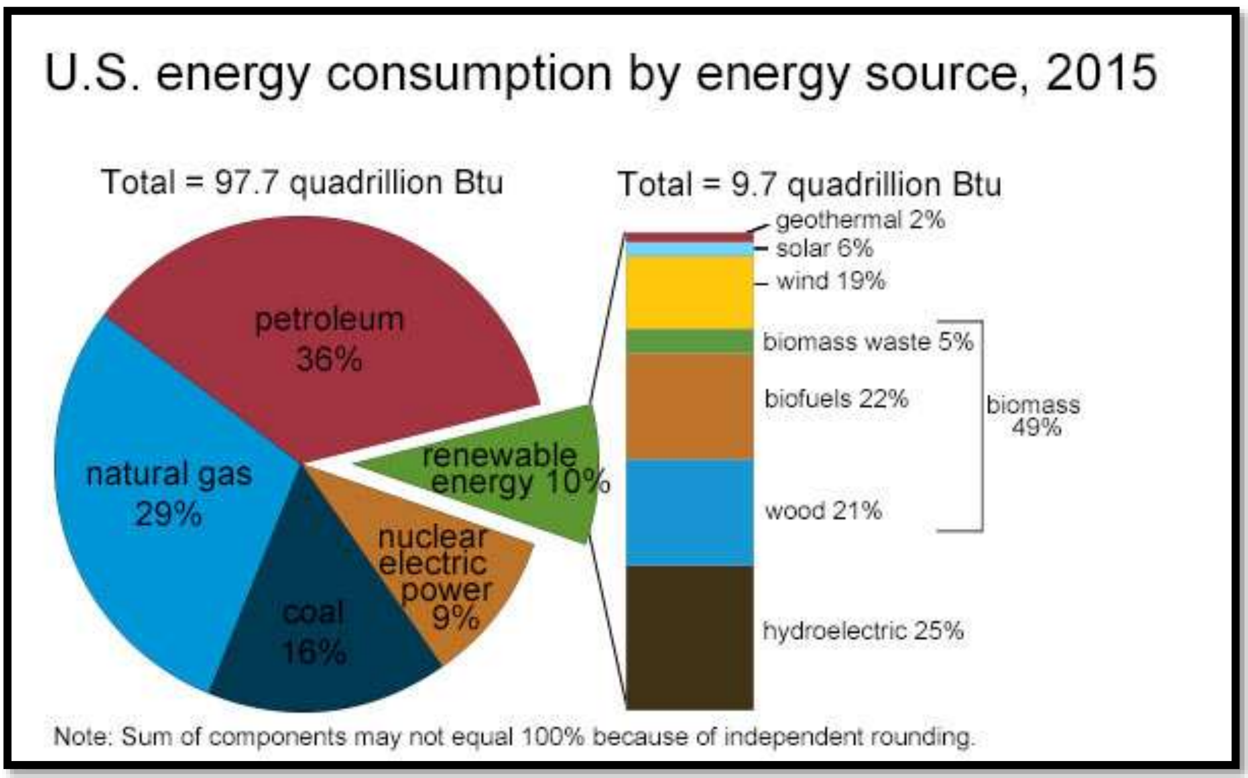


Figure 8: U.S. Energy Consumption by Energy Source, 2015[157]

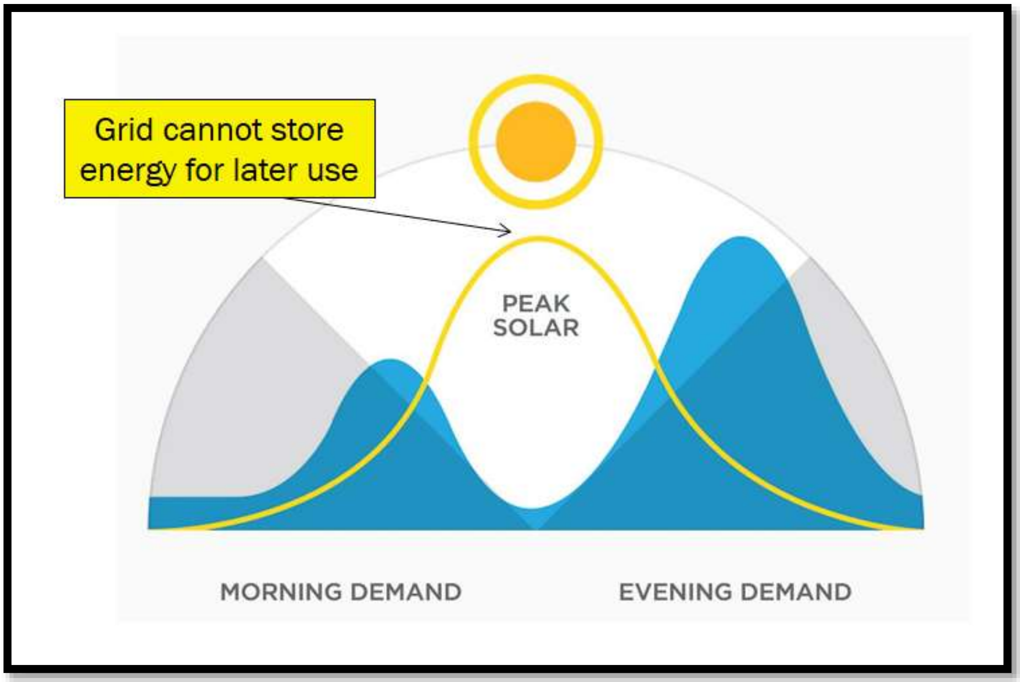


Figure 9: Generic Representation of Solar Supply vs. Energy Demand[158]

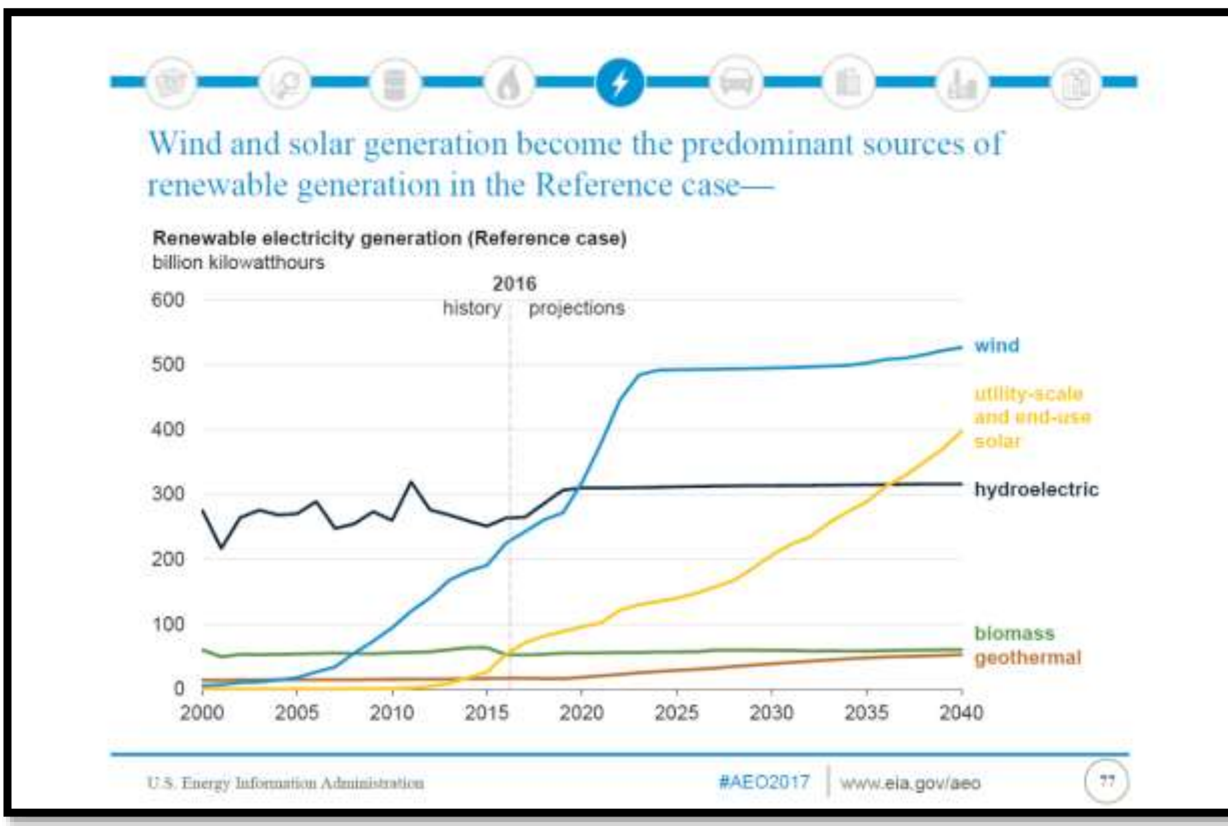
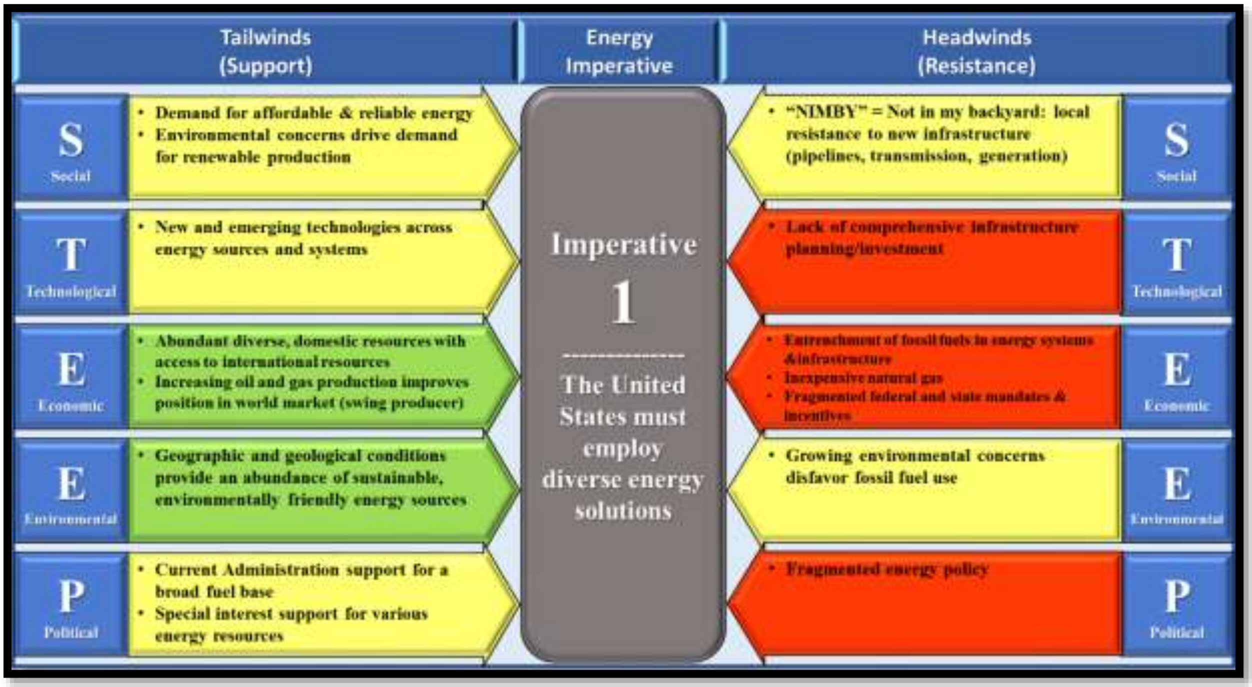
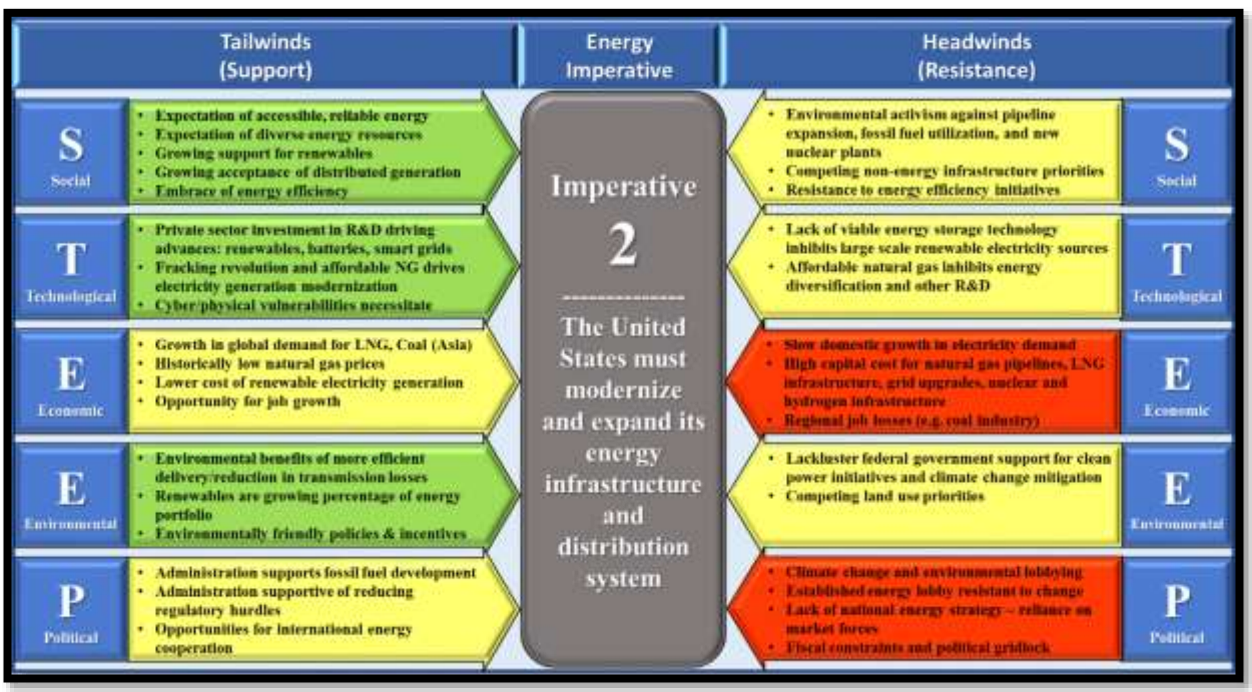


Figure 10: Renewable Electricity Generation (Reference Case)[159]

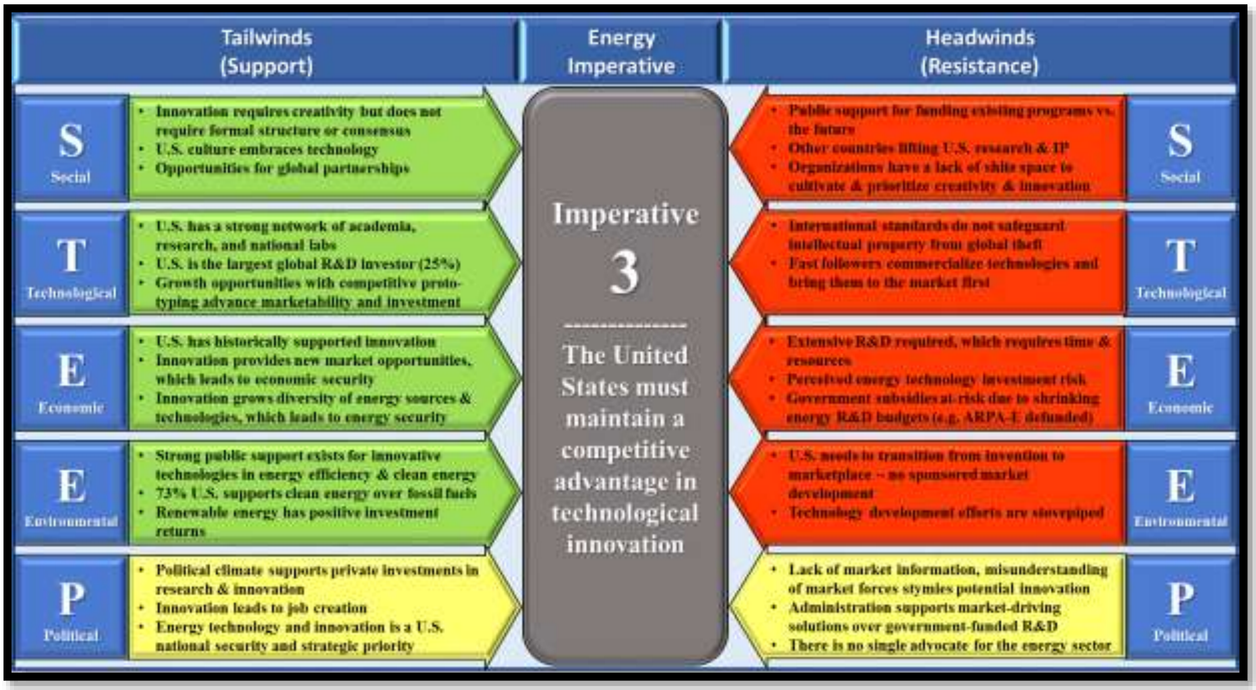
Diagrams for Force Field & STEEP Analysis



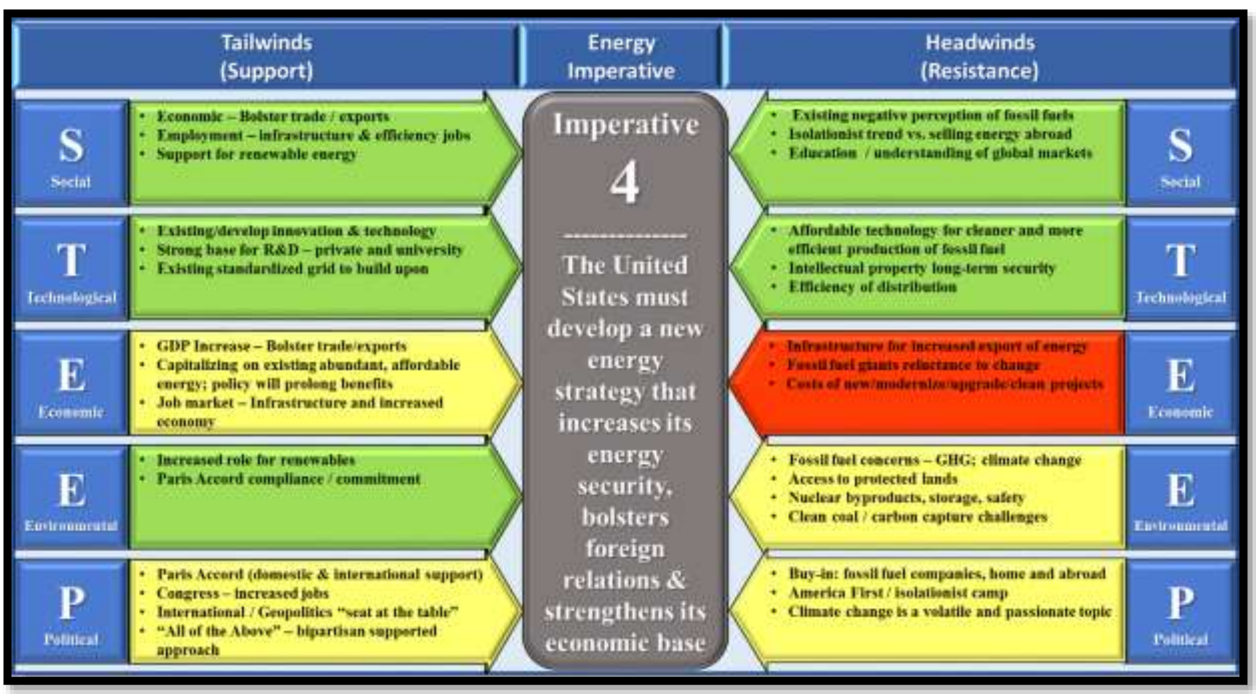
Imperative #1



Imperative #2



Imperative #3



Imperative #4

Glossary

- **Barrel (b)** – A barrel is a unit of volume or weight that is different depending on who uses the term and what it contains. For the purposes of the energy discussion:
  - 1 barrel (b) of petroleum or related products = 42 gallons

- **British Thermal Unit (Btu)** – A British Thermal Unit is the most commonly used unit for comparing the heat content of fuels. It is the quantity of heat required to raise the temperature of 1 pound of liquid water by 1 degree Fahrenheit at the temperature that water has its greatest density (approximately 39 degrees Fahrenheit). For Reference:
  - One Btu is approximately equal to the energy released by burning a match.
  - In 2013, the United States used about 98 quadrillion (written out, 1 quadrillion is a 1 followed by 15 zeros) Btu of energy
  - 1 barrel (42 gallons) of crude oil = 5,729,000 Btu (for U.S.-produced crude oil)
  - 1 gallon of gasoline = 120,405 Btu
  - 1 gallon of diesel fuel = 137,381 Btu (distillate fuel with less than 15 parts per million sulfur content)
  - 1 gallon of heating oil = 138,500 Btu (distillate fuel with 15 to 500 parts per million sulfur content)
  - 1 barrel of residual fuel oil = 6,287,000 Btu
  - 1 cubic foot of natural gas = 1,032 Btu
  - 1 gallon of propane = 91,333 Btu
  - 1 short ton (2,000 pounds) of coal = 19,882,000 Btu
  - 1 kilowatt-hour of electricity = 3,412 Btu

- **Million Tonnes Oil Equivalent (Mtoe)** – The tonne of oil equivalent is a unit of energy defined as the amount energy released by burning one tonne of crude oil.
  - 1 Toe = 39,683,207.2 Btu

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