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Energy

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ABSTRACT: New oil and natural gas discoveries, advances in drilling and extraction technology, and enhanced viability of renewable energy sources positions the United States on the cusp of an energy revolution. The current U.S. "All-of-the-Above" energy strategy fails to make a stand and chart a clear path to seize the initiative on this historic opportunity for U.S. energy security. The Eisenhower School energy study group recommends a new strategy—National Energy Transition 2050 (NET50)—and four prioritized sets of recommendations to shape the U.S. energy sector and better meet U.S. and allied interests.

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Industry Study Outreach and Field Studies

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Field Studies – Domestic:
Aramco Services Company Upstream, Houston TX
Atlantic Council, Washington DC
Cheniere Energy Inc. Sabine Pass Liquid Natural Gas Facility, Cameron LA
Congressional Research Service of the Library of Congress, Washington DC
CONSOL Energy Marine Terminal, Inc., Baltimore MD
Embassy of Canada, Washington DC
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EnerNOC, Inc., Boston MA
Engie Distrigas Liquid Natural Gas Import Terminal, Everett MA
Exelon Conowingo Hydroelectric Generating Station, Darlington MD
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Massachusetts Institute of Technology, Boston MA
National Security Council, Washington DC
PJM Interconnection, Audubon PA
Port of Houston Authority, Houston TX

SunEdison, Inc., Boston MA
U.S. Dept. of State, Washington DC
U.S. Energy Information Administration, Washington DC
U.S. Green Building Council, Washington DC
Wheelabrator Technologies, Inc. Waste-to-Energy Facility, Baltimore MD

Field Studies – International:
Blue Lagoon Research and Development Center, Svartsengi, Iceland
Carbon Recycling International Methanol Plant, Svartsengi, Iceland
Embassy of the United States of America, Reykjavik, Iceland
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HS Orka's Resource Park, Svartsengi, Iceland
Iceland Geothermal Conference, Reykjavik, Iceland
Icelandic Geothermal Cluster, Reykjavik, Iceland
Innovation Center Iceland, Reykjavik, Iceland
Landsvirkjun Hafid Wind Power Station, Hafid, Iceland
Landsvirkjun Irafoss Hydro Power Station, Irafossstod, Iceland
Landsvirkjun Ljosafoss Hydro Power Station, Ljosafossstod, Iceland
Minister of Industry and Commerce, Reykjavik, Iceland
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The starting point for energy security today as it has always been is diversification of supplies and sources.

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

Introduction

In 1901, the Hamill brothers struck oil at "Spindletop" mound in Beaumont, Texas.[1] It was the largest discovery of oil in America at the time and positioned the United States as a world leader in oil production and supply for the next seven decades.[2] This trend reached its zenith in the early 1970s, when U.S. oil production began to decline and the Middle Eastern "oil shocks" of 1973 and 1979 highlighted deep vulnerabilities in U.S. energy security.[3] The United States remained dependent on oil imports for the next four decades (see figure 1).[4] Then in 2006, EOG Resources, Inc. discovered the Parshall Oil Field in the Bakken shale formation of North Dakota.[5] Advances in horizontal drilling and hydraulic fracturing technologies enabled the shale oil boom that continues to present day. This development in the U.S. energy portfolio, combined with similar progress in natural gas exploration and energy conservation efforts, put the United States on a path to becoming a net exporter of energy potentially as early as 2019, by one Energy Information Administration (EIA) projection.[6] The recent transformation of U.S. energy production, however, still relies heavily on fossil fuels, the extraction, production and use of which releases significant amounts of greenhouse gases (GHG) into the atmosphere and contributes to climate change. A transition to cleaner renewable sources of energy such as hydroelectric, wind and solar would greatly reduce GHGs, although these sources have limitations of their own. Theoretically, supply and demand within energy-related markets will drive an equilibrium production quantity and price for the various sources of energy. Unbridled capitalist markets, however, are insufficient in providing public goods such as national security and environmental protection. For example, fossil fuels are at historically low prices, so markets would naturally select those sources at the expense of national security (dependence on foreign energy) and environmental protection (increases in GHG emissions). This report focuses on government intervention necessary to shape U.S. energy markets to balance the development of these public goods while simultaneously ensuring economic growth.

The United States must develop a comprehensive national energy strategy—National Energy Transition 2050 (NET50)—to realize an energy-enabled economic and national security advantage—or, an "Energy Offset"—and must pursue the following sets of recommendations: monetize negative *and positive* externalities of energy sources; promote policy to expand investment in European liquid natural gas (LNG) markets and enhance U.S. allies' energy security; expand investment in energy infrastructure; and expand energy research and development (R&D) to build energy enterprise resilience and manage risk. The associated vision is: a modernized U.S. energy infrastructure; U.S. economic markets that balance national security, environmental protection and economic benefit; a U.S. energy sector technologically modernized by the U.S. R&D establishment; and resilient energy security for U.S. allies. This report first defines the energy sector of the U.S. economy in three segments—fossil fuels, non-fossil fuels and enablers—and describes the energy sector's nexuses with national security, the environment and the economy. Second, the paper describes the current conditions, challenges and outlook for each of the three segments. Third, it summarizes the energy study group's findings. Fourth, it addresses proposed government goals, outlining the federal government's responsibility for an energy future. Finally, the report culminates with policy recommendations and implementation needed to position the nation for the energy transformation ahead.

The Energy Sector Defined

The energy sector of the U.S. economy is comprised of hundreds of related industries with thousands of firms that supply energy or related products and services predominately centered on 10 energy sources: oil, natural gas, coal, nuclear, hydroelectric, wind, biomass, solar, geothermal and biofuels. In 2014 the sector provided 1,989 million tons of oil equivalent (Mtoe), second only to China at 2,555 Mtoe.[7] For purposes of discussion, this report groups energy industries into three segments: fossil fuels, non-fossil sources and enablers. Firms in these segments supply electrical power, transportation fuels and related products and services as driven by demand from residential and commercial consumers both domestically and abroad.

Fossil Fuels, Non-fossil Sources and Enablers

Coal, natural gas and crude oil are the predominant fossil fuels, generating approximately 67 percent of electricity supply to the U.S. power grid in 2015.[8] Crude oil-based petroleum fuels such as gasoline, diesel and jet fuel account for approximately 89 percent of the U.S. transportation fuel market.[9]

Non-fossil energy sources encompass nuclear, hydropower, wind, biomass, solar, geothermal and biofuel. Running a distant third to coal and natural gas, nuclear energy contributes approximately 20 percent of U.S. electricity generation.[10] The remaining non-fossil fuels—"renewables"—represent 13 percent of electricity generation in the United States.[11] Heavily subsidized biofuels contribute a mere five percent of U.S. transportation fuel needs.[12] In full consideration of the impact fossil fuels have on the environment, renewable sources must play an expanded role in the U.S. energy portfolio of the future.

Numerous supporting industries provide critical enabling capabilities within the energy sector. Most notably, these include electrical grid infrastructure, pipeline infrastructure, water, energy storage, R&D and cybersecurity. The health of these industries are no less critical to the energy sector than the energy providers themselves. For example, the electrical grid is a foundational capability without which producers could not provide electrical power to consumers. Electricity is so integral to the American way of life and the U.S. economy that interruptions to its distribution can cost lives and billions of dollars. The 11 deaths and $6 billion in economic loss attributed to the 2003 Northeastern Blackout stands as an example of this.[13]

The Energy-National Security Nexus

In modern history, energy and national security are inseparable. Noted energy author Daniel Yergin observes, "The point at which energy security became a decisive factor in international relations was a century ago, in the years just preceding the First World War."[14] Since then, the energy sector greatly expanded in the number of sources and quantities supplied to match the seemingly insatiable growing demand. With global energy consumption projected to increase 50 percent by 2040, "energy security is not just about countering the wide variety of threats; it is about the relations among nations, how they interact with each other, and how energy impacts their overall national security."[15] Articulated in terms of threats to national security, "Today, this (oil) dependence constrains foreign policy, limits military options, and harms economic growth and fiscal stability."[16] Some of these sources of energy originate in unstable and unpredictable regions or nations. Some even suggest the United States fought the Gulf War in the early 1990s not to protect the Kuwaiti people but to preserve access to that nation's oil. The United States projects power globally through its expeditionary military, which consumes enormous amounts of energy in the process. Electricity is a critical enabler of operations at U.S. military bases in the United States and abroad, and petroleum products fuel many weapons of war. U.S. energy infrastructures also represent a potential national security issue as they come under attack by terrorists or state-sponsored actors. In a meticulously planned 2013 attack on the Metcalf Transmission Substation in California, snipers caused significant damage to 17 transformers at the Pacific Gas and Electric site.[17] While the disruption to electrical flows was minimal, and though officials believe the attack was an act of domestic terrorism, this incident illustrates that the potential for larger scale, internationally motivated attacks exists.[18] Many industry analysts believe that the infrastructure used to produce and transport energy is vulnerable to cyber as well as conventional attacks.

Allied energy security is a key element of U.S. national security as well. Trade in global energy markets provides leverage to suppliers in such a way that actors can "weaponize" energy as illustrated when Russia cut off gas supplies to European countries for political motives. While the United States cannot extend full energy independence to its allies, it can enhance their energy security by creating global markets and exporting U.S. energy surpluses to help stabilize the global energy marketplace. Energy markets also align the strategic interests of neighbors, leading to collaboration in the pursuit of shared interests. Specifically, in North America and the European Union, energy cooperation reinforces alliances, as seen in current initiatives to enhance LNG infrastructure in Europe. Secure, diversified and redundant energy sources stabilize energy markets, improve global security and help prevent conflict arising from energy scarcity and nefarious disruptions to energy supplies.

The Energy-Environment Nexus

There is an inextricable link between the energy sector and the environment. In particular, the phenomenon of manmade climate change is broadly accepted as fact by the scientific community. The cause of climate change is the "greenhouse effect" in which GHGs (carbon dioxide, methane, nitrous oxide, and water vapor) released into the atmosphere absorb energy and act as a blanket around the Earth.[19] This effect causes an increase of average temperatures across the Earth as more energy enters than leaves the atmosphere.[20] On average, Earth's temperature rose 1.4 degrees Fahrenheit over the last century.[21] As highlighted in figure 2, the 2014 U.S. National Climate Assessment illustrates that human contributions of GHGs drove the observed temperature increase over the last century.[22] Industrialization, energy production and energy consumption have driven an exponential rise in GHG emissions since the early 1900s (see figure 3).[23] Currently, scientists forecast a two to 12 degree Fahrenheit temperature increase by the year 2100.[24] They forecast that a simple two degree increase will equate to a five to 15 percent decrease in current crop yield, a three to 10 percent increase in precipitation during extreme weather events, a five to 10 percent decrease in some river flows, and a 200 to 400 percent increase in wildfire area burned.[25] Sea levels rose nine inches over the past 140 years and will likely rise an additional 1.5 to three feet by 2100, causing catastrophic flooding along coastlines worldwide.[26] Ultimately, climate change is causing heat and precipitation events to become more extreme in nature. This will continue to worsen unless GHG emissions are curbed.

At the recent 21st Conference of the Parties (COP21), 190 countries agreed to a "best effort" target of limiting global warming to no more than 2.0 degrees and an absolute target of no more than 1.5 degrees Celsius.[27] Each country pledged contributions to curb GHG emissions. The United States is currently on track to reduce GHG emissions by 17 percent from 2005 levels by 2020 (see figure 4). Further, the U.S. COP21 pledge aims to reduce all GHG emissions 26 to 28 percent below 2005 levels by 2025.[28] The U.S. contribution pledge is in line with a commitment to reduce overall GHG emissions by 80 percent from 2020 to 2050.[29]

The U.S. energy sector also impacts global water supplies, as some energy production requires significant amounts of water for cooling and other applications. This stresses the global fresh water supplies for human consumption and agriculture.

The Energy-Economic Prosperity Nexus

Energy sources, technology and geopolitics change over time, but "underlying everything else is the fundamental need of countries—and the world—for reliable energy with which to power economic growth."[30] Reliable electricity is vital to the investment culture in any country, serving as the foundation for economic development. Roughly two thirds of energy use powers the economy through industry, transportation and commercial buildings (see figure 5).[31] Without energy, industry comes to a standstill. Additionally, some advanced manufacturing industries such as superconductor and microchip production require extremely stable sources of electricity to produce their product.

Current Condition, Challenges and Outlook

As previously mentioned, the U.S. energy sector is vast, with thousands of firms competing in numerous industries and markets. The following section provides a broad overview of the current health, challenges and outlook for fossil fuel, non-fossil sources, and enabler segments of the sector.

Fossil Fuel Segment

Overall the fossil fuel segment operates in a monopolistically competitive environment with a relatively low concentration of firms. Though each fossil fuel industry is capital intensive and requires substantial permitting, a variety of firms operate within each industry with no truly dominant firms.

The significant challenge for the fossil fuel segment is reduced prices and a corresponding downturn in profitability. High oil prices over last decade led to profitability for higher cost extraction techniques like hydraulic fracturing—or "fracking"—which fueled the shale oil boom. Declining prices, however, put economic pressure on smaller firms. A drop in profits caused consolidation, especially in coal, and drove the remaining firms to find efficiencies and economies of scale in production. The oil and coal areas of the segment historically trade in a global market, while natural gas largely trades regionally (e.g., intra-Europe, -Asia, -North America) due to transport constraints.

The short-term outlook for fossil fuels includes higher prices for both oil and natural gas. The EIA predicts crude oil prices will rise in mid-2017 due to expanding demand in developing Asia, and natural gas prices will rise later this year due to continued expansion of its domestic use to generate electricity.[32] Conversely, coal prices will remain suppressed in the United States due to environmental policy demands, which will likely spur increased exports to developing countries as domestic demand wanes. Due to increased production capability in the United States and

Australia, modifications to U.S. export laws, and enhanced infrastructure, LNG is transforming the natural gas market from regional to global.

Crude Oil. Oil drilling and extraction in the United States doubled over the last decade from five to 10 million barrels per day, improving U.S. energy security by reducing dependence on oil imports.[33] Increased U.S. production, however, flooded global oil markets with abundant oil, which drove down global oil prices. The weak price of oil is economically challenging firms in these industries, especially those lacking industry diversification.

The U.S. oil extraction and petroleum refining industries' outlook in the short-term is challenged by historically low prices. However, global economic growth will reverse this trend over the next five years as the demand for oil and gas expands around the world.[34] Emerging economies such as China and India will drive prices up and stimulate U.S. exports of oil and refined hydrocarbon products.[35] While important technology advances in electric and hybrid vehicles will continue to permeate the automobile market, these will have only minimal impact on the demand for gasoline.[36] According to table 2, the major negative externalities of oil include emissions, safety, and long-term sustainability.[37]

Natural Gas. Fracking transformed the U.S. energy outlook and propelled natural gas to the forefront of the nation's energy profile. As of 2015, natural gas accounted for 33 percent of the electricity generation energy portfolio and is quickly overcoming coal as the backbone to U.S. electrical power production.[38] Domestic natural gas production increased during the last decade from 63 to 91 billion cubic feet per day, and enabled the ongoing transition from LNG imports to exports.[39] Though industry concentration is low, depressed prices continue to challenge smaller firms to remain competitive in the market forcing some consolidation. Larger firms, with greater economies of scale, can better withstand the interim downturn in prices.[40]

The natural gas outlook is strong for the foreseeable future. Production of natural gas is projected to increase 45 percent by 2040 within the United States.[41] Despite the downward trend in pricing, the forecast for future natural gas drilling is promising, with natural gas prices expected to rebound through 2020 due to demand. New power plants planned throughout the United States are expected to utilize natural gas due to environmental advantages over other fossil fuels. The abundance of domestic natural gas from fracking allows the United States to become a natural gas exporter and enables it to establish long-term commitments with international customers.[42] As of May 2016, industry firms are constructing six LNG export facilities with three additional facilities approved and awaiting construction.[43] As an LNG exporter, the United States can now leverage this resource by providing its partners and allies with alternatives to Russian gas. Natural gas is considered a much cleaner burning fossil fuel emitting approximately half the carbon dioxide (CO_2) when compared to coal.[44] Natural gas CO_2 emissions are still high compared to cleaner energy sources, so U.S. energy policy should consider it a bridging fuel as the United States transitions to renewable sources in the long-term. According to table 2, negative externalities include emissions and water quality impacts, while the positive externalities include reliability, dispatchability and responsiveness. Investments in carbon capture R&D could provide methods to mitigate and reduce the emissions externality.

Coal. Coal is a challenged resource. Despite the fact that it is cheap and abundant with a 265-year reserve, it is an unclean source of energy.[45] The negative effects of coal range from acid rain; elevated carbon dioxide, sulfur dioxide, and methane emissions creating greenhouse effects that in-turn contribute to global warming; contaminated ground water; coal seams that burn over long periods of time; and environmental pollutants that contribute to smog, haze and respiratory illness among other medical afflictions.[46]

These challenges spawned incentives and policies that forced the decline of coal use now and for the foreseeable future. The outlook for coal is changing from its previous position as the driving energy resource of the U.S. economy to that of a significantly minimized player in the sector. Overall the short-term economic outlook for coal will see upswings due to increased exports to developing countries. However, long-term downward pressures on coal production will increase as the global community continues its efforts to move away from coal towards a more comprehensive clean energy strategy.[47] Referencing table 2, coal's negative externalities include emissions, effects on water quality and safety, while the only positive externality is reliability. Potentially, only a breakthrough in water-efficient carbon capture would restore the coal industry's viability as a long-term energy source in the U.S. portfolio.

Non-fossil Fuel Segment

Overall Assessment. Non-fossil energy sources, including nuclear energy and renewables, play a vital role in energy security. This segment has a strong future in the United States but requires oversight and planning as America transitions from fossil fuel-based energy to renewable forms. Public support for non-fossil sources is high. Market support, however, wavered with the recent drop in fossil fuel costs. As a result, many non-fossil energy options rely on government-provided economic incentives to compete in the market. The market for non-fossil sources ranges from monopolistic to oligopolistic. The overall market environment for non-fossil energy is highly competitive with high barriers to entry. A second issue is solving how to store non-fossil fuel energy to enhance its dispatchability.

The non-fossil fuels segment of energy gained public support due in part to heightened awareness of climate change.[48] Developments in renewables enabled the beginnings of a transition of the American energy sector away from traditional forms of energy such as oil and coal. Nuclear and hydroelectric energy producers provide carbon-free base load power required for a stable and reliable grid. The main challenge for the non-fossil segment is the short-term year-by-year nature of tax credits and other government assistance. Firms need predictability to reduce risk, secure investment and financing, and establish a path forward for the transition to non-fossil based sources. Without a government strategy, the transition from fossil-based energy sources to non-fossil energy will be haphazard and inconsistent and will create energy gaps and undue stress on public and private firms.[49]

Nuclear. The nuclear energy industry is steadily receding due to market forces and lacks a long-term government plan. Nuclear energy is declining primarily in unregulated energy markets where producers must compete with a glut of inexpensive, domestically produced natural gas. However, nuclear power still provides a reliable source of electricity and will for at least the next 15 to 30 years. Proven reserves of the primary fuel, uranium, exist in a large number of countries including Australia, Canada, South Africa and the United States.[50] Nuclear power capacity is expected to decline unless the U.S. government enacts significant policy changes to support new plant construction. The recent defeat of U.S. GHG legislation, which includes a carbon cap-and-trade system, and delays to the Clean Power Plan exacerbate nuclear energy's uncertain position by continuing to ignore its positive externalities in the market.

Despite its strong record of safety, the public's perception of incidents like Three Mile Island, Chernobyl and Fukushima contribute to negative opinions of nuclear energy and a weakened outlook.[51] Further, market forces and a lack of consistent government support for nuclear energy limit the industry. Nuclear energy firms are attempting to increase production by up-rating existing power plants; however, this does not fully offset plants shuttered by competition with cheap natural gas. The most significant limiting factor for new nuclear power plant construction is the large capital investments required. Spent nuclear waste poses another significant challenge. The Obama administration closed the Yucca Mountain Nuclear Waste Repository not for technical or safety reasons but due to "social and political opposition."[52] The lack of a central repository for spent nuclear fuel will impose an undue economic burden on the industry and the American economy. Extended local storage of spent fuel will cost $30 to $60 million per site, and restarting the process to investigate repository alternatives will cost "billions" according to a General Accounting Office report.[53] As such, Congress legislating the reopening or restart of the Yucca Mountain Nuclear Waste Repository project is the least costly option.

The U.S. commitment to COP-21 could drive the monetization of the positive externalities of clean nuclear power, but that remains one of the only hopes for future nuclear power growth. Referring to table 2, one key positive externality of nuclear energy is that it emits no GHGs. Nuclear energy is also inexpensive, safe, reliable and resistant to price volatility.[54] Nuclear energy's negative externalities are its inability to adjust rapidly to demand loads, its reliance on non-domestically sourced fuel and complications associated with nuclear waste disposal.

Hydroelectric power. Hydropower has a positive outlook in the near and long-term. The industry is mature and revenue generally grows at the same pace as the economy.[55] Although social and political factors will likely limit the construction of new large-scale hydro facilities, operators will concentrate on projects that maximize the benefits of existing infrastructure, such as increasing the capacity and efficiency of current facilities and adding electricity generating infrastructure to pre-existing dams.[56] Hydropower will continue to be an important component of the renewable, low-emissions energy landscape. However, it remains vulnerable to decreased rainfall as a result of climate change. Hydropower has high barriers to entry due to infrastructure costs, limited suitable sites and state and federal regulations on damming water resources. Opportunities include increased demand for energy storage in the form of hydro closed-loop pumped storage systems, alleviating some of the current environmental and regulatory concerns.[57] Technology advances such as hydrokinetic, tidal and wave power have the potential to open up enormous new sources of hydropower generation.[58]

A positive externality is that hydro energy is a form of green baseload energy, easily dispatched to increased demand, and *black start* capability to recover from a power grid failure (i.e., blackout). Hydropower is susceptible to drought conditions, however, and dams present challenges for downstream fisheries. Hydropower has low emissions and, as shown in table 2, is highly sustainable, with low impact to air and water quality, and it is dispatchable and responsive. Its negative externality is susceptibility to precipitation shifts, which will persist with climate change, and it has the potential to impact fisheries.

Wind. In 2015, the wind industry produced 4.7 percent of the total U.S. demand for electricity.[59] Wind electricity generation is up 12 percent from 2014, and the EIA projects another nine percent increase into 2016.[60] The biggest barriers to the wind industry are the upfront cost of capital, transmission lines and intermittency. The majority of wind farms are far from highly populated areas, so grid infrastructure is necessary to transmit the power to population centers. An extension of multi-year production tax credits drives carbon emission reductions, and long-term power agreements have U.S. wind power projections trending in a positive direction through 2020. "The U.S. Department of Energy's new Wind Vision report found that the United States could obtain 10 percent of its electricity from wind by 2020, 20 percent by 2030, and 35 percent by 2050."[61] The industry has momentum but requires continued government assistance to achieve success.[62]

Positive externalities of wind power are low carbon emission, good sustainability, low impact on water resources and a strong safety record. With respect to negative externalities, wind is an unreliable intermittent source and thus lacks dispatchability and responsiveness.

Biomass. Firms produce energy from biomass by burning municipal waste or other combustibles (e.g., wood) to drive electricity generating turbines. High barriers to entry exist in the biomass energy sector due to economies of scale and heavy regulation of GHG emissions, setting the stage and conditions for intra-market competition.[63] Biomass energy firms compete not only with other power generators for customers but also with landfill owners and operators for their inputs of production. Biomass has a high competition from substitutes in the form of other renewable energy sources and low natural gas prices. The public largely perceives biomass facilities as visually and aromatically unappealing, resulting in limited siting in populous areas. Climate change will increase the demand for environmentally responsible means of waste disposal and potentially drive the sector to environmentally sound practices such as GHG capture and reuse, recycling and waste-to-energy conversion.

The outlook for the market is bright. In recent years, the market enjoyed two percent annual growth due to increases in the U.S. population's consumption and demand for associated services.[64] Continued growth would require government regulation support, such as allowing limited emissions in exchange for reducing landfill growth. Consistent with the theme of this report, by quantifying biomass's positive externalities, the U.S. government will recognize a need for this industry in the energy portfolio of the future. A positive externality for biomass energy is the reduction in the use of landfills to support a community's waste management, which also has positive effects on aquifer water quality. Additionally, biomass energy has low carbon impact as it is fueled by post-consumer goods which otherwise would end up in landfills contributing to methane production, a more potent GHG than CO_2. Additionally, biomass plants capture waste metals used during the incineration which is then recycled and sold to recycling firms.[65] Negative externalities are the unresponsive nature of biomass plants and its emissions of GHGs (e.g., CO_2). Advances in carbon capture technology would enable the biomass industry to reduce hazardous emissions.

Solar. In the United States, the development of renewable energy options, especially solar has grown largely because of initial regulatory support through tax credits and other incentives. That policy environment allowed the industry to expand and contributed to lower costs and more investment in R&D to improve efficiency. U.S. tax credits provide predictability and stability in the solar market, but if discontinued, the solar industry will become volatile resulting in high risk for investors.[66] Positive externalities of solar energy include its low emissions, sustainability and low impact on water quality. Negative externalities include unreliability and intermittency due to dependence on cloudless days. Advances in energy storage capacity would address intermittency issues associated with solar power.

Geothermal. Several limitations hamper geothermal from becoming more prominent, including significant costs associated with exploration and the uncertainties associated with site exploration. Another challenge is the financial risk associated with geothermal power plant construction, which is relatively expensive. Additionally, only a few areas in the United States (e.g., the west coast, Alaska, Hawaii) have a tectonic fault line or an active volcanic vent, which is required to support geothermal power plants.[67] There is a significant threat of substitute from other energy sources such as inexpensive natural gas and established nuclear power plants. Separating geothermal heating and energy will aid in its growth, as geothermal heat is not beholden to geography as is geothermal energy production. To properly support the industry, the U.S.

government would need to craft policy that distinctly addresses geothermal energy for electricity production and heating.[68]

Drawing a distinction between the two different types of geothermal energy (residential heating and electricity generation) can enhance policy for and propagation of both. For example, while geothermal electricity generation is only practical on the west coast, Alaska and Hawaii, geothermal residential heating is viable anywhere in the northern tier of the continental United States and Alaska.[69] According to the 2015 U.S. and Global Geothermal Power Production Report, the U.S. market has 1,250 megawatts (MW) of geothermal power under development with 500 MW awaiting power purchase agreements.[70]

Some positive externalities include sustainability and reliability. Geothermal energy has no significant negative externalities, with the exception of odors associated with hydrogen sulfide emissions.

Biofuels. The biofuels industry declined over the past five years due to subsidy reductions and public focus on water use, production costs and elevated food prices.[71] The biofuels industry is volatile, because farmers depend largely on government subsidies for revenue.[72] No single business maintains a controlling share of the market.

The biofuels outlook is modest growth with an anticipated increase in annual production value from $46.7 to $48.8 billion in the five years to 2021.[73] However, biofuels heavily depend on government policy support for renewable energy sources. This includes tax credits and farm subsidies, the latter of which indirectly supports the biofuels production industry.

Referencing table 2, the negative externality for biofuels is significant land use and water consumption, while some of the positive externalities include sustainability, dispatchability and responsiveness. Further R&D in genetic engineering could enable biofuels feedstock growth with less water consumption, reducing its negative externality.

Enablers Current Condition and Outlook

Overall Assessment. Energy enablers include pipeline and electrical grid infrastructure, energy storage, cybersecurity, water supply and R&D. In the United States these enablers require attention across their lifecycle, with investment required to update and enhance current capabilities while simultaneously designing and implementing next generation technologies. Pipeline and electrical infrastructure sectors, for example, continue to age, consisting of antiquated designs which are incompatible with emerging technologies. Additionally, most enabler designs predate cybersecurity concerns. Failure to keep pace with potential threats places energy infrastructure at significant risk. Furthermore, little monetary incentive exists for firms within this sector to repair and modernize existing systems. All of these concerns highlight potential reliability issues.

Generically, the enabler sector is dominated by competitive markets. Pipeline, grid and water supply infrastructures consist of smaller regional suppliers. R&D is predominantly performed by universities and smaller start-up firms. The only outlier, energy storage, generally operates as an oligopoly.[74] For the most part, few external threats exist throughout the enabler segment. Firms typically dominate their regions and do not compete on a national scale. Upfront capital costs maintain barriers to entry and reduce competition within the segment.

As a whole, enabler firms continue to show signs of economic health. There is, however, little economic incentive to improve infrastructure. Firms often collect fees for use of their systems and pass on costs to energy producers and consumers who typically bear the expense of any inefficiencies. Here again, energy storage is an outlier, struggling to find a method to develop a pricing structure for the offset to production it provides during peak demand and the associated resilience potential it holds for the grid. Ultimately, the enabler segment needs legislation to monetize externalities, spur investment and modernization, and reap the security benefits of the Energy Offset through R&D.

Pipeline infrastructure. The United States has nearly 2.5 million miles of pipelines.[75] The associated pipeline industries' outlook is positive as demand continues to increase due to affordable shale gas and oil production and a growing LNG export market. The EIA expects U.S. net exports of natural gas to range between 3.0 and 13.1 trillion cubic feet by the year 2040.[76] The removal of the U.S. crude oil export ban also promotes growth within these industries, increasing the demand for infrastructure to carry petroleum to export facilities.

A major challenge for the industries is that pipelines are not a single system but rather a disjointed conglomeration of individual systems. These aging systems are in need of repairs and improvements. In 2009, leak data indicated approximately one leak for every eight miles of main distribution lines and one leak for every two miles of service lines.[77] Storage facilities leak an estimated 100 billion cubic feet of methane per year.[78] Unfortunately, regulatory agencies do not have sufficient personnel to adequately inspect and enforce regulations pertaining to the natural gas pipeline system. Exacerbating the issue, there is currently little direct monetary incentive for firms to fix and upgrade systems. Producers and consumers pay for leak-induced losses without regard to the GHG emissions, creating a negative environmental externality.[79]

Electrical grid infrastructure and cybersecurity. The U.S. electrical grid is antiquated and inadequate to meet future demand. Electricity demand is forecast to grow in the years/decades to come, yet the backbone of the U.S. electrical transmission system is not postured to accommodate this growth.[80] Additionally, current infrastructure is not optimized for the distribution of renewable power inputs like solar and wind. Some grid infrastructure, including the transmission lines, power plants, and substations entered service in the mid-1960s and are in dire need of replacement.[81] By operating with outdated equipment, the grid is not fully optimized and thus operates at a diminished efficiency and capacity.

Grid structure was not originally designed with cybersecurity in mind, yet cybersecurity grows more important with time as the extent of digitized controls grow within the industry. A myriad of public regulators and the complexity of the current regulatory structure stymied efforts to secure the grid in the cyber domain. Aligning these disparate entities to prioritize cybersecurity for the grid as a whole proves difficult. To date, the U.S. government has issued few policies to incentivize or drive adoption of greater security controls. Left on its own, the infrastructure segment is unlikely to make significant changes and advancements in reliability and security.

Energy Storage. Utility-scale energy storage is poised for success and has the potential to be a true game-changer in the global energy market by providing the United States with enhanced energy security at home and abroad. Storage technology can improve grid efficiency and capacity, enable growth in renewable energy sources and provide a viable alternative to fossil fuel powered transportation. Energy storage has touch points across multiple energy sectors, including power generation, transportation, transmission and distribution. Technologies that contribute to a lower carbon footprint, more rapid and higher power density charging, efficiency, reliability and cycle rates are likely to emerge as costs decline.[82] Revolutionary possibilities exist at the intersection of nano-materials, storage devices, sensors and networked communications.[83]

Realizing the future potential of energy storage will require overcoming a number of barriers to large-scale use. The energy storage industry must develop a method to quantify, in economic terms, the value storage systems provide to grid operations. The benefit of enterprise energy storage is its ability to bank excess energy at a given time and release it into the grid when consumption peaks and wholesale energy prices spike. Complicating the issue, using energy storage to shave peaks inherently reduces its potential profitability. Releasing stored energy decreases the need for peak power generation and correspondingly lowers the peak electricity price paid for the stored energy. Storage is literally a victim of its own success. For electric vehicles, the challenge lies in economies of scale. It will take time to reach the required economies of scale to improve technologies and reduce the cost-of-ownership. With proper R&D efforts focused on overcoming these challenges, energy storage can create strong positive externalities, such as increased efficiency, greater use of renewable sources, reduced dependence on fossil fuels, reduced GHG emissions and mature technology that the United States can export around the globe.

Water supply. The future of the water-energy nexus is uncertain. Increased temperatures, changes in precipitation patterns, and extreme weather brought on by climate change will significantly impact the water availability and alter energy demands in an unpredictable manner.[84] Furthermore, population growth and migratory patterns of the U.S. population will place additional strain on the water supply and increase energy demand.[85] The International Energy Agency projects water consumption associated with energy production in the United States will increase 80 percent over current levels by 2035.[86] A study by the Electric Power Research Institute estimates water availability will constrain the expansion of thermoelectric generation in 14 percent of counties across the United States.[87] Notably, the areas most impacted in this study are the southwest, southern plains and Florida.

The shift to new energy sources and technologies will alter water demands. With the transition to clean power, understanding the impacts to water withdrawal and consumption requires careful consideration. While carbon sequestration technologies are important for reducing GHGs, they will also increase water consumption during energy production by 20 to 30 percent.[88] Furthermore, experts have only begun to assess the impacts of fracking on water consumption and quality. The continued production of shale gas and oil will further amplify these impacts. As the water-energy nexus evolves, policy makers and legislators will face difficult decisions to balance the demand for energy with the sustainability of water now and into the future. In certain regions of the country, water consumption becomes a negative externality not currently priced into the cost of energy.

Research and development. With vast new sources of natural gas, commercially competitive wind and solar coming on line, and smarter grids under development, the United States is in the midst of an energy revolution. R&D is the critical enabler, indirectly underpinning security and prosperity.

With global energy consumption projected to increase 50 percent by 2040,[89] about 60 percent of U.S. government R&D goes towards defense, 25 percent to health, and only two percent to energy.[90] Established with $400 million in appropriated funds in 2009, the U.S. Department of Energy's Advanced Research Projects Agency – Energy (ARPA-E) supports high-impact energy technologies that are too immature for private-sector investment and "have the potential to radically improve U.S. economic prosperity, national security, and environmental well-being."[91] Through Fiscal Year 2015 (FY15), however, the total R&D investment in ARPA-E projects was under $2 billion, a small amount in the U.S. overall investment strategy.[92] R&D investment is a proven model, having a dramatic multiplier effect in hundreds of projects across the country in diverse areas from building and manufacturing efficiency, to generation and storage, to transportation networks. Despite this fact, R&D suffered underinvestment, and current efforts fail to achieve maximum potential. While R&D can and will yield substantial benefits for U.S. energy generation, transmission and storage capabilities, the greatest global opportunity for the enablers is exporting technology, best practices and intellectual property. This positive externality has the potential to lock in advantages and bend the curve of innovation to a national strategic advantage in the 21st century.

Findings

Over a period of five months, the energy study group conducted an extensive review of the energy sector. The group met with over 60 different experts, government officials, industry executives and association representatives, spanning over 20 energy-related markets. The study group also conducted site visits to over 22 locations domestically and 19 locations in Iceland and Sweden. This unique and intensive curriculum exposed the group participants to a broad overview of the energy sector from government, international and commercial perspectives in a relatively short period of time.

Detailed below is a summary of the study group's major findings, which fit into four categories: fragmented policy; externalities; underinvestment; and allied energy security vulnerability.

Fragmented Policy

In spite of energy's prominent place in the U.S. National Security Strategy, there is no corresponding blueprint articulating how the United States should meet its energy security objectives. To date, U.S. efforts have been piecemeal and focused on individual industries within the energy sector, and rarely coordinated around full-scale, national, cross-market plans. There is no one agency or department within the U.S. government empowered to direct the development of a comprehensive national energy strategy that considers the nexuses between energy and national security, the environment and the economy. Nor does any one entity have sufficient clout to successfully drive such a strategy through the interagency process. Furthermore, the political landscape on energy is complicated and generally biased against united action to reform a complex sector. By comparison, Canada, Iceland and Sweden—though much smaller than the United States in terms of energy demands—demonstrated the utility of national level energy strategies. Some lessons from these countries may be applicable, though admittedly the United States is currently more politically divided and less cohesive than any of the three. Still, the rapidly evolving nature of the energy sector demands that the United States reassess its fragmented policy in order to address energy threats and opportunities.

Externalities

President Obama's "all-of-the-above energy strategy" fails to achieve the necessary policy changes to address the concerns surrounding the energy and environment nexus. The strategy focuses more on energy security, promoting an intermediate solution that favors only somewhat cleaner natural gas.[93] Additionally, supports and promotes energy sources seemingly without regard to their economic viability or lack thereof (see figures 6 and 7 for cost of energy by source), and fails to appropriately value energy storage and clean, reliable nuclear energy. The strategy ultimately fails to fully account for all externalities.

Climate change highlights the critical nature of the energy and environment nexus. U.S. reliance on fossil fuels harms the environment and increases security vulnerabilities by depending on foreign energy sources. Exploiting the energy and environment nexus is about balancing tradeoffs between relatively cheap fossil fuel and environmental impacts while enhancing national security with diverse and plentiful energy. The best methodology monetizes both negative and positive externalities on the supply and demand sides of energy markets and leverages economics to find the proper balance.

Underinvestment

Multiple elements throughout the energy sector that serve as enablers—all of the pieces in between extraction and production—suffer from underinvestment. Much of the U.S. electricity grid has not been updated in half a century and is inadequate to meet future needs.[94] The United States endures more blackouts than any other developed country and the grid fails almost three times as often today as it did in 1984.[95] American businesses lose $150 billion from these outages.[96] Moreover, the electric grid was not designed with modern cybersecurity threats in mind. Excessive regulations complicate efforts to secure the grid. Stakeholders in cybersecurity include federal and state governments and commercial enterprises whose interests do not fully align.

Energy storage has all the potential to introduce game-changing technology into the power grid and enable an accelerated transition to renewables that are currently only marginally dispatchable (e.g., wind, solar). That industry, however, lacks a pricing construct that monetizes its benefit to the electrical grid enterprise. R&D into the integration and business case for this important capability is currently lacking.

Pipelines are another vital but outdated infrastructure system. The system leaks methane prolifically, releasing enormous amounts of GHGs into the atmosphere. A hodge-podge of federal and local government entities provides inconsistent and under-resourced oversight of this system, and no single entity at the national, state or local level has the overall authority to overhaul this critical infrastructure. The system needs stronger oversight, repair and, in some stretches, complete replacement.

The United States must overcome several barriers to greater and faster R&D, pursuing energy innovation dominance. The United States spends a mere fraction of its R&D budget on energy.[97] Estimates indicate the U.S. energy sector invests less than half of one percent in R&D, compared to 20 percent in pharmaceuticals.[98]

Allied Energy Security Vulnerability

European allies pursued inconsistent—and in some cases short-sighted—policies in assuring their energy security. For example, Russia masterfully "weaponized" its energy supplies, using pricing, contracts and infrastructure to maximize Europe's dependence on its gas. Russia then leverages this virtual monopoly to intimidate its neighbors and extract political gains. For example, Russia interrupted gas flows to Ukraine in 2006, the winter of 2008 to 2009, 2014 and 2015 as a negotiating tactic during various disputes between the two nations.[99] If the United States is the ultimate guarantor of European security (under NATO and other commitments or interests), then it is at a disadvantage unless it can develop energy alternatives to Russian gas. A U.S. role in diversifying European energy infrastructure can become a source of strength, as it establishes a basis for collaboration and strategic partnership. For example, as Turkey strives to reduce its reliance on Russian gas, and the United States can help broker alternative sources in Cyprus or

Israel. Similarly, the United States can help Israel, Jordan, and Egypt collaborate on energy trade to the benefit of each country.

Government Goals

Analysis of the data and information gathered by the energy study group illuminated four goals the U.S. government must adopt in order to achieve the following vision: a modernized U.S. energy infrastructure; U.S. economic markets that balance national security, environmental protection and economic benefit; a U.S. energy sector technologically modernized by the U.S. R&D establishment; and resilient energy security for U.S. allies.

(1) ***Adequate, diversified & resilient energy sources to meet U.S. requirements.*** The United States must achieve *sustainable* energy security by the year 2050. As part of this, the United States must incorporate conservation measures into new and existing structures, transportation modes, and industry to decrease demand. Fossil fuel market pressures frequently originate in regions where the United States has little influence, it is important to transition away from coal, natural gas and oil on the mid- to long-term. Additionally, these energy sources are inconsistent with climate change prevention goals, so the U.S. government must phase these out for that reason as well. Furthermore, the United States needs to improve its aging infrastructure to enhance resiliency and improve efficiency.

(2) ***Reduce GHG emission in the US by 80 percent from 2005 levels by 2050 to slow climate change.*** Not only is climate change jeopardizing property, facilities and assets in the civilian realm, it is also threatening U.S. military bases and assets, both domestic and abroad. Further, as climate change creates uncertainty and crises overseas, the resulting unrest may draw the United States and its allies more and more into conflict. The United States must lead a transformation of Organization for Economic Co-operation and Development national energy policies to slow the ongoing effects of climate change that negatively impact the energy sector such as sea-level rise, extreme weather patterns and changes in regional precipitation.

(3) ***Energy innovation as an "Offset."*** Similar to technology advances in military weapons, advances in energy technology can enhance U.S. national security. The shale gas fracking revolution demonstrated how advanced technology can change the nature of a nation's energy status. Comparably, breakthrough technology will enable economically unviable renewable energy sources to become economically competitive. Additionally, advancing technology will provide more efficient energy use and decreased demand. The United States and its allies should accelerate advancements in energy development and production to enable a more expeditious transition away from fossil fuels and to increase the available energy resources to enhance security.

(4) ***Reduced external leverage over the United States and its allies.*** As Russia demonstrated by interrupting critical natural gas flows to the Ukraine and other parts of Europe at the height of winter, some players on the global stage are willing and able to use energy as a policy weapon.[100] The United States should adopt energy policies that protect the nation and its allies from potential adversaries that wield energy as a policy weapon. Further, energy policies should seek to minimize the necessity of military entanglements in unstable regions (e.g., Middle East). This goal is best achieved by globalizing markets, enabling redundant supply sources and establishing a robust U.S. capacity for exports.

Policy Recommendations and Implementation

First and foremost, the US must develop a comprehensive national energy strategy that fully considers U.S. and allied security, the environment, and U.S. economic growth. The energy study group observes that both Canada and Iceland published such a strategy, and Sweden is in the process of developing that country's strategic way-ahead for a potential transition away from nuclear energy. The Obama administration's "All-of-the-Above" energy strategy, by emphasizing *all* U.S. energy sources, sidesteps some negative externalities and fails to recognize positive externalities. Further, it fails to fully integrate long-term economic and security concerns in an explicit and comprehensive manner. As discussed in the introduction, the study group recommends development and implementation of NET50, which entails four sets of prioritized recommendations. First, the Basic Strategy aims to shape the energy environment by guiding the United States and its allies towards a more sustainable and secure energy future and includes two sets of recommendations: (1) monetize both negative and positive externalities of various energy sources, and (2) promote LNG export investment. Second, the Core Strategy addresses critical components to all potential energy environments by investing in infrastructure improvements. Third, the Hedging Strategy focuses on R&D to build resilience and manage against potential exogenous contingencies or required shifts in basic strategy along the way.

Basic Strategy: Monetize Positive and Negative Externalities

Aligned under the Basic Strategy and designed to push the US towards a new energy future is the goal of adequate, diversified and resilient energy sources to meet U.S. energy requirements and reduce U.S. GHG emissions by 80 percent from 2005 levels by 2050 to slow climate change. To achieve this portion of the strategy, the energy study group recommends implementing three tax policies to monetize externalities, enable economic market forces to promote lasting clean energy security, and provide funding for infrastructure improvements and R&D: GHG Cap and Trade program, Externality Tax and Tax Credit system, and Gas Tax system. While implementation of the recommendations in this report presents significant political challenges, if implemented as described, these tax recommendations yield funding to fully offset the other recommendations that require resources.

***To reach the goal of reducing GHG emissions by 80 percent by the year 2050, the US must institute a program that sets limits on greenhouse gas emissions and slowly lowers them over time towards the desired end state*.**

Cap-and-trade is a proven policy that reduced acid rain pollutants in the US[101] and GHG emissions in the European Union.[102] These policies would serve as the framework for a U.S. GHG Cap and Trade program.[103] To implement this program, the Environmental Protection Agency (EPA) would set an annually decreasing cap on GHG emissions, quantified by total mass of GHGs produced based on lifecycle rates, aligned to meet future GHG emission limits. Once the EPA calculates the maximum desired allowable GHG requirements for the year, they issue options to buy GHG certificates for each energy producer.

For example, the EPA sets the limit on GHG emissions to 4.8 billion tons for 2017, decreased 0.4 billion tons from 2015.[104] The US is currently producing four trillion kilowatt hours (kWh) of electricity per year, which would mean each energy producer would receive options to purchase their share of the overall GHG emissions at the rate of 0.0012 tons of GHGs per kWh.[105]

A nuclear firm that produces 1,000,000 kWh per year would receive options to buy certificates worth 1,200 tons of GHGs for a price of $100 per ton. GHGs produced over the lifecycle of a nuclear plant are minimal, and in this example the plant would only need 10 tons of GHG certificates. They can trade or sell their remaining certificates (1,190 tons) to a plant producing more GHGs like coal. A coal plant producing 1,000,000 kWh per year would receive the same options for 1,200 tons of GHGs, but they may produce 2,000 tons of GHGs. They would need to buy 800 tons worth of GHG certificates, on the secondary market, from clean energy sources such as nuclear and renewables. This policy guarantees the US produces less than a pre-established amount of GHGs per year and prices this key negative externality into the cost equation of the energy market's supply side.

To provide stability for producers, the EPA should provide certificates with a five-year term so that firms can adapt their strategies accordingly. The sale of these certificates will provide a consistent revenue stream to fund infrastructure improvements and focused R&D. The American Clean Energy and Security Act, which included a GHG cap-and-trade provision, failed to pass Congress in 2009 and prevented a national carbon program from going into effect.[106] However, the political and social environment evolved over the past seven years and is more accommodating to environmental initiatives as highlighted by the recent COP21 agreements.[107] Congress must pass associated legislation to enable the cap-and-trade structure. Of the three tax policies in the Basic Strategy, the energy study group believes this policy holds the greatest promise for passage, because a similar cap-and-trade tax for carbon already exists. This proposal merely takes that construct to the next level.

To enable market forces to establish the proper balance across the energy sector, the federal government in conjunction with state governments must create a flexible taxation strategy that assigns monetary values to externalities.

GHG emissions is not the only externality not properly accounted for in the energy sector. As noted previously, the remaining externalities of sustainability, reliability, dispatchability, responsiveness, safety, water consumption and water quality affect U.S. energy security and environmental concerns. As highlighted in table 2, each energy source scores differently on the spectrum of positive and negative externalities and in general non-fossil fuels fair better across the spectrum than fossil fuels.

The focus of this effort is development of a flexible tax construct that maximizes the benefit for those technologies and methods that have the greatest account of positive externalities and minimized negative externalities.[108] In this model, an energy source like hydropower that scores well in table 2 for the externalities of sustainability, water consumption, dispatchability and responsiveness and marginal for reliability and safety would receive a tax credit. Conversely, the government would tax an energy source like coal that scores poorly in table 2 for responsiveness and safety; marginally for sustainability, water consumption and dispatchability; and only good for reliability. The tax on poor performing energy sources will fund the tax credit for the positive performing energy sources. Additionally, the U.S. Treasury will divert 10 percent of the taxes to fund infrastructure improvements and R&D. The EPA will need to conduct data and analysis to determine the weightings and associated tax rates for each externality in terms of kWh. Congress will need to enact legislature to establish the tax appropriate tax code. This system will spur the U.S. energy sector towards security and economic viability.

The U.S. government must increase the federal motor fuel (i.e., gasoline and diesel) tax to achieve two goals: (1) generate revenue to cover the Highway Transportation Fund (HTF) and fund investment in energy related research and development and infrastructure; and (2) drive consumers to electric or more fuel efficient vehicles.

The current motor fuel tax is 18.4 cents for gasoline and 24.4 cents for diesel.[109] Of those amounts, 0.1 cent is for the Leaking Underground Storage Tank Trust Fund and the remainder is for the HTF.[110] At the current rate, the revenue from these taxes are not producing adequate funds to sustain the HTF or altering consumer behavior.[111] To further exacerbate this issue, on September 30, 2016 the tax rates for gasoline and diesel will drop to 4.3 cents per gallon.[112]

Data from 2008 suggests approximately $4.00 per gallon is the price point at which consumers in the United States alter their driving behavior. For example, the Department of Transportation observed a 3.6 percent reduction in road travel and 107 billion fewer vehicle miles as compared to 2007.[113] Also, sale of sport utility vehicles (SUVs) dropped by 32.8 percent.[114] Recognizing other forces were at play in the 2008 timeframe (i.e., The Great Recession), $4.00 per gallon is a reasonable starting point. To this end, the U.S. government should institute a variable fuel tax in FY17 equivalent to the differential of the market price and $3.00 per gallon. The ceiling price should increase incrementally to $4.00 per gallon by FY21. Under this plan, the government would levy no tax if at any time the market price of gasoline exceeds the ceiling price.

At the current average price of gasoline ($2.325 per gallon) if the $3.00 per gallon ceiling were in place, the tax would yield $255 million per day or $93 billion per year based on a daily consumption rate of 378 million gallons of gas.[115] This amount would adequately cover the existing HTF requirement ($52 billion) and leave approximately $41 billion available for investment.[116] To offset the regressive nature of a gas tax, the government could return a portion of the tax income to lower income households in the form of a tax rebate. Understanding the debate surrounding a federal fuel tax is contentious, the U.S. government should leverage the momentum from the COP21 Paris talks and the forthcoming change in the fuel tax to drive a thoughtful dialogue on the benefits of adopting the proposed fuel tax increase.

Basic Strategy: Promote Policy to Expand Investment in European LNG Markets and Enhance U.S. Allies' Energy Security

Amend the American Job Creation and Strategic Alliances LNG Act to allow and encourage U.S. firms to invest in European LNG infrastructure.

The "shale-gas revolution" in the United States facilitated a fundamental shift in America's ability to influence the energy security of her allies by allowing them to leverage U.S. liquid natural gas (LNG) as an alternative to Russian natural gas in the European market. Access to shale gas deposits in the United States contributed to increased U.S. energy security by reducing American reliance on foreign LNG. The shale gas revolution also encouraged the construction of LNG export facilities in the United States, providing economic benefit to U.S. firms and enabling LNG exports to Europe. Greater access to reasonably priced LNG imports and market policies encouraged European investment in LNG import facilities and greater interconnectivity infrastructure between European states.[117] New and planned LNG import facilities under construction in the Netherlands, France and Poland cost Russia billions of dollars in exports as a result of preemptive price cuts, forced by new competition and the resulting loss of market share.[118] The shifting dynamic in European energy dependence will reduce Russian energy hegemony and political influence in the region by eliminating a key lever of power.

The US has multiple means by which it can enhance European energy security as it relates to natural gas imports. The U.S. Congress is currently reviewing the American Job Creation and Strategic Alliances LNG Act, a bill to amend the Natural Gas Act to promote economic growth and job creation in the United States and to strengthen strategic partnerships with U.S. allies.[119] Congress must amend this bill to include provisions allowing and encouraging U.S. firms to invest in infrastructure that will enable greater interconnectivity within Europe. For example, interconnection investments in Croatia and Romania would allow those countries to move imported LNG to Central European infrastructure networks and enable European countries to support each other in the event of Russian supply disruptions.[120] Furthermore, U.S. investment in European LNG import facilities would accelerate energy diversification on the continent reducing Russian economic and political influence.

Core Strategy: Infrastructure Investment

***Modernize electric power grid infrastructure through an enhanced collaboration with federal government, industry, environmental groups and other stakeholders, leveraging funding generated from the monetization of externalities*.**

As part of a focused infrastructure reinvestment, the federal government must work in close collaboration with industry, environmental groups and other relevant stakeholders in order to modernize the electric power grid infrastructure that prioritizes the most critical needs and concentrates on the most significant areas of risk within the current system. The broader effort will include a robust analysis and an associated investment strategy focused on modernizing key elements of the grid including power generation plants, transmission lines, distribution lines and substations to determine where the most critical electric grid deficiencies exist.[121] In addition, the modernization effort will focus on enhancing smart grid technologies to include interactive communication tools that will enable real-time data and information on electricity usage and provide critical information for decision-making purposes. The monetization instruments described in the Basic Strategy (gas tax, tax credits, and cap and trade of GHG emissions) will fund such a comprehensive infrastructure upgrade. The electric power grid serves as a critical enabler that provides us with critical infrastructure paramount to U.S. economic prosperity and provides the energy to fuel growth in the U.S. gross domestic product.

***The federal government must work in partnership with industry to leverage advancements in key technologies and modernize the pipeline infrastructure*.**

In order to improve the integrity and safety of existing pipeline infrastructure, the federal government must work in collaboration with industry to apply advanced technology enhancements to existing pipeline infrastructure. For example, ultrasonic technology and technology to identify the health of buried pipelines without digging show promise and could provide decision-makers with real time information such as reporting and inspection data. As part of broader effort, the United States must conduct a system wide review and identify risks and deficiencies within the existing pipeline infrastructure and apply these technology enhancements accordingly. By focusing on near-term and long term solutions the United States will improve pipeline safety and reduce environmental impact of pipeline failures, thus provide greater efficiency and reliability in pipeline operations. As the government seeks to globalize the LNG market and provide energy security to allies, the United States must repair, replace and expand pipeline infrastructure to increase efficiency and drive down U.S. LNG prices. By adopting this recommendation, the United States will enhance its role as a global leader in oil and natural gas.

Legislate an investment tax credit (ITC) for electrical grid security measures.

Federal government efforts to mitigate vulnerabilities in the electric power grid have been stymied by differences in electricity market structures across the nation and disjointed regulatory authorities. To better secure the grid and offset increased vulnerabilities imposed by smart grid technology, the US must move past routine regulations and standards towards incentivizing security measures and resilient systems.

To mitigate cyber vulnerabilities to the U.S. electrical grid and reduce the leverage potential adversaries can wield over the United States, Congress must pass an authorization for an ITC for electrical grid related cybersecurity measures. Congress should pattern this legislation after the successful 30 percent ITC for solar energy installations that spurred growth and investment in solar installations across the United States, regardless of the nature of the affected markets.[122] Funding that results from the previously discussed monetization of positive and negative externalities will offset this tax credit. By following this model, Congress can stimulate grid cybersecurity related investments across both regulated and deregulated markets while also equally incentivizing firms across generation, transmission, distribution and grid operations.

Hedging Strategy: R&D Investment to Build Resilience and Manage Risk

Appropriate $600 million annually toward ARPA-E, an amount equal to tripling the average ARPA-E budget during the last decade and almost double the pending FY16 request.

Energy visionary Amory Lovins asserts in *Reinventing Fire* that an energy revolution by 2050 is “not based on miracles of magic but on purposeful application of what's already proven. Our analysis did not rely on breakthrough technologies or new inventions.”[123] As discussed previously, ARPA-E is a proven concept that the government should scale up accordingly to build resilience and manage risk in the energy sector. Increasing ARPA-E funding from taxes on negative externalities is a cost-effective hedging strategy against resource conflict scenarios and demonstrates a commitment to solving geopolitical problems without resorting to hard power and instead emphasizing the use of technology as a soft power.

R&D is the critical enabler in energy competitiveness, indirectly underpinning U.S. security and prosperity. ARPA-E supports high-impact energy technologies that are too immature for private-sector investment but have significant potential for impact, functioning as a developmental bridge to commercial R&D.[124] For example, President Obama announced in February of 2016 that 45 ARPA-E projects secured over $1.25 billion in follow-on private sector funding, a multiplier effect to catalyze development technologies too risky for commercial capital.[125]

Energy storage is the most important target for increased R&D investment because it holds the key to improving the economic performance of the electric power grid, supporting the uptake of renewable energy sources, and enabling greater penetration of electrically powered transportation. Although renewable energy sources provide a glimpse into the nation’s future energy usage, the current electric power grid is not leveraging this existing capability to its fullest. One of the biggest impediments to success is the lack of storage possibilities to harness the full potential of renewable sources such as wind and solar energy. Greater use of energy storage will improve grid reliability and security, reduce the requirement of fossil fuels and improve environmental sustainability.

Conclusion

Energy and national security policy epitomize the strategic maxim that *threats are opportunities*. The United States can overcome the challenges identified—fragmented policy, vulnerability and underinvestment—by abandoning the "all-of-the-above" approach to energy. The proposed NET50 prioritizes cap and trade first as an element of the Basic Strategy, in order to efficiently price negative and positive externalities. This report demonstrates the rationale of this requirement in economic, environmental and national security terms. Second, the Core Strategy focuses on modernizing outdated energy infrastructure based on safety, environmental, security and efficiency concerns; it is also necessary to fully realize the potential of renewable sources. Third, the Hedging Strategy is founded on investing in innovation to ensure the U.S. energy sector is sufficiently robust and adaptable. Finally, the three remaining recommendations from the Basic Strategy round out the list.

The recommendations to implement NET50 are as economically obvious as they are politically controversial. Implementers must invoke national security imperatives to harness the ongoing energy revolution in fossil, non-fossil and enabling segments. The U.S. government must widely disseminate this report's findings and recommendations through a national communication plan: energy is in transformation; energy and national security are linked; climate change is recognized by industry; the tax regime fails to maximize energy potential; nuclear energy is underappreciated; natural gas is a bridge fuel; U.S. fossil fuel exports are critical to allies' security; renewable technologies need more R&D; U.S. government energy R&D is inadequate; and enablers must receive due attention. Accordingly, U.S. government energy goals must be: adequate, diversified, sustainable and resilient energy; reduced external (hostile) leverage over the United States and its allies; energy innovation as a strategic "offset;" and GHG reduction by 80 percent from 2005 levels by 2050 to demonstrate leadership in slowing climate change.

The US must set decreasing limits on GHG emissions. In order to establish balance across the energy sector, federal and state governments must coordinate flexible taxation regimes that monetize externalities. The US must increase the federal motor fuel tax (1) to generate revenue to cover the HTF and fund needed investments; and (2) to incentivize consumers to drive more efficient or electric vehicles. The U.S. government must leverage new revenue streams in a coordinated effort of public and private stakeholders to modernize the electric power grid and pipeline infrastructures. Congress must legislate an Investment Tax Credit for Electrical Grid Security Management to mitigate cyber threats to the system. Congress must also appropriate $600 million annually toward ARPA-E for innovation toward the Energy Offset. Finally, Congress must amend the American Job Creation and Strategic Alliances LNG Act to allow and encourage U.S. firms to invest in European LNG infrastructure, justified on national security grounds.

In short, the time for a U.S. Energy Offset is now.

Tables

Energy Source	Grams per kWh
Coal	900
Natural Gas	450
Wind	126
Nuclear	99
Photo Voltaic Solar	46
Solar Thermal	36

Table 1. Lifecycle CO_2 produced during electricity generation by source[126]

	Sustain-ability[127, 128]	Reliability[129, 130]	GHG Emissions[131]	Water Consumption[132, 133]	Water Quality[134]	Dispatch-ability[135]	Responsive-ness[136]	Safety[137]
Crude	Based on domestic supply							
Natural Gas	Based on domestic supply							
Coal	Based on domestic supply							
Nuclear	Based on domestic supply							
Hydro		Based on local climate						
Wind						Lacks storage capability	W/out storage capability	
Biomass			Dependent on energy replacement				W/out storage capability	
Solar					Solar Thermal (yellow)	Solar Thermal-yes, PV-no		
Geothermal			Dependent upon source					
Biofuels	Dependent upon product used		Dependent on energy replacement					

Table 2. Externality assessment by energy source

Figures

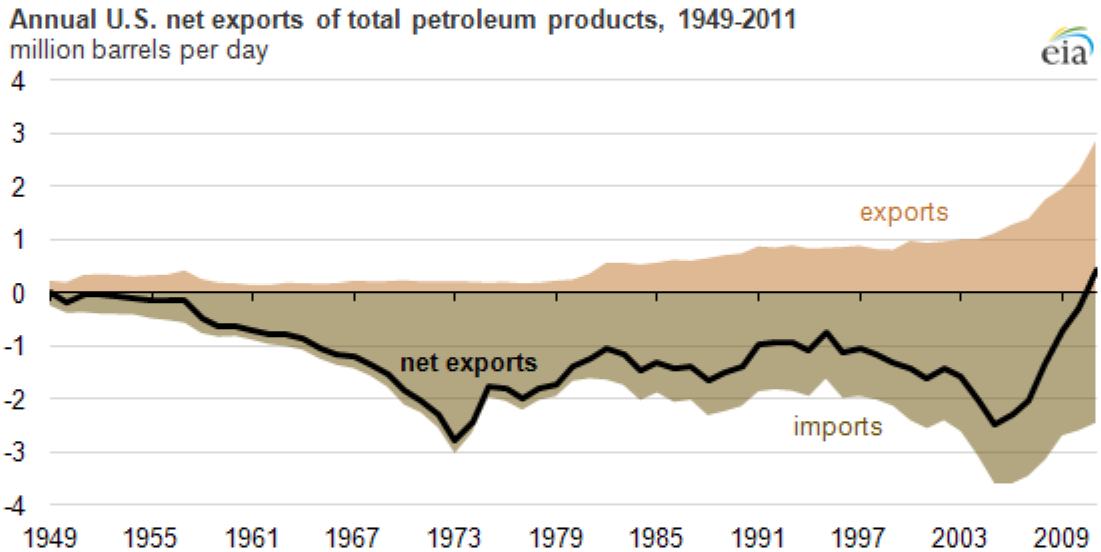

Figure 1. Annual U.S. net exports of total petroleum products, 1949-2011[138]

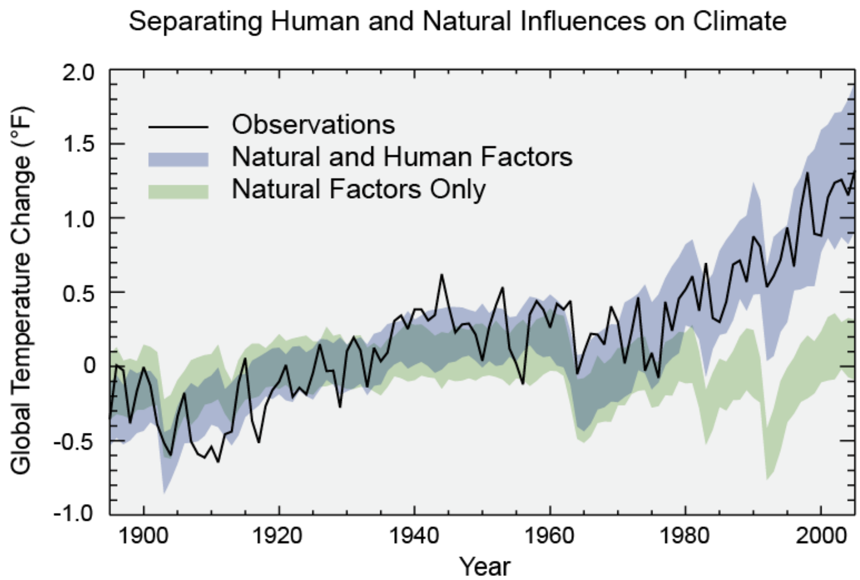

Figure 2. Separating human and natural influences on climate[139]

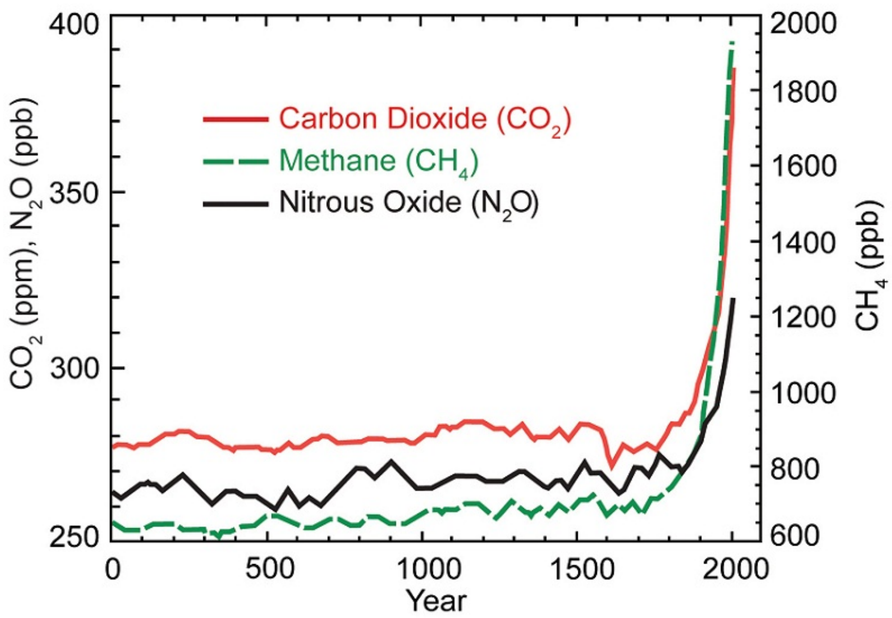

Figure 3. Levels of GHGs over time[140]

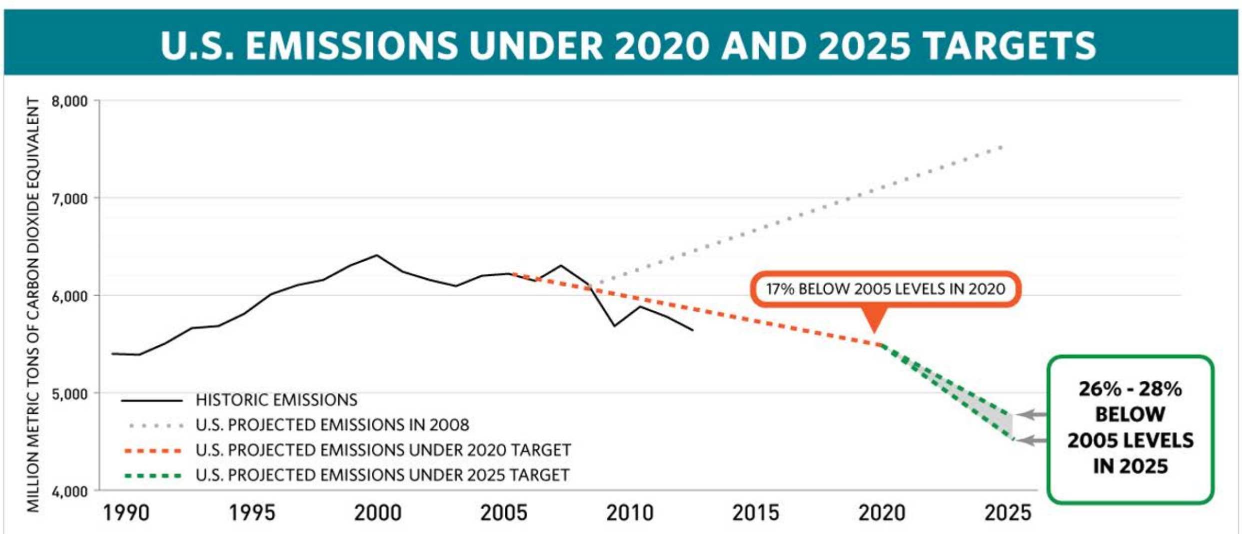

Figure 4. U.S. emissions under 2020 and 2025 targets[141]

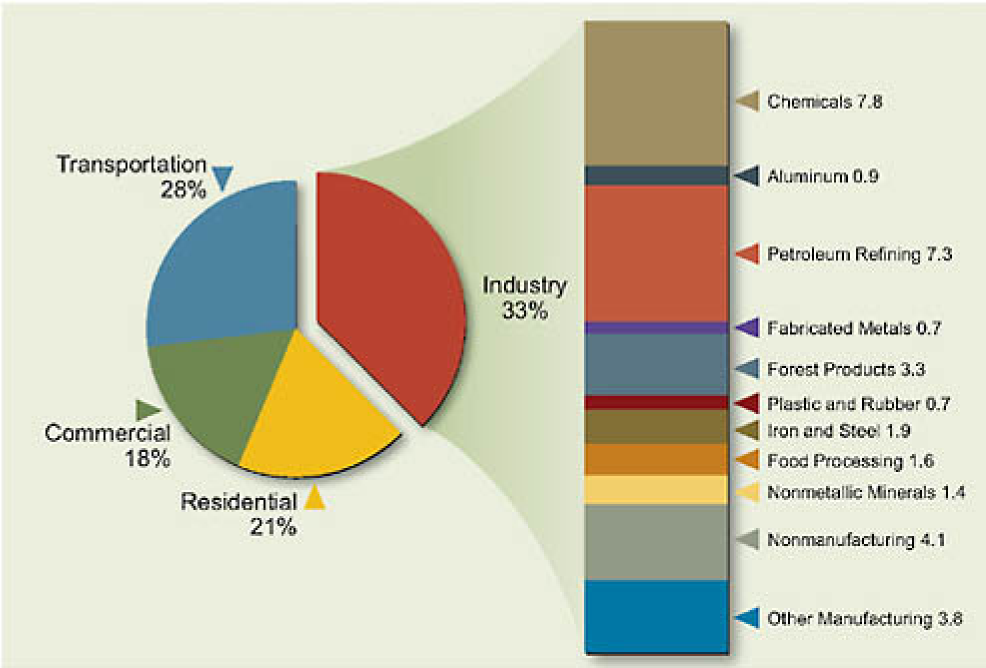

Figure 5. U.S. energy use by sector[142]

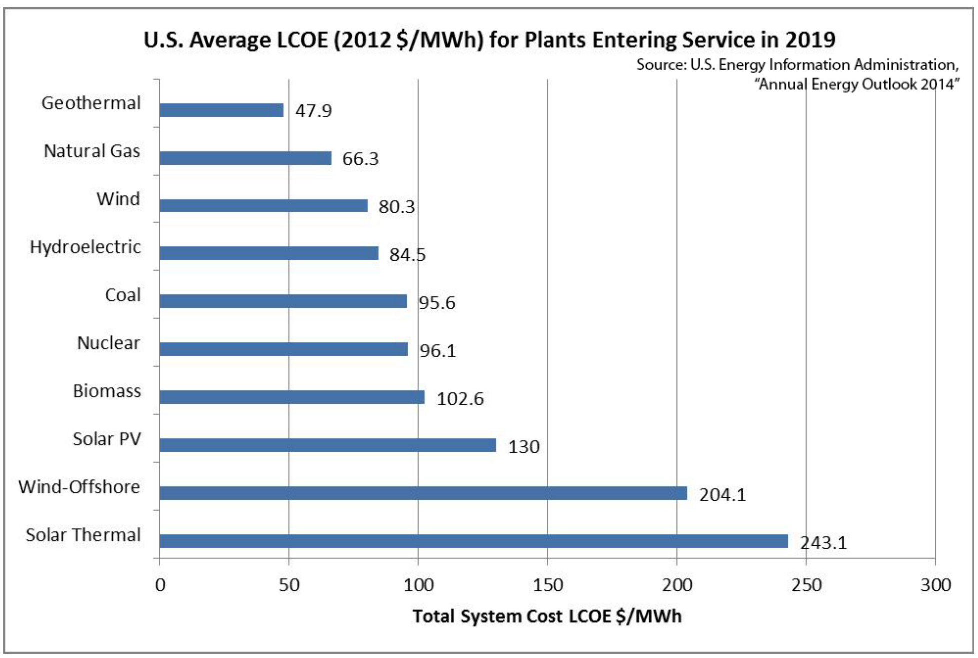

Figure 6. Average lifecycle cost of energy[143]

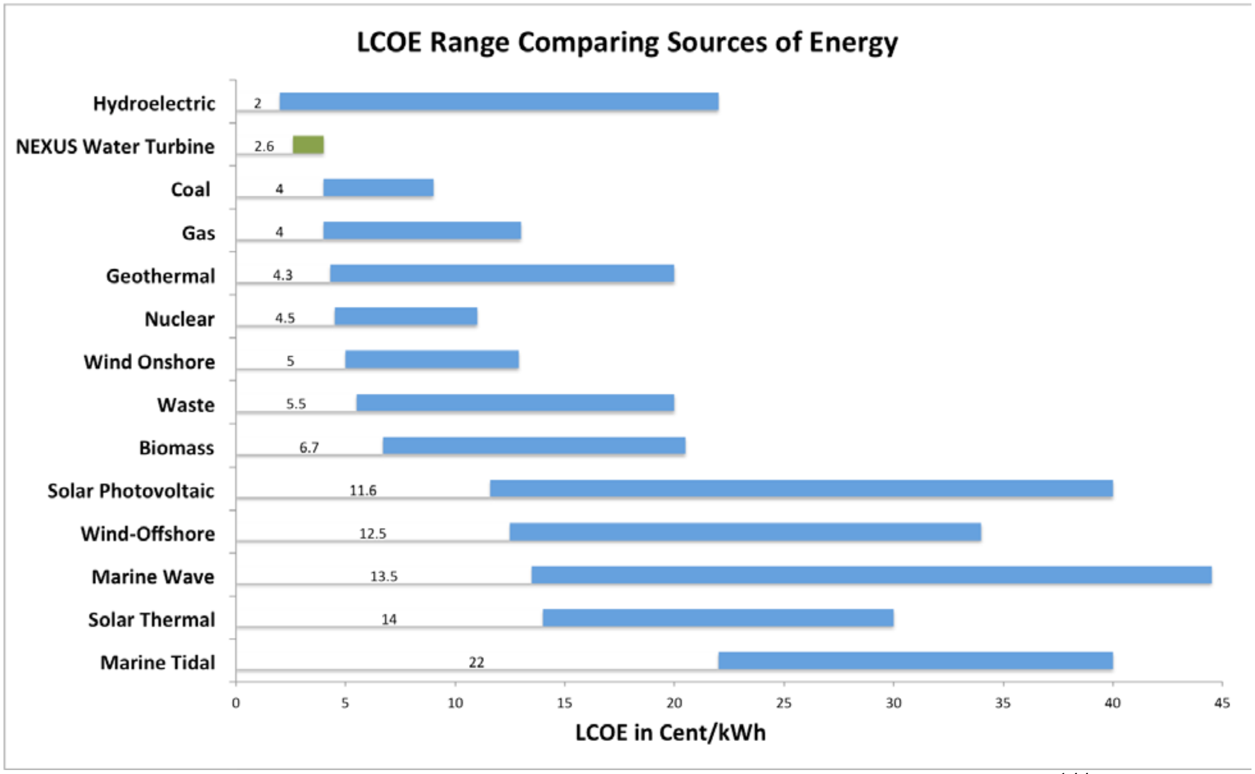

Figure 7. Lifecycle cost of energy range comparing sources of energy[144]

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