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TASK FORCE

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Energy and climate change: Nonpartisan policies for
the next U.S. President

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Energy and Climate Change: Nonpartisan Policies for the Next US President

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To Professor Scott L. Montgomery

"For his endless patience, expert guidance, and selfless dedication to an
incredibly important cause."

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Glossary

Advanced Manufacturing Office (AMO):

AMO supports R&D projects and early-stage technical partnerships with national laboratories, companies (for-profit and not-for profit), state and local governments, and universities through funding opportunities designed to investigate new manufacturing technologies.

Advanced Research Projects Agency-Energy (ARPA-E):

Advanced Research Projects Agency-Energy is a US government agency set up in 2009 to invest in high risk, high reward research, development and scientific projects. Energy innovation is a major focus.

American Geosciences Institute (AGI):

AGI was founded in 1948, as a network of associations representing geoscientists with a diverse array of skills and knowledge of our planet. The goal of the institute is to provide information services to increase public awareness of the vital role the geosciences play in society's use of resources, resilience to natural hazards, and the health of the environment.

American Nuclear Society (ANS):

A non-profit, international, scientific and educational organization. It was established by a group of individuals who recognized the need to unify the professional activities within the diverse fields of nuclear science and technology.

Annual Energy Outlook (AEO):

The US Energy Information Administration's *Annual Energy Outlook* provides yearly modeled projections of domestic energy markets throughout to a certain date (in this case 2050). The outlooks it includes cases with different assumptions about macroeconomic growth, world oil prices, and technological progress in different sectors.

Arctic National Wildlife Refuge (ANWR):

The largest national wildlife refuge in the United States, located in northeastern Alaska. It spans 19,286,722 acres and includes a wide variety of plant and animal species that heavily rely on the refuge (caribou, wolves, eagles, migratory birds, etc.).

Association of State Dam Safety Officials (ASDSO):

Founded in 1983, ASDSO is an association whose mission it is to improve the condition and safety of dams through education, support for state dam safety programs and fostering a unified dam safety community.

Belt and Road Initiative (BRI):

The BRI is Chinese-government development project meant to improve regional connectivity on a trans-continental scale. The initiative is believed to be part of a larger strategy by the Chinese government to expand influence in the developing world.

Capacity Factor (CF):

The maximum energy output possible that can be achieved by an energy generator or fuel source.

Carbon Capture and Storage (CCS):

The process of capturing waste carbon dioxide from large point sources, such as biomass or fossil fuel power plants, transporting it to a storage site, and depositing it where it will not enter the atmosphere, normally an underground geological formation.

Clean Air Act (CAA):

A federal law that regulates air emissions from stationary and mobile sources. The Act was passed in 1963, but important and major amendments were added to the original Act in 1970 and 1990.

Clean Power Plan (CPP):

Enacted policy by the Obama Administration in 2014, aimed to combat anthropogenic climate change by lowering the carbon dioxide emitted by power generators.

Clean Water Act (CWA):

The Clean Water Act is a U.S. federal law that regulates the discharge of pollutants into the nation's surface waters, including lakes, rivers, streams, wetlands, and coastal areas. Passed in 1972 and amended in 1977 and 1987.

Department of Energy (DOE):

A cabinet-level department of the United States government founded in 1977 under the Carter administration. Its mission is to ensure America's security and prosperity by addressing its energy, environmental and nuclear challenges through transformative science and technology solutions.

Energy Efficiency Resource Standards (EERS):

Establishes specific, long-term targets for energy savings that utilities or non-utility program administrators must meet through customer energy efficiency programs.

Energy Policy and Conservation Act (EPCA):

This 1975 law created a comprehensive approach to federal energy policy after the 1973 oil crisis. One major component of the law banned most crude oil exports, a provision repealed by the Obama administration in 2015.

Energy Star:

The government backed symbol for energy efficiency. It provides simple, credible, and unbiased information that makes easy for consumers and businesses to buy products that save them money and protect the environment.

Environmental Protection Agency (EPA):

An independent agency of the United States federal government for environmental protection. It was established by the president Richard Nixon on July 9, 1970. Its mission is to protect human health and the environment.

Exclusive Economic Zone (EEZ):

This term refers to an exclusive economic zone is a 200 nautical mile zone over which a state entity has special rights regarding the extraction and management of natural resources.

Fukushima Nuclear Accident:

An energy accident at the Fukushima Daiichi Nuclear Power Plant in Okuma, Fukushima Prefecture. Initiated by the tsunami following the Tohoku earthquake on March 22, 2011. About 40-50 people experienced radiation burns or physical injury at the nuclear facility, but the number of direct deaths from this event are quoted to be zero.

Institute for Energy Research (IER):

A non-profit organization that conducts research and analysis on functions, operations, and government regulation of global energy markets. In favor of free markets, objective science, public policy tradeoffs, efficient outcomes and impartial and unbiased policies.

International Atomic Energy Agency (IAEA):

A global organization apart of the United Nations that promotes safe secure and peaceful use of nuclear technology.

International Energy Agency (IEA):

A Paris-based autonomous intergovernmental established in 1974 in the wake of the 1973 oil crisis. The organization is the global energy authority, providing data, analysis and solutions on all fuels and all technologies; helping governments, industry and citizens make good energy choices.

Intergovernmental Panel on Climate Change (IPCC):

An intergovernmental body of the United Nations assigned with providing an objective and scientific view of climate change and its impacts to the world.

Investment Tax Credit (ITC):

ITC refers to the percentage reduction of income taxes that a person or company typically would pay to the federal government.

International Thermonuclear Experimental Reactor (ITER):

An international nuclear fusion research and engineering mega project funded by the European Union, India, Japan, China, Russia, South Korea, and the United States. The collaboration to build the world's largest tokamak, a magnetic fusion device designed to prove the feasibility of fusion as a large-scale and carbon-free source of energy.

Iran National Oil Company:

A government-owned corporation under the direction of the Ministry of Petroleum of Iran, it is a national oil and natural gas producer and distributor headquartered in Tehran.

Global Marine Oil Pollution Information Gateway (GPA):

The GPA seeks to establish a gateway for providing information on the global, regional and local problems caused by marine oil pollution.

Graying of America:

The 'graying of America' refers to the oncoming demographic crisis that the U.S. is expected to suffer. The number of children born within the United States is not enough to balance out the number of elderly people rising within the country.

Grid Reliability:

Reliability is the ability of a power system to deliver electricity in the quantity and with the quality demanded by users.

Grid Resilience:

Resilience is the ability of a power system to reduce the magnitude and/or duration of disruptive events. The effectiveness of a resilient grid system depends upon its ability to anticipate, absorb, adapt to, and/or rapidly recover from a potentially disruptive event.

Liquid Natural Gas (LNG):

Liquefied natural gas is natural gas that has been cooled down to liquid form for ease and safety of non-pressurized storage or transport. It takes up about 1/600th the volume of natural gas in the gaseous state. It is odorless, colorless, non-toxic and non-corrosive.

Loan Program Office (LPO):

The Loan Programs Office is a division of the Department of Energy that assists capital-intensive prototype research that have high commercial potential.

Low Economically Developed Countries (LEDCs):

Low Economically Developed Countries are the list of countries that have the lowest socioeconomic development, ranking below US \$1,025 Gross National Income per capita.

Mission Innovation (MI):

Mission Innovation was formed during the Paris Climate Accord consisting of 20 countries that represent about 80% of the world's investment in energy R&D. One of the goals of MI is to encourage joint technology development and encourage private sector investment at the domestic level.

National Climate Assessment (NCA):

A report summarizing the effects of climate change on the US created by the US Global Change Research Program, a US government interagency.

National Science Fund (NSF):

An independent federal agency created by congress in 1950 to promote the progress and basic research of science, advance the national health, prosperity and welfare, and to secure national defence to drive the US economy, enhance national security, and advance knowledge to sustain global leadership.

Natural Gas Plant Liquids (NGPLs):

Those hydrocarbons in natural gas that are separated as liquids at natural gas processing plants, fractionating and cycling plants. Products obtained include ethane, liquefied petroleum gases (propane and butanes), and pentanes plus. Component products may be fractionated or mixed. Lease condensate is excluded.

National Infrastructure Advisory Council (NIAC):

The NIAC is a branch of the US Department of Homeland Security it includes executive leaders from private industry and state/local government who advise the White House on how to reduce physical and cyber risks and improve the security and resilience of the nation's critical infrastructure sectors.

New York State Energy Research and Development Authority (NYSERDA):

A public benefit corporation, established in 1975. Located in Albany, New York, with regional offices in NYC, Buffalo, and West Valley. NYSERDA provides objective information and analysis, innovative programs, technical expertise and support to assist New Yorkers increase energy efficiency, save money, use renewable energy, and reduce fossil fuels uses.

Office of Cybersecurity, Energy Security, and Emergency Response (CESER):

CESER leads the Department of Energy's emergency preparedness and coordinated response to disruptions to the energy sector, including physical and cyber-attacks, natural disasters, and man-made events.

Organization of Petroleum Exporting Countries (OPEC):

A permanent, intergovernmental organization of 14 oil-exporting nations. Established in 1960 in Baghdad and headquartered in Vienna, Austria since 1965. Founding members include Iran, Iraq, Kuwait, Saudi Arabia and Venezuela.

Price Controls:

A government regulation establishing a maximum price to be charged for specified goods and services, especially in times of war or inflation. President Nixon introduced price controls on oil and gas to combat the energy insecurity that followed the 1973 Oil Embargo.

Power of Siberia:

Power of Siberia is a Russian natural gas pipeline in Eastern Siberia that will connect China to Russian natural gas.

Strategic Petroleum Reserve (SPR):

A 727 million-barrel-capacity complex of four underground storage caverns, located along the Texas and Louisiana Gulf Coasts. It is the largest emergency supply in the world and acts as a buffer in case of future disruptions to energy supply. Established in 1977 in accordance with the Energy Policy and Conservation Act of 1975.

Renewable Portfolio Standard (RPS):

A regulation that requires the increased production of energy from renewable energy sources, such as wind, solar, biomass, and geothermal.

Reference Case:

The Reference Case refers to represents EIA's best assessment of how U.S. and world energy markets will operate through 2050, based on many key assumptions. The economic and demographic trends reflected in the Reference case reflect current views of leading economic forecasters and demographers.

Representative Concentration Pathways (RCPs):

Diagrams of possible future scenarios for atmospheric greenhouse-gas concentrations used in identifying climate change's various future effects and impacts.

Small Modular Reactors:

Physically smaller nuclear reactors that allow for lower manufacturing and construction costs, shorter construction periods, and simplified designs that enhance safety.

Trans-Alaskan Oil Pipeline (TAPS):

A pipeline that connects the oil fields of Prudhoe Bay in northern Alaska to the harbor at Valdez, covering an expanse of 800 miles, and carries an average of 500,000 barrels per day to the lower 48 states.

Transmission and Distribution (T&D):

Transmission is the part of electricity delivery that moves bulk and high voltage electricity from the generation sites over long distances to substations near areas with higher electricity demand. High voltage electricity is sent through transmission lines, reduced to consumer acceptable voltages with transformers, and sent through distribution lines, which are then connected to homes and businesses.

Transmission Pipelines:

Transmission pipelines are used to transport crude oil and natural gas from their respective gathering systems to refining, processing, or storage facilities. Transmission pipelines also transport refined petroleum products and natural gas to customers, for use or for further distribution.

Trans-Pacific Partnership (TPP):

TPP refers to a proposed trade agreement signed by 12 nations in 2016 that would have lowered barriers to trade for all participants (with important implications for energy trade). President Trump pulled out of the agreement in 2017, prompting the remaining members to create a new deal.

Yamal LNG:

Launched in 2013, Yamal LNG is one of the largest LNG projects in the world. Located in central Russia, Yamal LNG consists of development of a gas field, a new gas plant, and transport infrastructure.

Zero-Emission Credits:

Monetary incentives that are funded by the government in order to compensate consumers for decreased carbon emissions.

123 Agreement:

Section 123 of the Atomic Energy Act outlines the conditions for nuclear cooperation between the US and other countries. A commitment to a total of nine nonproliferation mandates are required for nuclear partnerships.

Executive Summary

Liam Casey & Serena Baserman

The world currently stands at a crossroads in terms of its energy future. The two choices laid before us could not be more stark. Either mankind can continue to burn fossil fuels at an astonishing rate and suffer the deleterious effects of global climate change, or we can commit ourselves to a sustainable, and attainable energy future. The United States—with the world's largest GDP and third largest population—remains the second largest emitter of carbon dioxide. Regardless of its role as a major fossil fuel consumer, the United States has a clear opportunity to change its ways. By developing a sustainable carbon footprint, enhancing renewable energy partnerships, and pioneering new energy technologies, this nation has the opportunity to transform itself from major polluter to a green energy leader.

Given the failures of the Trump administration to commit the United States to a sustainable carbon footprint and to make meaningful strides in sustainability, the authors of this document have tailored their respective reports for the next administration. President Trump's decision to withdraw from the Paris Climate Accords, refusal to invest in alternative energy resources, and multiple reversals of vital environmental regulations undercuts our country's credibility as the leader of the free world. As undergraduate students of the University of Washington, however, we understand that future generations—including our own—will be directly impacted by issues related to energy security and climate change. It is therefore up to students such as ourselves to make young voices heard by the future president.

The title of this Task Force—*Energy and Climate Change: Non-Partisan Policies for the Next US President*—makes self-evident the overarching aims of our capstone project. Simply put, we wish to present energy and climate change issues in a non-partisan light to build political consensus on these issues. To tackle these broad ideas, we have divided our report into five major subsections. These sections include “US Energy Outlook,” “US Energy Usage,” “Central Energy and Climate Concerns,” “Global Role for US Energy,” and the “Role of Government in Energy and Climate Change.” Each of these subsections features individual chapters discussing current problems with various energy-related issues. Example chapters include titles such as “Energy and National Security” and “Public Awareness and Education.” After analyzing current problems related to energy and climate change, our task force introduced five overarching policy recommendations to remedy these dilemmas. It is our hope that the next president will build upon these recommendations to steer the country's energy and climate policy in a direction that the Trump administration never could.

Thank you for taking the time to read this report. We hope you carefully consider and evaluate our perspective on these topics and our subsequent policy recommendations.

US Energy Outlook

Russell Rose, Anna Tegelberg, Annette Singleterry & Jillian Roller

One

US Energy Outlook and Overview

Current Factors and Future Trends

Russell Rose

Introduction

The United States is in the midst of a new energy era: one that involves a huge expansion in the country's energy-producing capabilities while also presenting major issues for the future. It is no secret that the US is gifted with immense energy resources, particularly when both carbon and non-carbon options are considered. While carbon sources have long contributed to the prosperity and advancement of the US, non-carbon resources like nuclear and hydropower have also had a significant role in the power sector. Few experts, however, anticipated even a decade ago the current boom in oil and gas production, the rapid decrease in coal consumption, and the accelerated level of growth in renewable technologies. The United States must find a way to balance the benefits of increased oil and gas production with the need to reduce greenhouse gas emissions. These benefits include new trade exports, and with them, geopolitical leverage as the US continues to compete with the Organization of the Petroleum Exporting Countries (OPEC) to control shares of the oil market. To fully grasp the extent and implications of this challenge requires a clear understanding of the current U.S. energy situation as well as projections for its future. The following discussion will provide such understanding in the form of a summary overview.

Current US Energy Production and Usage

The United States uses and produces energy from a variety of major sources, which can be grouped as petroleum, natural gas, coal, renewables (including hydropower), and nuclear. Its fossil fuel (petroleum, natural gas, and coal) resources are especially large, and continue to comprise more than 80% of total energy consumption ("Energy Information Explained"). At the same time, the US remains for now the world's largest producer of non-carbon electricity from nuclear power and has considerable resources for solar, wind, and geothermal power expansion. For purposes of consistency and comparison in discussing these resources, this summary uses the metric of British thermal units (Btu).

Total U.S. energy consumption in 2017 was 97.7 quadrillion Btu, which can be divided into five primary sectors. According to the U.S. Energy Administration (EIA) in 2017, electric power was the largest sector at 38.1% of the share followed by transportation at 28.8%, industry at 22.4%, residential at 6.2% and finally commercial at 4.5% (Fig. 1.1) ("Energy Information Explained"). Of the 97.7 quadrillion Btu consumed in 2017, 87.5 quadrillion Btu was produced in the United States. Natural gas had the largest share at 31.8%, petroleum at 28.0%, Coal at 17.8%, Renewable energy at 12.7%, and nuclear power at 9.6% respectively ("EIA Explained").

The remainder of energy consumption is imported, coming primarily from net imports of crude oil. This is significant because it means that net exporters of petroleum have geopolitical leverage over the United States, especially OPEC, as they can control the oil market. Petroleum is the most important fuel in the transportation sector, as it contributes to 92% of all its energy production. Natural gas, on the other hand, makes up 76% of the residential and commercial sectors, as well as the largest share, 34%, of power generation (“EIA Forecasts Natural Gas to Remain Primary Energy Source for Electricity Generation”).

U.S. primary energy consumption by source and sector, 2017
Total = 97.7 quadrillion British thermal units (Btu)

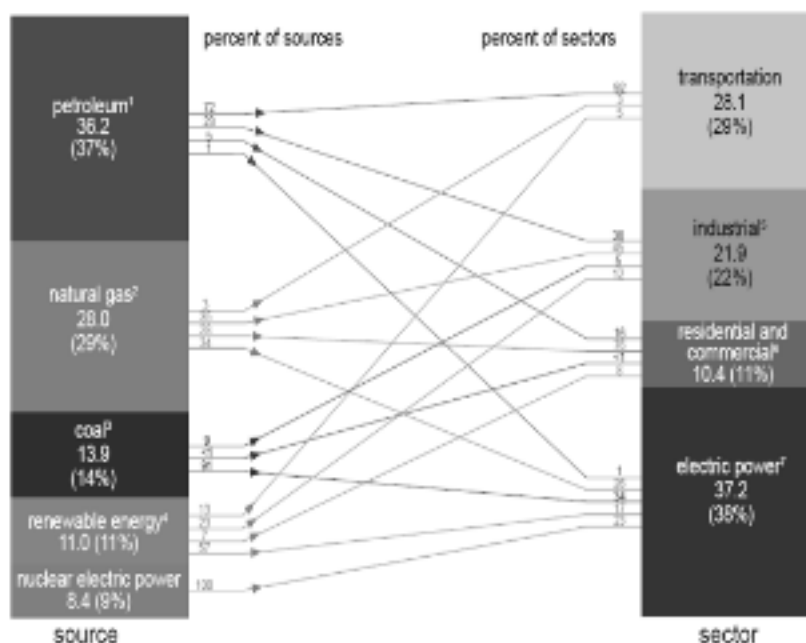


Fig. 1.1: U.S. Primary Energy Consumption by Source and Sector, 2017.
Source: “US Energy Facts Explained.” *Energy Information Administration*, n.d.,
<https://bit.ly/2gA4YAK>. Accessed 11 February 2019.

Current Energy Imports and Exports

The percentages that each major source contributes to the total share of energy produced has changed over time (Fig. 1.2), with carbon sources typically dominating. Since 2010 there has been enormous growth in oil and gas production due to new technologies. Drilling techniques are the main factor leading to increased production. This has brought the U.S. to historically new highs in both sources, such that it is now a net exporter of natural gas exporting 3.17 trillion cubic feet (Tcf) and importing only 3.04 Tcf in 2017 (“Natural Gas Imports and Exports”). It is also one of the world’s largest exporters of petroleum fuels exporting an average of 6.3 million barrels of petroleum per day (MMb/d). The increase in exports of petroleum has decreased the United States net imports from 3.7 MMb/d at the end of 2017 to 0.55 MMb/d as of November 2018 (“Oil Imports and Exports”). 33% or 3.37 MMb/d of petroleum imports come from OPEC countries which is significant because this gives OPEC leverage over

the oil market in the United States. Continued increase in production of petroleum in the United States will impact U.S. reliance on foreign oil and increase revenue from the top five export destinations which are Mexico (17% of export share), Canada (14%), China (7%), Brazil (6%), and Japan (5%) respectively. While petroleum exports have positive benefits economically and geopolitically, it will increase carbon emissions contributing to climate change.

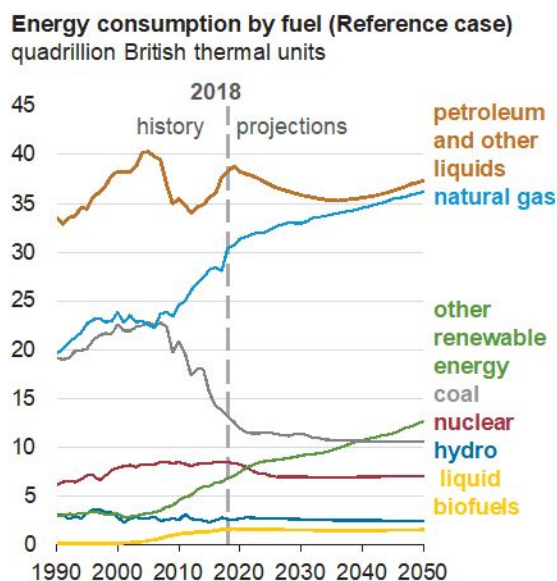


Fig. 1.2: US Energy consumption by fuel, 1990 – 2050.

Source: “Annual Energy Outlook 2019.” *US Energy Information Administration*, n.d., <https://bit.ly/2tGb1eo>. Accessed 21 February 2019.

Alternatively, coal peaked around 2008 and has trended down through 2016 with a slight increase in 2017. The EIA attributes this increase to lowered production costs caused by the bankruptcy of several major coal producers and an increased worldwide demand for coal, specifically Asian and European countries (“U.S. Coal Production, Exports, and Prices Increased in 2017”). The trending decline is largely due to the cheap cost of natural gas as well as the increase of environmental regulations under the Obama Administration. These regulations included the Clean Power Plan to reduce 32% of CO₂ emissions from electrical power plants below 2005 levels by 2030. The Trump Administration, however, is currently diminishing these standards and has given states more leeway to create carbon emission regulations. The plan under the current administration projects to change the plan from 32% reduction of CO₂ emissions to between 0.7 and 1.5% (Friedman). Between 2005 and 2014 the transition between coal and natural gas resulted in the avoidance of 1,254 trillion metric tons of CO₂ emissions (“Breakthrough Energy”). The U.S. is still a net exporter of coal, but net exports are down as well due to slow economic growth and increased natural gas trade (Krauss).

There has been growth in the non-carbon sector as well. Wind and solar technologies represented 60% of new generation capacity in the United States. There were over 1.6 million

solar installations in 2017 which attributed to solar producing over 1% of total power generation (“Breakthrough Energy”). This increase is largely due to technology and the ability to utilize solar for domestic as well as industrial purposes. New innovations have allowed for solar to be installed into homes and interconnected to the grid. Consumers can produce their own power and sell excess power back to the grid. There is also continuing political support for renewable energy. A primary example includes California’s requirement for solar panels on new homes. Technological innovations and declining costs have also increased the production in wind power. Wind power accounted for roughly 6% of total US electricity output in 2017 (“Energy in the US”). Hydroelectric power has been increasing, but its growth has slowed 2% from its 50 year average (“EIA Explained”). There have been over 1,800 megawatts of additions since 2010 (“National Renewable Energy Laboratory”). Hydroelectric plants produce about 7% of total U.S. electricity generation. Finally, the United States is the world’s largest producer of nuclear power but has seen no real growth in the last 30 years as the implementation of new reactors has come to a halt: The US currently has 98 operating reactors accounting for about 10% of the nation’s total capacity¹ but generating 19% of actual electricity and 60% of non-carbon power (World Nuclear Association).

Jobs in the Energy Sector

Many Americans are worried that a decrease in carbon-based energy production will lead to the destruction of thousands of jobs, when it just means the transition of jobs from carbon to non-carbon. In 2017 Energy sectors employed roughly 6.5 million Americans increasing by nearly 133,000 from the year before. Within the overall energy sector, energy power generation and fuels employed over 1.9 million workers. There is a common belief that the transition to non-carbon sources will leave many Americans without jobs. However according to the 2017 data collected by the U.S. Energy and Employment Report, 1.1 million of the employees working in the energy power generation sector work in coal, oil, and gas, while 800,000 work in renewables, nuclear and low emission natural gas. This sector continues to grow as wind power increased by 107,000 workers and Natural gas increased by roughly 19,000 employees from 2016 to 2017 alone. The only decrease that renewables saw was solar, which decreased by 24,000 jobs (National Association of State Energy Officials). Jobs in energy trend with the overall production of each resource and as non-carbon increases it creates jobs in the sector. As Production slows coal jobs are lost as factories close and production slows. There is no evidence to support that in the transition from carbon to non-carbon there would be a decrease in jobs, as non-carbon jobs continue to rise with increased implementation.

Future Trends for Energy

Since 1953 the US has been a net energy importer, but future projections show this changing in the 2020s due largely to the increase of petroleum and natural gas exports. The United States is already a net exporter of natural gas and is projected to achieve this position consistently in petroleum by 2020 (EIA Outlook 2019). According to the Annual Energy Outlook

¹ Capacity is the percentage of actual electrical energy output compared to the maximum potential for energy output.

2019 reference case which is the U.S. Energy Information Administration's best assessment of how U.S. and world energy markets will operate through 2050, U.S. crude oil production will continue to increase each year through 2027. After 2027 crude oil production is predicted to stay at over 14 million barrels per day through 2040, compared to the 11 million today. According to the same reference case, Natural gas will experience the largest increase through 2050, due to the low-cost development of shale gas and oil resources. This growth is projected at 7% per year in the next couple years before dropping down to 1%. It is important to note that the average growth between 2005 and 2015 was only at 4%. The energy production share of natural gas is expected to increase from 34% to 39% by 2050. Partially due to this increase, coal is expected to decline from 28% total generation in 2018 to 17% by 2050 in the reference case. Despite this decrease, the U.S. is predicted to continue to be a net coal exporter through the reference period. Its top five destinations being India (12% of coal exports, South Korea (10%), The Netherlands (10%), Japan (8%) and Brazil (8%) ("EIA Outlook 2019"). The increase in carbon sources is significant for a few reasons. The first is that it provides increased economic production, through the creation of jobs and net exports. Secondly it provides geopolitical leverage as the United States gets closer to being energy self-sufficient. Finally, it is important to note because this is ultimately detrimental to climate change as it means an increase in emissions. In order to decrease CO₂ emissions, energy will need to switch from carbon based to non-carbon sources.

Non-carbon energy is set to increase in all areas except for nuclear according to the same prediction. Wind and solar will become increasingly competitive due to performance improvements and declining costs for a more competitive product. Increased integration of solar panels to the grid will continue to drive the demand up for domestic consumers. For larger plants, solar through 2024 has a near-term investment tax credit (ITC)² (Department of Energy) through the Internal Revenue Service (IRS). Utility-scale photovoltaic (PV) solar plants with construction starting before 2020 and completed before 2024 receive a 30% ITC and any plants completed after 2024 will receive 10% ITC. According to the reference this will have a significant impact on the increase of solar power through 2024, and through 2050 43% of total capacity additions will be in PV solar plants ("EIA Outlook 2019"). These decreased tax breaks (as well as the technological advancements) have already made wind and solar the lowest cost option in some markets which will increase in the future. The cost of wind equipment is expected to fall by 30% between 2018 and 2050, resulting in a 4% annual growth rate ("EIA Outlook 2019"). In the short-term wind too has an ITC for small wind equipment as part of the 2018 Bipartisan Budget Act. This legislation gives a 30% ITC to plants before 2020 and only drops to 22% by 2023 while large wind turbines over 100 kilowatts will receive 12% through 2020 (US Department of Energy).

Other Non-carbon resources are expected to see future growth, just not at the same level as wind or solar. Hydropower and geothermal power see potential growth as often they

²An Investment Tax Credit is a percentage reduction of income taxes that a person or company typically would pay to the federal government.

can be incorporated into existing infrastructure. For hydropower, turbines can be added to already completed dams, and for geothermal, already established facilities can be expanded. Due to these cost-effective and environmentally friendly alterations, hydropower has the third largest renewable capacity behind wind and solar (NREL). Nuclear energy, on the other hand, is expected to drop in the coming years. According to the EIA reference case Nuclear power is set to decline from 19% down to 12% in 2050. These projections are determined from decreasing revenues from low growth in electrical output, the competition of cheap natural gas, and cheaper renewables from increases in technology (EIA 2019 Outlook). However, according to research done by HIS Markit and Energy Futures Initiative, privately funded nuclear research initiatives are creating safer, cost effective, and more efficient options for nuclear reactors. They are currently working with the Canadian Nuclear Safety Commission to qualify their designs to the criteria of the International Atomic Energy Agency (“Breakthrough Initiatives”).³ These designs could prove to be monumental in the change from Carbon to non-carbon sources, but currently there is a negative connotation surrounding nuclear power in the United States. For nuclear to see an increase in future years public perception will need to be changed.

Conclusion

Analyzing the current energy situation as well as future trends it is clear we are in a period of increased energy use in all sectors. While the increases in non-carbon sources are promising, they need to be increased at a significant rate and matched with other emissions-reducing approaches in order to balance and eventually curb the increase to petroleum production.

- Coal is at a steady decline but could be phased out quicker to make room for low-carbon and non-carbon energy production.
- The trend in the decrease of nuclear energy is concerning, as it is an important and efficient non-carbon producer and the largest source by far of non-carbon electricity.
- Oil and gas production are projected to continue to expand for the foreseeable future. This will be a tough issue as it provides economic prosperity and gives the United States more geopolitical leverage but is harmful to the environment.
- Natural gas will continue to increase. While it is carbon based, it produces a significant percentage less emissions than coal or oil
- Jobs will decrease in the carbon industry but be created through implementing non-carbon sources.

³ These criteria are safety standards that each new nuclear plant must meet according to the IAEA to ensure safety of people and the environment.

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Two

The Importance and Challenge of Oil

US Fossil Fuel Energy – Part One

Anna Tegelberg

Introduction

The United States has among the world's largest endowments of fossil fuel resources, including oil, gas, and coal. These fuels--especially oil and coal--have provided the overwhelming majority of US energy for more than 150 years. Since 2010, as a result of technological advances primarily in drilling and completion, America has entered a major new boom period in oil and gas production that has dramatically changed its energy outlook, its concerns over energy security, and its role in global oil and gas markets and geopolitics. Concern over growing oil imports, a dominant issue for the US following the oil crises of the 1970s, has given way to the reality of America as a top global producer and net exporter of crude oil and petroleum fuels. This stunning turnaround has made the US a competitor to the Organization of Petroleum Exporting Countries (OPEC) and Russia on the world stage, with the possibility of reducing American allies' reliance on these nations in Europe and East Asia.

At the same time, the boom in hydrocarbon production arrives in the historical moment that climate change has placed fossil fuels in a new context—one that argues forcefully for a profound reduction in the use of these fuels. As the world grows more serious about decarbonization, the US faces a dilemma in how to balance its newfound wealth in oil and gas with the clear need to reduce emissions from carbon-based energy sources. While this dilemma exists for the world as a whole, it is intensified in the United States as a new global oil power.

In 2015, fossil fuels made up 81.5 percent of total US-energy use, the lowest share in a century. This decline reflects a growing shift in America's energy mix, as coal consumption has rapidly declined, oil has declined only slightly, and both natural gas and renewable sources have grown significantly. These changes are themselves a result of economic factors related to the new hydrocarbon era (abundant, cheap natural gas replacing coal), but also priorities related to lowering carbon emissions. The situation reposes the dilemma noted above while adding an element of realism. Fossil fuels will remain essential to the global economy for some time, even as the demand and momentum for decarbonization continues to intensify. By dealing with this situation head on, the US has the opportunity to act as a global leader in a domain that will dominate energy development in the current century.

Growing US Oil Production and Consumption

As a strategic energy source, oil has long been a major concern for national security and economic activity. Petroleum-derived fuels power more than 90 percent of global transport, which makes them essential to military prowess and the movement of people and goods. Until

recently, oil imports were a key worry for the US, as they had continued to increase for decades, reaching 50 percent of total consumption by 2005. Yet a surge in domestic production has occurred since then due to the widespread use of advanced hydrofracturing, especially in petroleum-rich shales, with the result that imports have fallen to their lowest levels in more than half-a-century and are no longer considered an urgent issue.

As of 2017, the US is officially the largest crude oil producer in the world. It produces about 16 percent of total world production, above Saudi Arabia and Russia (Oil, EIA). US oil is produced in 32 states and in US coastal waters, with the largest and most rapidly rising volumes from Texas and North Dakota, where advanced fracking is especially widespread (Oil, EIA). The 2019 Annual Energy Outlook (AEO) Report by the Energy Information Administration (EIA) projects that US crude oil will continue to set annual production records through 2027 and remain at levels above 14.0 million barrels per day through 2040 (Fig. 2.1) (EIA).

Currently, the US is one of the world's largest exporters of liquid hydrocarbons. In 2017, these exports (crude oil and refined fuels) averaged about 6.3 million barrels per day (Oil, EIA), making the US a net exporter for the first time in many years. This level of exports places the US behind Russia (~7.4 mb/d)(EIA) and Saudi Arabia (~8.4 mb/d), but proves it is already a major competitor (Russia, EIA). The five largest destinations of US petroleum exports are Mexico, Canada, China, Brazil and Japan (Oil, EIA). Oil drilling and gas extraction exports in 2018 were valued at just under 50 billion dollars (Oil Drilling & Gas Extraction, IBISWorld). As the US continues to grow in crude production, its international market share may also grow, expanding the number of export destinations significantly.

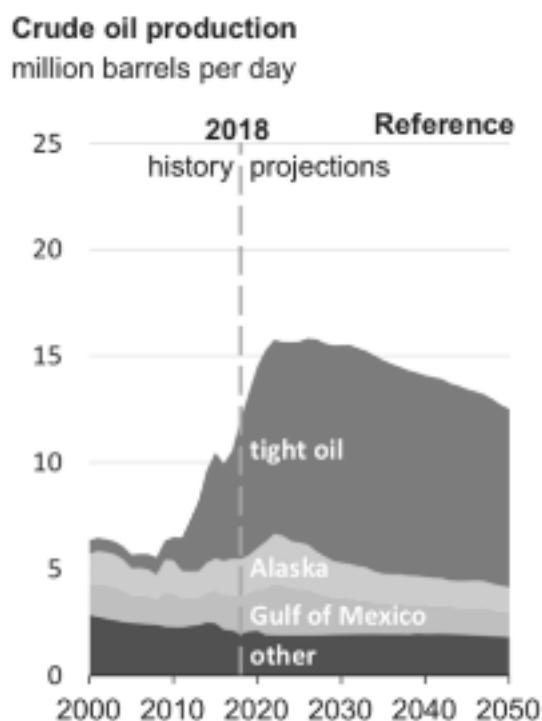


Fig. 2.1 Crude oil production from 2000 to 2050

Source: U.S. Energy Information Administration. *Annual Energy Outlook 2019*. EIA. Page 55. Accessed 24 January 2019.

Domestically, the US consumes more petroleum liquids than any other nation, with the great majority (about 90 percent) for transportation. In 2017, the total amounted to just under 20 mb/d, slightly below the historical peak of 20.8 mb/d in 2005. As shown in Fig. 2.2, most consumption will come from light, medium, and heavy-duty vehicles running on motor gasoline and diesel (distillate) fuel (EIA, 118). In addition to the transport sector, oil serves as a major feedstock (along with natural gas) for petrochemicals, including plastics.

Recent forecasts by the EIA show consumption for transport rising slightly then declining until the late 2030s, at which point it begins to rise again ((Fig. 2.2). This trend is based on current federal rules for increased fuel economy followed by growth in the number of vehicles after 2037. Fuel economy rules extend only to 2025 for new light vehicles and 2027 for new heavy-duty trucks. The trend could therefore alter considerably with continued improvement in fuel economy, such that consumption would keep falling into the 2040s and possibly beyond. As for a possible “rebound effect”—by which consumers erase some gains in fuel savings by driving more—recent research suggests that this will not significantly diminish the benefits of reduced consumption (Hoekstra).

It is essential to point out that only with a long-term decline in consumption will the US achieve full self-reliance (no imports) in petroleum fuels. This reality has important meaning for national security in terms of the US military. Oil is likely to remain essential to military vehicles for some time, since electrification of heavier land transport and jet-powered hardware, or other advances that provide alternatives to petroleum fuels will take more time to develop and become economical.⁴

⁴Fig. 2.2 does not reflect major increase in alternative and electric vehicle use (EV), another factor that could add to a decrease in light-duty vehicles and gasoline use.

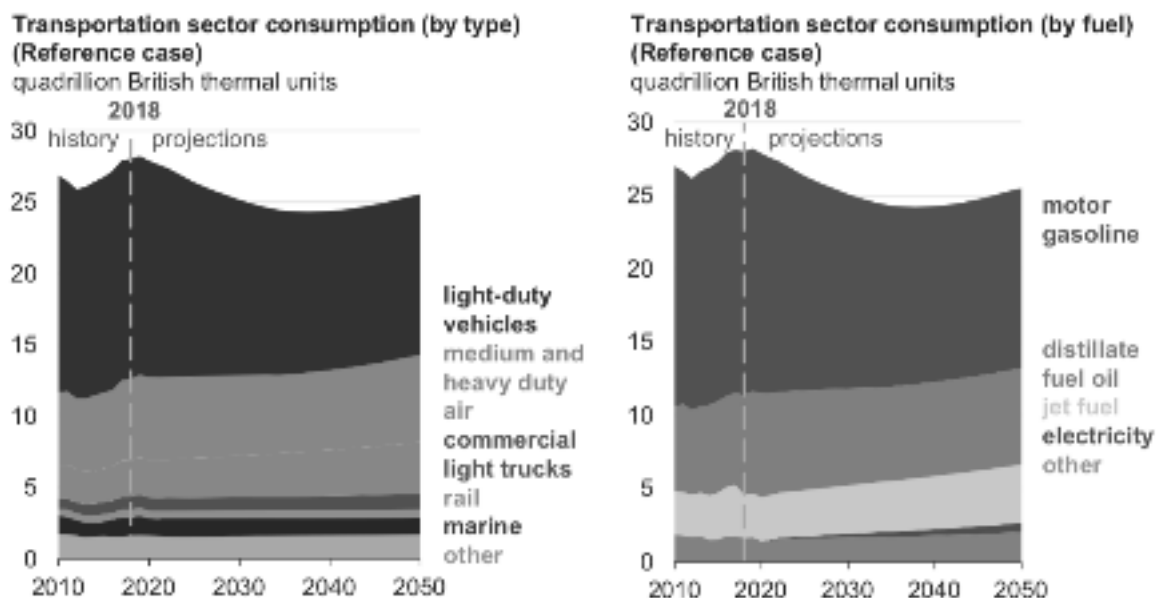


Fig. 2.2 Transportation sector oil consumption through 2050 by vehicle and fuel type
Source: U.S. Energy Information Administration. *Annual Energy Outlook 2019*. EIA. Page 117.
Accessed 24 January 2019.

The US oil industry generates a large amount of domestic revenue and supports many jobs. Oil and gas drilling and production, combined with petroleum refining and petrochemical manufacture, generate a total revenue of no less than 850 billion dollars. (Oil Drilling, IBISWorld), (Petroleum Refining, IBISWorld), (Petrochemical Manufacturing, IBISWorld). A joint report by PricewaterhouseCoopers and API states that in 2015 the oil and gas industry supported 10.3 million US jobs and added 1.3 trillion dollars to the US economy (Tadeo). These industries provide high paying jobs and a multitude of technical and nontechnical career paths. All of this shows the high economic importance of hydrocarbon industries.

Impact of US Oil Reliance

At the same time, the refining and consumption of petroleum generates large amounts of greenhouse gases, as well as a number of natural resource management issues. Exploring and drilling for oil can disturb land and marine ecosystems, and hydraulic fracturing has become controversial due to its water use and presumed capability to contaminate surface and ground water with hazardous chemicals. (Oil, EIA). Fracking is one of the technological advances that has widely increased US oil production, but it can affect local water availability by not recycling flowback (Oil, EIA). Oil spills are another major concern and source of public dissent. The US government has set standards and procedures to reduce and properly clean up spills when they occur, but a majority of spills occur in state-regulated pipelines, many of which are old and poorly maintained. (Oil, EIA).

By far, the most damaging effect of the oil industry, however, is driven by gasoline consumption. The transportation sector is one of the largest contributors to US GHG emissions and has the highest carbon intensity (mass of carbon dioxide produced per unit of energy generated) of any sector of the economy. In 2017, total US carbon dioxide emissions from aviation and vehicle gasoline were about 22 percent of total US energy-related carbon dioxide emissions (Oil, EIA). The EPA reports that light-duty vehicles were responsible for roughly 60 percent of the total, while medium and heavy-duty trucks accounted for another 23 percent, with aircraft another 9 percent (EPA). This places light-duty vehicles in the spotlight of concern for the next several decades. If the US is to seriously deal with the threat of global warming, it needs to consider measures able to reduce or capture emissions from these vehicles or replace them with alternative kinds.

Government Support for the Oil Industry

Although the correlation between increased petroleum consumption and climate change is known, the US government has not enacted widespread policy solution to decrease fuel consumption—such as a cap and trade policy or carbon fee. Part of this stems from the reality that oil is essential to the US military, globally for modern transportation, and a booming sector of the US economy. A certain level of government support for the oil industry is necessary, but further regulation of transportation sector emissions would not prove detrimental to US interests domestically and globally and would, in fact, contribute to long-term national security.

The US military is the largest institutional consumer of oil in the world, using more than 100 million barrels of oil per year (US Military and Oil, UCS). A ten dollar increase in the price per barrel of oil costs the US military billions of dollars. This heavy military reliance on oil renders the US vulnerable to price fluctuations, which are often determined by global conflict. The US has a national security interest in continuing domestic production of oil and maintaining order in the global market. Yet, moving oil is dangerous and inefficient. With nearly 70 percent of the weight brought to any battlefield being fuel, there is a need for innovation in military mobility when weighing the costs of over-reliance on oil.

Regarding gasoline, the EPA has required emissions control devices and cleaner burning engines, among other regulations (Oil, EIA). Yet current fuel economy standards will stop requiring additional efficiency increases within the next 5 to 7 years (EIA, 28). New fuel economy standards and incentives to opt away from traditional gasoline-powered vehicles need to be set for the coming decades. The transportation sector needs a clear, long-term goal for reducing emissions, just as the US government must further protect at risk public land and groundwater from being available to oil and gas drilling.

Conclusion

As the world grows more serious about decarbonization, the US faces a dilemma in how to balance its newfound wealth in oil and gas with the clear need to reduce emissions from carbon-based energy sources. The US faces serious and detrimental effects of climate change without significant reduction in annual GHG emissions from oil production and consumption.

- The US is now the world's largest oil producer and a growing exporter. Thus, it has new geopolitical sway as a competitor to OPEC and its attempts to influence global prices.
- Oil is likely to remain essential to transport and the US military for many decades unless alternative vehicle technologies (e.g. EVs) are rapidly advanced and brought to market.
- Due to high emissions, oil forms a large part of the dilemma facing the US regarding its challenge to balance hydrocarbon abundance with the need to reduce emissions.
- New vehicle fuel economy is projected to rise by 43 percent from 2018 to 2050, but this is not enough to offset the increase in gasoline consuming cars overall. Strong incentives for lifestyle change are needed in order to significantly reduce the long-term reliance on gasoline powered vehicles.
- Heavy military reliance on oil renders the US vulnerable to price spikes, which are often determined by global conflict. The US has a national security interest in continuing high levels of domestic production of oil.
- Oil industry regulation lacks a clear direction and goal for reducing emissions. This will need to be addressed for both economic and national security reasons.

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Three

Abundance and Issues of Natural Gas & Coal

US Fossil Fuel Energy – Part Two

Anna Tegelberg

Introduction

As major sources of energy for the US, natural gas and coal have undergone dramatic changes in recent years with opposite trends. The shale gas revolution and the drive to lower domestic carbon emissions have combined to make gas the most rapidly expanding fuel nationwide and a major replacement for coal in both power generation and industry. As a result, natural gas consumption has risen in tandem with a collapse in coal use since 2008 (Fig. 3.1). However, while the rise in gas demand is anticipated to continue, this collapse in coal use is expected to end in the near future, with more stable long-term consumption and production levels (Fig. 3.1). Combined with the projections given for oil discussed in the previous chapter, these forecasts strongly suggest that fossil fuels will remain the dominant sources of energy in the US at mid-century. However realistic in terms of the present, this can be considered a less-than-optimal outlook because of the continued high level of US emissions and the increasingly dangerous effects of climate change caused by reliance on carbon energy.

Natural Gas: Overview

Natural gas abundance in the US, like that of oil, has expanded greatly due to technologies responsible for the “shale revolution.” This has been matched by rapid growth in the use of natural gas (Fig. 3.1) as a replacement for coal, especially in power generation and industry. New abundance has made gas cheaper than nearly any other source (Natural Gas, EIA). Other advantages include much lower carbon emissions than oil or coal and the existence of large, in-place infrastructure allowing nationwide access via networks of transmission pipelines (Natural Gas, EIA). Moreover, the US has very recently become a new global exporter of (liquefied natural gas) LNG, enhancing the affordability of gas worldwide, and thereby providing a possible long-term geopolitical buffer against over-dependence on OPEC and Russia. Globally, the US is now estimated to have the fourth largest proven natural gas reserves, behind Russia, Iran, and Qatar (Central Intelligence Agency).

The domestic and export outlook for natural gas is strong in the US, but it does not come free of concerns. While gas is widely considered to play a useful role in the transition to a low-carbon power supply and grid flexibility (Deyette), it has also been the most common replacement for coal and nuclear plants that have proven economically non-competitive. While cheap natural gas has reduced emissions overall, it has also stifled development of other non-carbon sources like nuclear, hydropower, and renewables. As natural gas plants for power generation are long-lived capital stock, this trend could prove a significant barrier to long-term decarbonization, as suggested by the forecast in Fig. 3.1.

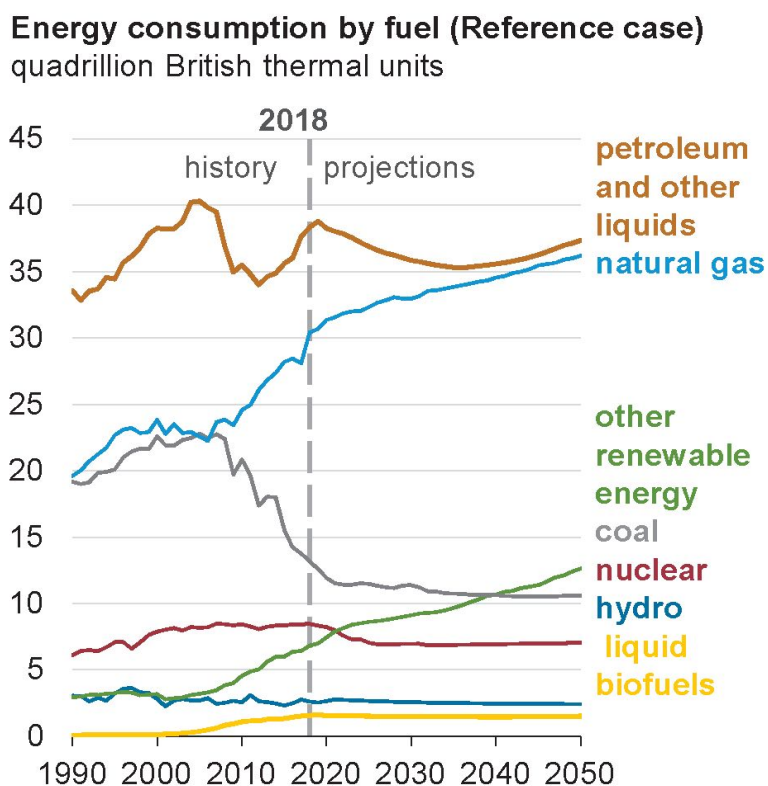


Fig. 3.1: US Energy consumption by fuel, 1990 – 2050.

Source: U.S. Energy Information Administration. *Annual Energy Outlook 2019*. EIA. Page 27.
Accessed 24 January 2019.

Natural Gas: Production and Consumption

US natural gas production in 2017 was the second-highest level ever recorded (By some measures, EIA). Production increases from shale gas in particular have grown rapidly, from about 4 billion cubic feet per day (bcf/d) in 2005 to 65 bcf/d at the end of 2018 (Natural Gas, EIA). In 2017, five states accounted for 65 percent of US dry natural gas production—Texas and Pennsylvania with the largest shares, Oklahoma, Louisiana and Ohio (Natural Gas, EIA). Proven reserves of shale gas are now estimated by the EIA at about 308 trillion cubic feet (tcf), raising total proven reserves for the US to 464 tcf (US Crude Oil and Natural Gas, EIA). Technically recoverable reserves (those recoverable using current technology, irrespective of prices) have risen to no less than 1,986 tcf, an all-time high (Natural Gas, EIA).

Most gas produced in the US is consumed domestically (Natural Gas, EIA). Fig. 3.2 shows that a majority of this consumption goes to power generation and industry, with the former growing rapidly in the past decade to 26 percent of total electricity in 2017 (Natural Gas, EIA). The forecast given in Fig. 3.2 suggests these two sectors will continue to dominate gas consumption long-term. In the industrial sector, natural gas is used as a fuel for process heating and as a raw material to produce chemicals, fertilizer, and hydrogen (Natural Gas, EIA).

LNG exports beyond the Americas began in 2014 and have grown rapidly (Natural Gas Exports, EIA). With nine more terminals approved (five under construction) and at least 13 proposed, it is virtually certain that such exports will increase considerably over the next decade (Natural Gas, FERC). Destinations for these exports include many nations, with larger volumes headed to China, Mexico, South Korea, and Japan, and rapidly growing (but smaller) amounts to India, UK, France, Italy, Netherlands, Taiwan, and Chile. With the exception of China, at present the largest source of global LNG demand, these trends suggest an overall preference for US allies in Europe and East Asia.

Similar to the oil industry, the natural gas industry in the US is highly lucrative and provides well-paying jobs. As the industry grows, so will many Americans' reliance on the natural gas industry for their livelihoods. This is in contrast to the loss of employment in the coal industry that has come with falling use of that energy source.

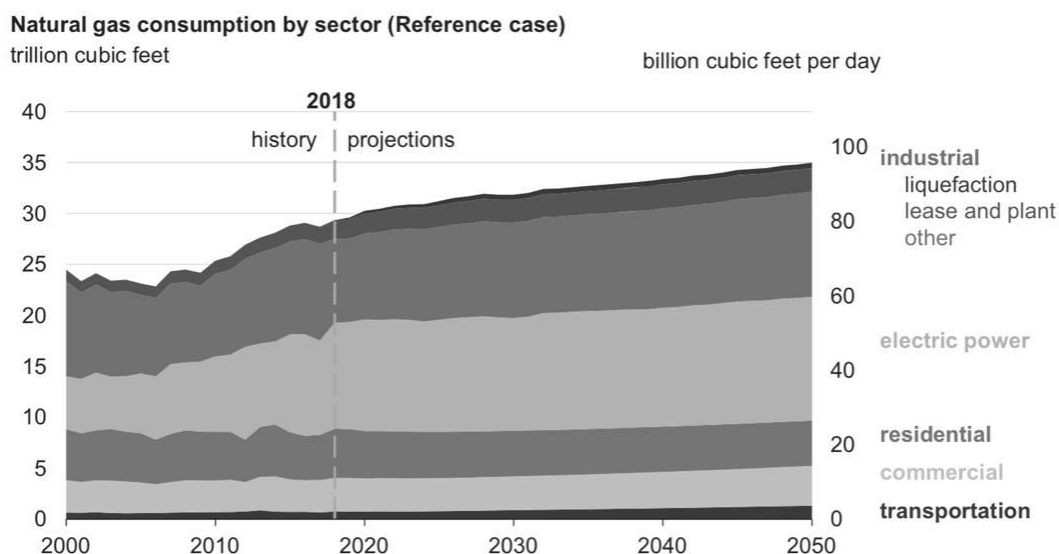


Fig. 3.2: Natural gas consumption by industry sector through 2050

Source: U.S. Energy Information Administration. *Annual Energy Outlook 2019*. EIA. Page 81.

Accessed 24 January 2019.

Natural Gas: Future Outlook and Environmental Issues

The 2019 AEO Report forecasts that of the three fossil fuels, natural gas will expand most in production through 2050 (EIA, 12). Both domestically and globally, such increased volumes will put downward pressure on prices. At the same time, since US oil and gas companies will receive higher prices for exported gas, growing LNG sales will likely provide added motivation for increased gas drilling and production.

While good for the natural gas industry, such increased abundance and use will compete directly in the US with non-carbon sources like nuclear and renewables. There is concern, therefore, that expanded consumption of gas will lock-in this carbon source for the larger part of this century and possibly beyond. An analysis by the Energy Department's National Renewable Energy Laboratory found that with today's technology, the US could reliably and affordably produce 80 percent of its electricity by renewable sources in 2050 (US Energy Department). This does not include the potential for retaining or expanding nuclear-generated electricity, which today is responsible for roughly 60 percent of non-carbon power in the US. The concern therefore appears justified that continued decadal growth in US natural gas consumption would result in a significant limit to long-term decarbonization. This must be a policy concern, if climate change is to be a priority issue for the federal government.

Coal: Overview

The US has the largest coal reserves of any nation and for well over a century used them for the overwhelming majority of US electricity. Yet the age of coal's dominance has ended, and its future is less than bright. The major reason for this is economic: surging natural gas production from shale has made this source particularly cheap, causing many existing coal power plants to become uncompetitive. By 2018, natural gas had surpassed coal as the top fuel for power generation.

In addition, there has been mounting public pressure to reduce coal use, given its high GHG emissions, production of mercury, large volumes of solid waste, and damaging health impacts. Though considerable attention has focused recently on job losses with decreased coal use, the industry has been downsizing for decades. The largest decline in employment occurred between 1985 and 2000, even while coal production held steady, primarily because of the shift in production centers from smaller, more expensive mines in the East to larger, cheaper strip mines in the West (Kolstad). In terms of the future, the outlook is for coal use to continue its decline, possibly reaching a low but still significant level. This, however, will depend on a number of factors, including natural gas prices, cost of renewable technologies, and level of support for nuclear power.

Coal: Production and Consumption

US coal production peaked in 2008 and has since then entered a period of major decline. Forecasts are for production to fall from 762 million short tons (MMst) in 2018 to 608 MMst in 2035, where output will stabilize (Fig. 3.5) (EIA, 110). It is notable that the US has 22 percent of global reserves, sufficient to last for more than 300 years at 2017 levels of production (Coal, EIA).⁵ There are three major coal-producing regions: the Appalachian, Interior, and Western. Wyoming is the top state, with 41 percent of US production (Coal, EIA).

⁵Behind the US is Russia with 16 percent and Australia and China with 14 percent and 13 percent of world reserves respectively.

Currently, coal makes up about 14 percent of total US energy consumption (Coal, EIA). The electric power industry accounts for almost all coal use today. Specifically, coal generated about 30 percent of US electricity in 2017 (Coal, EIA). This, however, is projected to decline to around 17 percent by 2050 (See fig. 3.3) (EIA, 22). This means that somewhere around half of all existing coal plants will be converted to natural gas or shut down and replaced by renewable and possibly nuclear facilities.

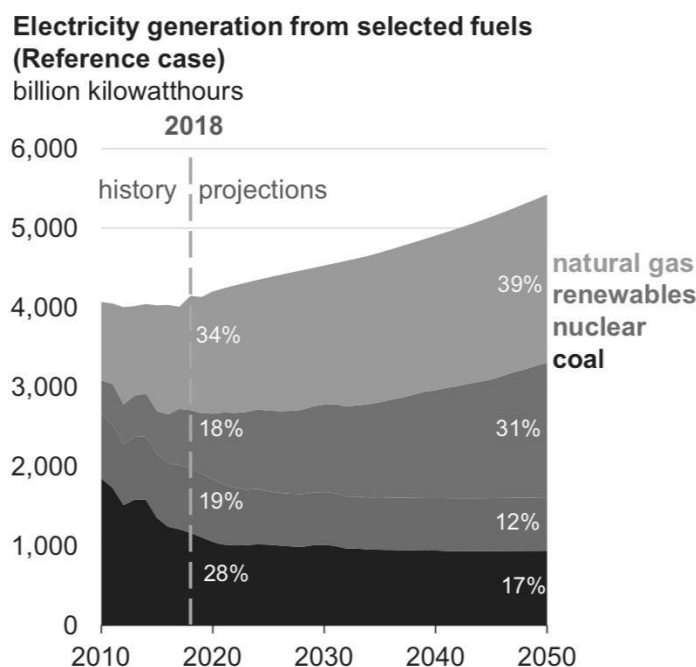


Fig. 3.3 Electricity Generation by Fuel Source Through 2050

Source: U.S. Energy Information Administration. *Annual Energy Outlook 2019*. EIA. Page 21. Accessed 24 January 2019.

However, despite such decline, the US is projected to be a net exporter of coal through 2050 (EIA, 14). Exports, in fact, accounted for about 13 percent of US coal production in 2017 (Coal, EIA), yielding nearly 10 billion dollars (Coal Mining, IBISWorld). The US exports coal to over 42 countries, the top five being India, South Korea, The Netherlands, Japan, and Brazil (Coal, EIA); all nations to which US companies also export LNG. Overall, US coal exports are not expected to increase significantly, in contrast to LNG, due in part to competitors like Australia and China that are closer to centers of demand in Asia (EIA, 14).

Coal: Environmental Issues

Coal is the most highly polluting fossil fuel and generates the largest amount of GHG per unit of produced energy. It releases toxic airborne pollutants and heavy metals like mercury, sulfur dioxide, nitrous oxides, and particulate matter (soot) (Coal and Air Pollution, UCS). Soot is linked with chronic bronchitis, asthma, premature death, and negative cardiovascular effects. While most of these effects have been greatly reduced in a majority of US power plants, there

continue to exist dozens that were built before clean air legislation that lack modern pollution controls. Moreover, US exports cannot be guaranteed to find use in upgraded plants.

At the same time, coal is also the most abundant and widespread energy source on earth, except for the sun and wind. Yet in an era when air pollution from coal burning has been found responsible for hundreds of thousands of premature deaths and when climate change primarily caused by carbon emissions defines a major global threat, it is the environmental factors that must be given precedence.

It is therefore a concern of some importance that the US lacks a comprehensive plan to reduce coal-powered GHG emissions. During the Obama Administration, the Clean Power Plan was designed to curtail emissions from coal power plants some 32 percent by 2030 (Environmental Defense Fund). It would have been the first legislation to set national US pollution limits on coal plants. Yet the plan was rejected and curtailed by the Trump Administration, which instead put in place new government supports for coal plant investment (Milman). Because coal is being priced out by natural gas and renewables and coal exports are expected to remain stable, new coal plants defy economic rationale.

Coal & Natural Gas: Key Analysis

The substantial shift from coal to natural gas in the US power sector will continue, thus aiding decarbonization in the short term while potentially opposing it long-term. Such is integral to the dilemma facing the US today in terms of its great abundance in carbon sources and yet its need to considerably reduce levels of emissions and pollution.

Conclusion

- The US is now a top nation in gas reserves and production and will soon be a major global exporter of LNG. As such it will compete against other key suppliers and have the potential to reduce dependence of its allies on Russia and OPEC.
- Gas consumption is projected to grow rapidly through 2050. Such growth may act to limit over time the level of decarbonization in the US power and industrial sectors.
- The US has the largest reserves of coal in the world and will continue to be a net exporter through 2050 even as domestic consumption and production fall (Coal, EIA).
- Coal is being rapidly replaced by natural gas in the power sector, which will help to reduce GHG emissions and air pollution.
- The replacement of coal by natural gas must be a temporary bridge to a non-carbon future, which may or may not be distant at this point. The federal government can help to build such a bridge by allowing economic forces to work.
- While it does so, the federal government must also support preparations for that future, so that the US in the long-term does not remain prey to its own great abundance of fossil resources.

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Four

Renewables

Development of Wind, Solar, Geothermal, and Hydropower

Annette Singleterry

Introduction

Non-carbon energy sources are crucial to both the US's efforts to combat climate change and to achieve energy security. With its massive size, sprawling coastlines, and variety of climate, geology, and topography—the US has an abundant supply of non-carbon energy sources of every kind. The US currently relies on carbon energy sources to supply the majority of its energy needs, but the energy supplied by non-carbon energy sources has been growing consistently since the turn of the century. As seen in Fig. 4.1, carbon energy sources provided approximately 80% of the energy consumed in 2017, while renewable energy sources only supplied 11% of the total. Two major factors have led to the recent growth in the renewable energy industry: concerns about climate change from carbon energy greenhouse gas emissions and fears related to energy security and high oil prices. These factors are why the diversification of the US's energy portfolio with new non-carbon energy sources is so crucial. Effectively exploiting these resources could significantly expand the US's supply and diversity of natural energy sources, thereby increasing national self-reliance and security. Non-carbon sources also produce little to no greenhouse gases during the energy production process. Additionally, this expansion has also increased our economic competitiveness worldwide and has provided many new jobs. The expansion of the non-carbon energy industry within the US has already increased the overall abundance, reliability, and affordability of the US's energy supply, and it will continue to do so.

U.S. energy consumption by energy source, 2017

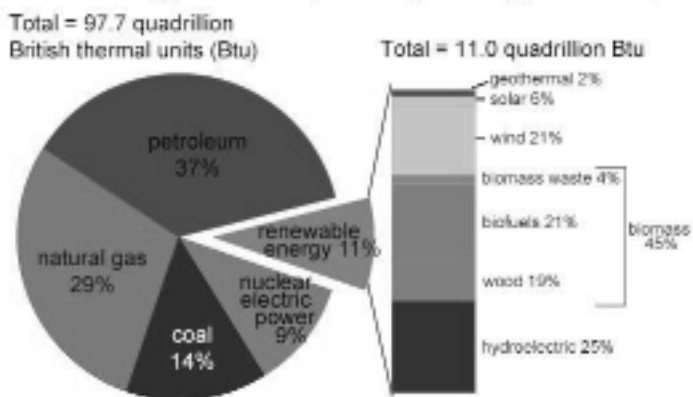


Fig. 4.1 US Energy Consumption by Energy Source for 2017

Source: “Renewable Energy Explained.” *EIA*, 13 July 2018, https://www.eia.gov/energyexplained/index.php?page=renewable_home. Accessed 17 February 2019.

There are very large resources of renewable energy in the US—including those related to wind, solar, geothermal, and hydropower. Some of these resources—particularly wind and solar—are diffuse and intermittent in nature and require support from energy storage and an updated grid. Nevertheless, renewables could considerably advance U.S. self-reliance in the power sector. The future of these sources, however, is not completely open and secure. Non-carbon energy industries have advanced dramatically in the last few decades due to federal and state government support, but the future of these industries is largely uncertain without this support. This is mainly due to the competition of cheap and abundant natural gas resources. As of now, only horizontal onshore wind turbines, photovoltaic (PV) solar cells, traditional geothermal systems, and hydroelectric dams could safely compete in the US market with no government support.

It is true that wind and solar have become the least expensive option for new power generation in some markets where carbon energy is more expensive. However, these sources are inherently intermittent and variable, so their actual energy production is low per unit area. Except for geothermal and hydropower sources, renewable energy needs support from other technologies and energy sources to be integrated into the US grid systems. Despite the competition it provides, natural gas often helps bridge this gap between supply and demand from renewables by delivering a backup source of energy whenever necessary. To be widely used on a national level, wind and solar require support from forms of energy storage. At present, lithium-ion batteries dominate the market, but their supply is limited by rising competition for their use in electric vehicles and geopolitical factors (e.g. effort by both state and private companies in China to gain market control). Sodium-sulfur (NaS) batteries, pumped hydro, and compressed air energy storage (CAES) also have the potential for future growth and large storage capacities. Nevertheless, the application of these technologies in the market is still limited in scope. The energy storage industry definitely still needs further development in order to support the growing wind and solar industries. It thus remains unclear at present just how quickly and fully wind and solar power generation can be expanded in the US.

Wind

The wind industry has exploded in the last couple of decades, and its potential for future growth has often been claimed as exceptional. In 2017, wind turbines provided approximately 6.3% of the US’s total utility-scale electricity generation. This is equivalent to about 254 billion kWh, compared to only 6 billion kWh produced in 2000 (Beckford). Except for hydropower, wind power was the first renewable energy source to become fully economically competitive with carbon energy sources (Montgomery 162). This economic viability also seems to be improving with every new year due to improvements in the cost and efficiency of technologies. The largest horizontal-axis wind turbines today have capacities up to 10 MW (Beckford). Despite continual increases in size, wind turbines now cost between \$750 to \$950/kW, and this has also

significantly reduced installed project costs ("2017 Wind Technologies Market Report."). The nationwide average levelized long-term price from wind power sales agreements is now about 2¢/kWh ("2017 Wind Technologies Market Report"). These declines in cost, the relatively easy installation process, and favorable tax policies have allowed the total installed wind power capacity to grow to 96,487 MW as of 2018 ("2017 Wind Technologies Market Report"). In 2017 alone, 7,017 MW of new wind power capacity was added, and \$11 billion was invested in the US ("2017 Wind Technologies Market Report"). Additionally, the rapid expansion of the wind power industry has also created many new job opportunities—mostly in construction, manufacturing, and professional services. In 2017, 107,444 workers were employed by the wind technology industry ("2017 Wind Technologies Market Report").

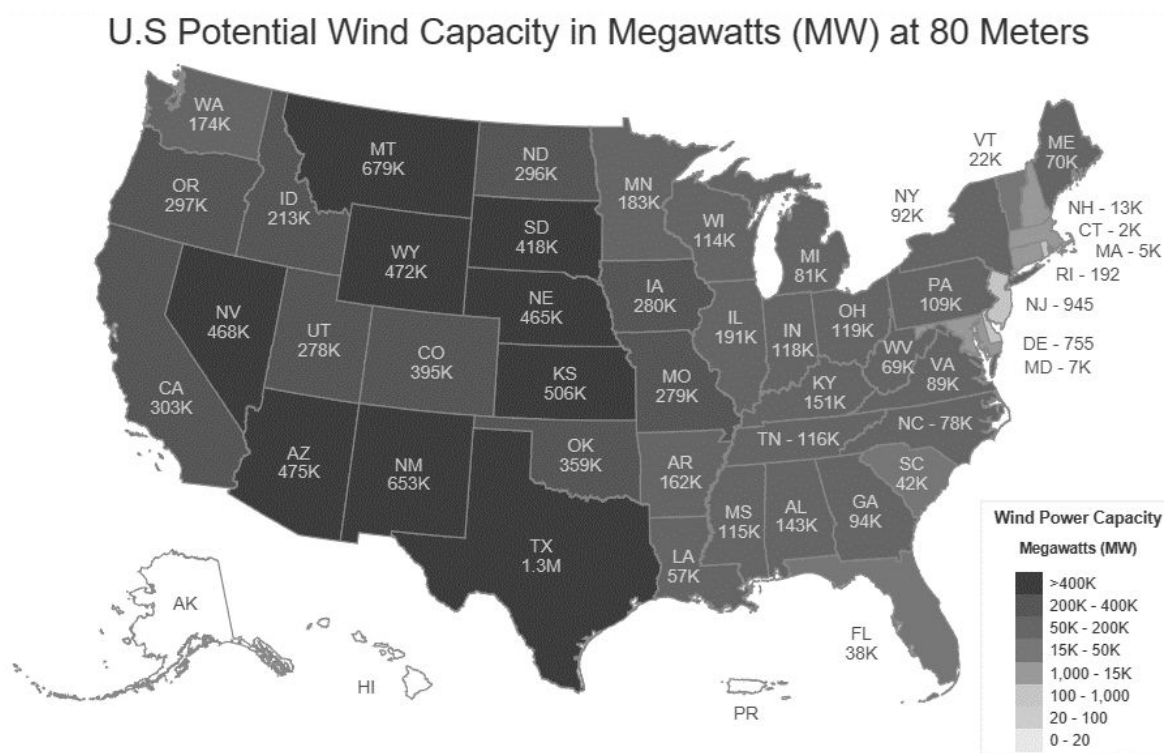


Fig. 4.2 US Potential Wind Capacity in MW at 80 Meters

Source: "Wind Energy Technologies Office." *WINDEXchange*, 26 Feb. 2018, <https://windexchange.energy.gov/>. Accessed 18 February 2019.

The availability and strength of wind power are varied throughout the US, with the strongest winds generally being on the coasts, on flat plains and hills, and in some mountainous areas. The largest continuous region with significant resource capability is the High Plains Wind Corridor, which reaches north-south from Texas to North Dakota and Montana ("2017 Wind Technologies Market Report"). Many onshore wind farms have been developed throughout the US in the past two decades to exploit these great energy resources.

Distribution of wind power plants in the Lower 48 states (as of December 2016)

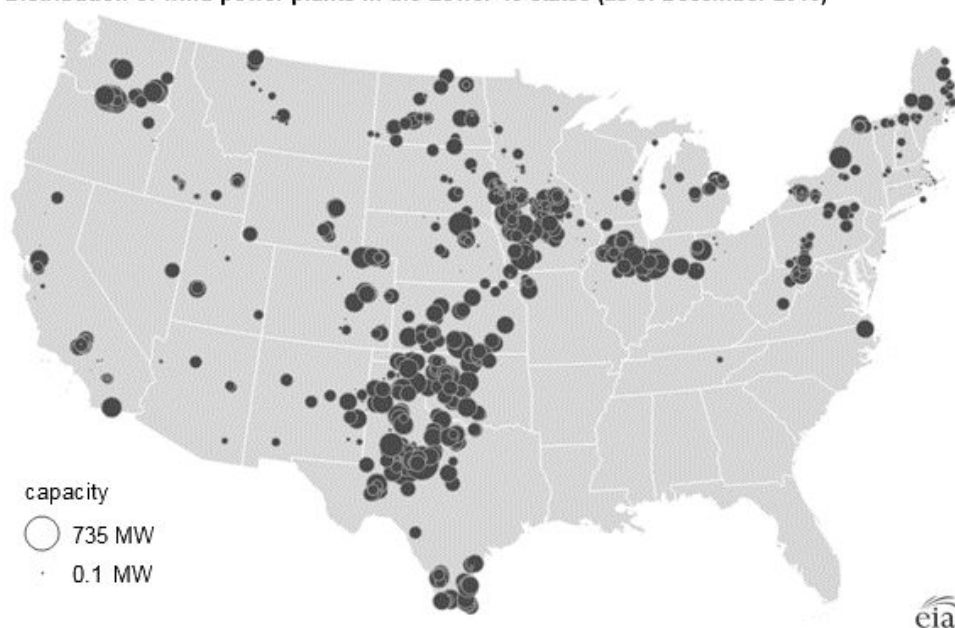


Fig. 4.3 Distribution of Wind Power Plants in Mainland US in December 2016

Source: Beckford, Tasha. "Wind Turbines Provide 8% of US Generating Capacity." *EIA*, 5 Feb. 2017, <https://www.eia.gov/todayinenergy/detail.php?id=31032#tab1>. Accessed 17 February 2019.

Wind power does have limitations and disadvantages. As mentioned above, the wind is a variable resource that is highly reliant on the season and weather. Winds are also usually the strongest at night-time, when demand for energy is the lowest, and weakest on hot days, when demand is the highest due to air conditioning (Montgomery 166). The energy generated by wind turbines often requires additional support from energy storage devices and natural gas plants to be integrated into the grid system and satisfy consumer demand. Wind patterns could also shift due to climate change, so investments made now could later become useless. The efficiency of wind turbines is variable as well. These turbines rarely operate at full efficiency and capacity. The strongest winds are several hundred feet in the air because of the multiplier effect⁶, so wind turbines must be able to reach those high winds. To maximize the efficiency of turbines, the average size of the turbine capacity, rotor diameter, and hub height are increased almost constantly. The massive size of these turbines can affect the look of landscapes, often in negative ways. In addition, the spinning turbines create significant amounts of sound pollution, so they are a nuisance to nearby communities if they are too close. The spinning turbines could also potentially endanger birds, but the slow rpm that turbines spin at makes this threat trivial. Moreover, this threat is negligible in comparison to the amount of avian deaths caused by

⁶The velocity of wind at ground level gets exponentially multiplied the farther away from the surface wind is. The wind velocity hundreds of feet in the air is multiple times stronger than the velocity at the ground, and the power that can be generated corresponds to this. See Muller.

skyscrapers and power lines. Furthermore, wind farms are no longer built in major bird migration pathways.

Offshore wind (OSW) turbines face even more challenges than onshore options do. The strongest and most consistent winds exist just off the coasts, but despite this, the US does not have many OSW turbines. In the past, these OSW turbines have not been economically viable in the US due to the high installation and maintenance costs. This has gradually changed due to the continuous development of the technology by European countries, though. By the end of 2017, the world had a total capacity of 17,000 MW generated by OSW. This growth has already significantly lowered costs in Europe, and these costs have made it possible for OSW to grow in the US as well. In 2016, the 30-MW Block Island wind farm began operating off the coast of Rhode Island, which is the first and only OSW facility in the US (Feldman et. al 23). OSW development in the US is currently mainly supported by individual state governments through subsidies and partnerships with private companies, and many new projects have been announced for the next few years in a number of coastal states.

Solar

In addition to wind power, solar power is an increasingly viable renewable power option. Peak solar energy generation is in the middle of the day, so it aligns perfectly with peak usage times. In 2017, the US contained over 1.6 million solar installations, which included about 41.1 GW of capacity. This was less than 2% of the US's total power generation for that year, but solar power technology is still expanding at a rapid pace. For the last decade, solar has grown an average of 59% every year. In 2017 alone, solar generated a \$17 billion investment in the US economy ("US Solar Resource Installed Capacity"). The solar electric generation industry also employed 349,725 people in 2017. Most of these workers were in construction and installation industries, but manufacturing and professional service industries also employed a significant portion of these workers. Additionally, Fig. 4.4 shows that the installed capacity for solar is well distributed throughout the US, with significant assets in both the West and the East. Unlike other renewable technologies, solar could truly be implemented in every single state, with varying degrees of success.

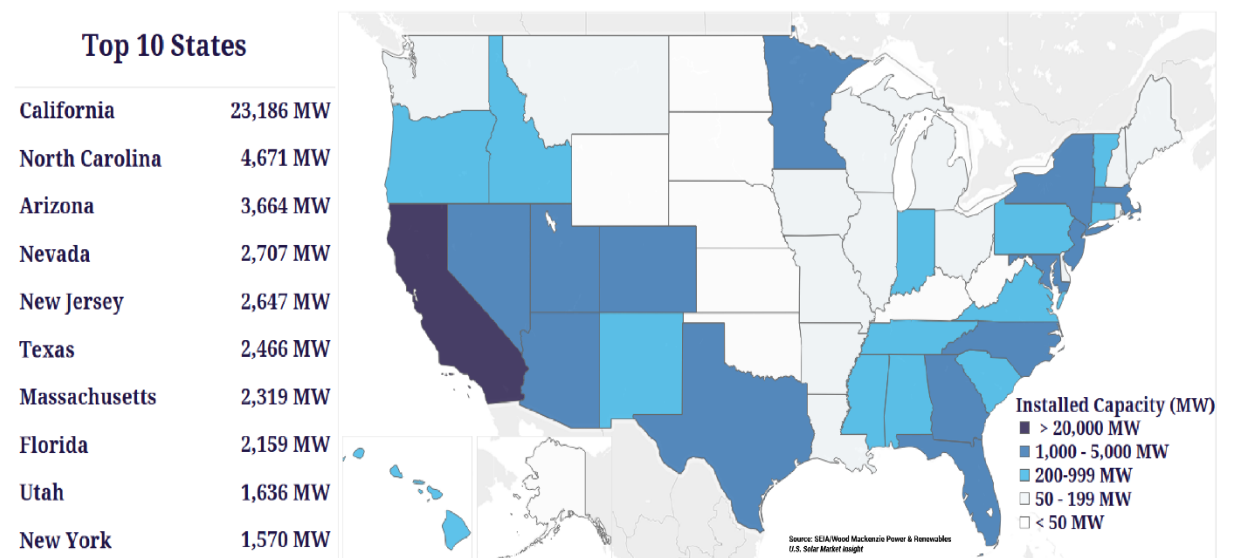


Fig. 4.4 US Solar Resource Installed Capacity

Source: "US Solar Resource Installed Capacity." *Solar Energy Industries Association*, 1 Aug. 2018. <https://www.seia.org/solar-industry-research-data>. Accessed 20 February 2019.

The most prevalent type of solar power is currently photovoltaic (PV) cells. This is because of its increasingly low costs per kWh. It can also be used in both residential and industrial settings. In 2010, an average residential system cost about \$40,000, but now that price has been reduced to \$17,000 without incentives. Utility-scale prices are also now completely competitive in the energy market at \$28/MWh to \$45/MWh ("US Solar Resource Installed Capacity"). The rate at which prices have been declining is astonishing. Prices of PV modules during the third quarter of 2018 was 21% lower than it had been in the fourth quarter of 2017 (Feldman et. al 45). A combination of the advantages of price and flexibility with strong policy support in recent years has allowed PV solar cells to dominate the solar market in the US (IHS Markit and Energy Futures Initiative 25). In the third quarter of 2018, the US had 1.82 million PV systems (Feldman et. al 20). Utility-scale power plants produced about 50 billion kWh in 2017 (U.S. Energy Information Administration). By the end of October 2018, the US contained 47 GW-AC of solar PV systems, with 28 GW utility-scale and 19 GW distributed⁷ (Feldman et. al 15). To put these numbers in perspective, that is enough electricity to power over 11.3 million homes ("US Solar Resource Installed Capacity").

The foremost obstacles inhibiting PV solar development are the efficiency and reliability of these systems. Most commercially available models have efficiency levels of only 5% to 15%. The efficiency is also undercut by the need to use inverters to convert direct current electricity from the cells to alternating current electricity to be used in distribution systems. This reliance on inverters has also affected the price, but US inverter prices have also been reducing steadily for

⁷Distributed energy refers to energy generated from PV solar panels installed in residential, commercial, and industrial settings.

the last few years. Because of the inherent variability of the sun, PV solar is also heavily reliant on storage technologies. In the first three quarters of 2018, approximately 425 MWh (169 MW) of energy storage was installed onto the electric grid in the US (Feldman et. al 34). The potential energy that could be harvested in the US also varies greatly depending on location. PV cells could be employed in any state to generate electricity, but the largest resources of solar energy are mostly concentrated in the West and the Southwest.

The second most prevalent type of solar technology is called concentrating solar power (CSP). CSP facilities use mirrors to concentrate solar energy on a receiver and then, this concentrated thermal energy can be used to generate electricity by creating steam to spin turbines or by using a generator. This thermal energy can also be stored for later conversion to electricity. However, this technology is far less developed than PV cells and cannot compete in the market without government support. The US grid currently includes approximately 1.8 GW of CSP ("Concentrating Solar Power"). The CSP industry also only provides 7.5% of the jobs in the solar industry (U.S. Energy and Employment Report 47). Energy from PV cells is significantly cheaper, and this has limited growth in the CSP industry. Construction and operation costs are still too high. But these costs would definitely be reduced with the implementation of a mass-manufacturing system for CSP system components. This would also increase the speed of construction and enable more efficient plants.

Despite these limitations, the CSP industry has a decent potential for future growth. Energy production from CSP facilities is far less variable than that from PV ones. In fact, CSP systems can supply power whenever necessary through the thermal storage system. Further development of CSP technologies could actually help more PV and wind power become integrated into the grid without needing to rely on support from natural gas ("Solar Industry Research Data"). Solar thermal technologies could also be used for other purposes besides energy generation—like water desalination and other industrial thermal needs ("Solar Research Spotlight: Concentrating Solar-Thermal Power"). With a reduction in prices to competitive levels, the number of CSP systems in the US would rapidly increase.

Geothermal

Geothermal energy resources have not been developed to the same degree as wind and solar, but the potential for future growth is significant. The inner layers of the Earth contain massive amounts of thermal energy created from the decay of radioactive material, and this thermal energy is mainly transferred to the surface at plate boundaries and deep interior fractures in the plates (Montgomery 149). Traditional hydrothermal systems convert the heat that exists in these places to energy by using water vapor to spin turbines. These hydrothermal plants rely on extremely high temperatures, between 300°F and 700°F, the existence of water, and rock permeability. In 2017, US conventional geothermal plants produced 16 billion kWh, which was 0.4% of total U.S. utility-scale electricity generation ("Renewables Explained"). Enhanced geothermal systems (EGS) and low temperature and co-produced resources are also being developed. EGS are man-made geothermal systems that exploit reservoirs of thermal energy that naturally lack either water or rock permeability. EGS technologies are not

commercially available yet, but when they are, they will expand the available thermal resources across the US (Feldman et. al 45). Low temperature and co-produced resources focus on resources with temperatures below 300°F and will also help expand the availability of geothermal resources. Regardless of the type, geothermal energy is very stable and is not subject to changes in the weather like solar and wind are. Most geothermal energy plants can even operate over 90% of the time ("2017 Annual Report Geothermal Technologies Office").

Geothermal energy expansion is only limited by a few issues. To access the high temperatures needed, power plants must drill thousands of feet. This is easily achievable using modern mining technologies that were developed to extract oil and gas, yet it is a costly process. The initial investment is usually about \$2500 per installed kW. The creation of new geothermal plants also still comes with a major exploration risk because of the inability to accurately predict temperature and permeability at depth from the surface ("2017 Annual Report Geothermal Technologies Office"). Because of these reasons, initial investment costs in geothermal plants are relatively high, but the low maintenance cost makes up for this. Maintenance and operating ("2017 Annual Report Geothermal Technologies Office"). The initial drilling has also been known to cause small earthquakes in the past, but modern technology can control them by adjusting the rate of fluid extraction and reinjection. Geothermal energy is also not completely constant over time as plates shift and water carves out new pathways underneath the Earth, so future profitability of geothermal plants is not completely predictable.

Geothermal energy can generate water pollution as well if handled improperly. After pumping the heated water to the surface, the water contains many different chemicals in it. The water must, therefore, be contained and pumped back into the Earth to sustain the resource and limit outside pollution. Power plants can also use scrubbers to remove the naturally occurring hydrogen sulfide ("Renewables Explained"). Even this polluted water sometimes creates revenue, though. The water often contains low concentrations of rare and valuable earth minerals and elements, like lithium and manganese, and these can be extracted from the water before it is pumped back ("2017 Annual Report Geothermal Technologies Office").

From 2010 to 2017, there were 17 new geothermal capacity additions in the US, with most occurring in the West (Roberts). This is because most of the US's geothermal resources are concentrated in the West along the Pacific Ring of Fire. California currently produces the most electricity from geothermal energy in the US at the Geysers, a 30 square mile region (Muller 240). In fact, California alone produces over 20% of the total global geothermal energy production ("2017 Annual Report Geothermal Technologies Office"). The Geysers produce steady and cheap electricity at \$0.03 to \$0.035 per kWh, and this demonstrates the feasibility of geothermal energy development. New power plants could even produce energy at \$0.05 per kWh ("2017 Annual Report Geothermal Technologies Office"). Moreover, as of 2008, the West still contained approximately 30 GWe of undiscovered geothermal resources ("2017 Annual Report Geothermal Technologies Office"). The US could also expand its production of energy from geothermal resources by improving existing facilities, which is significantly cheaper than investing in new infrastructure. This is because the resource quality has already been confirmed

and connected to the grid (Roberts). Geothermal energy certainly has a high potential for future growth, particularly in the West.

Hydropower

Hydropower has been developed in the US for decades, but it could still be developed further. Hydroelectricity is mostly produced in the western states, with Washington producing the most by far. The hydropower industry employed 66,871 people in 2017. These jobs were also spread out fairly evenly across the manufacturing, utilities, professional services, construction, and trade industries. Because of its long history in the US, hydroelectricity already accounted for approximately 7.5% of total US utility-scale electricity, or 300 million kWh, in 2017. The total U.S. hydroelectricity generation capacity was 80 GW. The dams producing this power are called run-of-the-river systems, and they generate power by utilizing water force to spin turbines. Some energy is also stored in dams and is released whenever necessary to generate power. Hydroelectric and energy storage dams actually only account for a small percentage of the total dams in the US, though.

Most dams throughout the US are non-powered and were created for irrigation, flood control, and municipal water supply. According to a study conducted by the Department of Energy in 2012, over 54,000 of these non-powered dams could be converted to hydroelectric dams. Altogether, these dams contain about 12 GW of potential hydropower capacity (“Renewable Energy Explained”). Moreover, as seen in Fig. 4.5, most of the opportunities for expansion actually exist in the East, not the West. Developing these dams could help more states become less dependent on carbon fuels and create new jobs. Most of the potential energy also exists in only 100 non-powered dams. They could easily add 8 GW of hydropower production capacity (“An Assessment of Energy Potential at Non-Powered Dams in the United States”). Many existing hydropower dams could also be improved and upgraded to expand their capacity and efficiency.

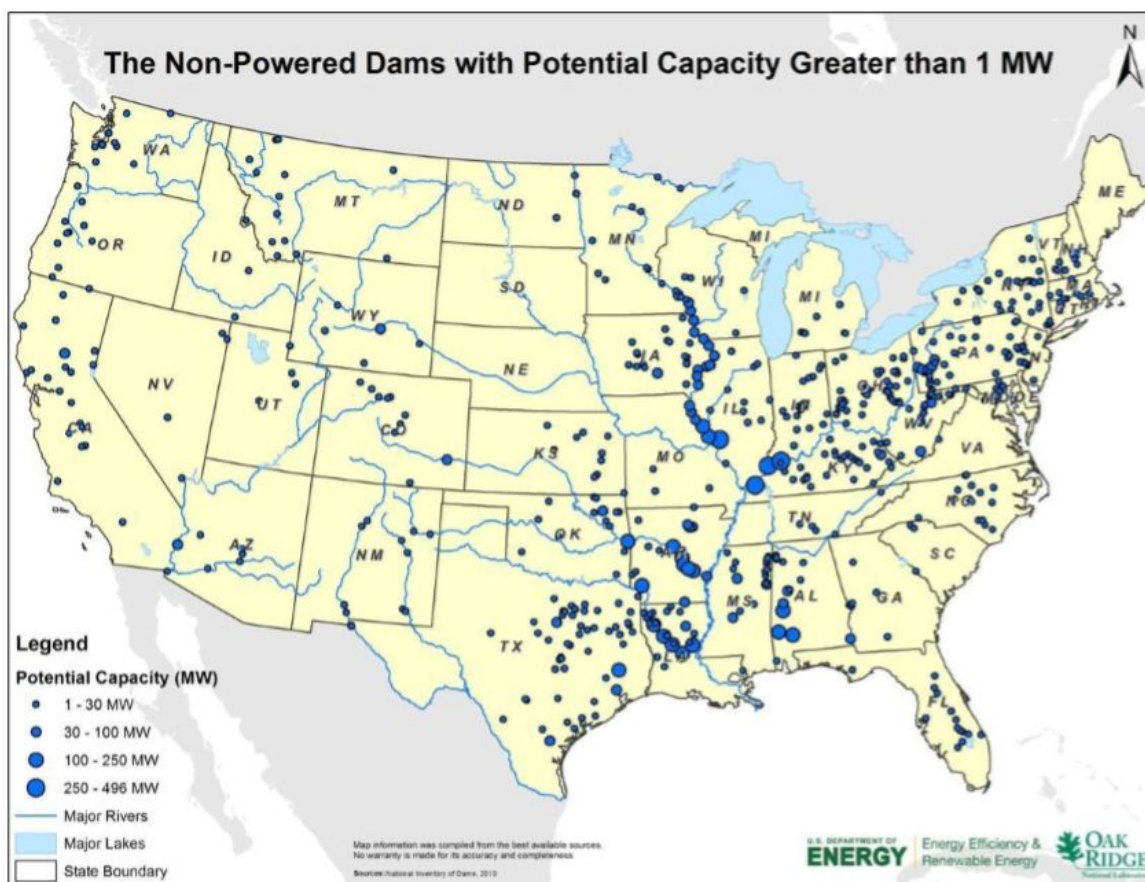


Fig. 4.5 US Non-Powered Dams with Potential Capacity Greater than 1 MW
 Source: "An Assessment of Energy Potential at Non-Powered Dams in the United States." Oak Ridge National Laboratory, 2 Jan. 2012.

https://www.energy.gov/sites/prod/files/2013/12/f5/npd_report_0.pdf. Accessed 19 February 2019.

The expansion of hydropower dams would not likely create much new environmental damage, but the general risks are still worth mentioning. Hydroelectric dams can obstruct fish migrations, and the turbines can kill and injure some fish. Current turbines generally kill between 5%-10% of fish that pass through, but new technology is being developed to reduce that to 2%. Fish ladders⁸ can be constructed to help migrating fish safely pass through as well. The ecology of the river could also be affected by a change in water temperatures, chemistry, and flow characteristics caused by a hydroelectric dam. This change in ecology could have a cascading effect in surrounding regions ("Renewable Energy Explained"). Additionally, carbon dioxide and methane are released when the construction of a new dam causes new areas to become flooded and plants begin to degrade. Climate change could also change water patterns and make certain infrastructure useless in time. Overall, most of these flaws only exist when new

⁸This is a system that allows fish to climb a gradual set of stairs covered with flowing water to move upstream. See "Renewable Energy Explained."

dams are built. Because of this, adding hydroelectric capabilities to a non-powered dam only provides a slight danger for fish.

Conclusion

- Onshore horizontal wind turbines have been extremely successful within the US. Wind can compete on the national energy market. Onshore wind production will also continue to expand as the efficiency and capacity of turbines is improved and as wind farms are built.
- Offshore horizontal wind turbines in the US are currently becoming economically viable for the first time ever thanks to technological advances made in Europe, and this industry will continue develop. This unlocks a major source of energy production potential for the US.
- PV solar cells have expanded rapidly throughout the US due to the relatively consistent declines in cost and the applications for both utility and distributed energy. PV solar will continue to expand at a rapid pace throughout the US. The efficiency of this system needs to be improved before it can start producing more significant amounts of energy.
- Conventional hydropower geothermal locations have already been successful in the US, and future projects need to be invested in throughout the West. GHS technologies also need to become commercially available in order to expand the possible areas available for geothermal energy production.
- The hydropower industry in the US already produces the most energy of any renewable, and hydropower energy prices are cheap and economically competitive.
- There is currently no future in the US for the construction of new dams because of the ecological damage it causes, but many non-powered dams, especially in the East, could easily be converted to hydroelectric dams. Converting just the top 100 dams could significantly expand the US's current hydroelectric capabilities.

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Five

Nuclear Energy: Moving Forward

Safe, Reliable, Non-Carbon

Jillian Roller

Introduction

At present, the United States is the world's largest generator of electricity from nuclear energy. Despite public anxiety, nuclear is the primary source of non-carbon electricity in the U.S. In addition to producing large amounts of non-carbon power, the benefits of nuclear include long operational life, high reliability, exceptional capacity factor, and small environmental footprint. Such advantages have long contributed to national energy security and economic prosperity, as well as to stability and resiliency of America's grid system. These benefits could be continued and possibly multiplied in coming decades if technological advances now underway are exploited at a significant level. Nuclear power can benefit both national security and public interest.

Despite these facts, nuclear faces uncertainty with regard to its long-term future as a major non-carbon source and its potential for expansion. A principal factor is the economics of nuclear power, which has suffered in recent years due to the considerable abundance and thus low price of natural gas. The competitiveness of existing nuclear plants has been improved in a few cases where states have given them added support in recognition of their value for achieving decarbonization. Whether this trend will continue to grow is unclear. Other factors include the high upfront cost of building new plants. Such hurdles are far from insurmountable, however. New technologies, including small modular reactors and advanced reactor designs that can be built more quickly and cheaply, offer new opportunities. An increase in federal support for related research and development, as well as revision in licensing procedures, would help open the door to retaining and even expanding nuclear as a key technology for mitigating climate change.

Capacity, Safety, and Environment

Nuclear power is a key component for the nation's electricity generation. With 9% of the nation's total generation capacity, it yields nearly 20% of the country's actual power ("What is Generation Capacity?"). This amounted to 805 TWh in 2017 ("Nuclear Power in the USA") and is due to the ability of nuclear to produce carbon-free power reliably 92% of the time a plant is in operation ("What is Generation Capacity?") (See Fig 5.1).

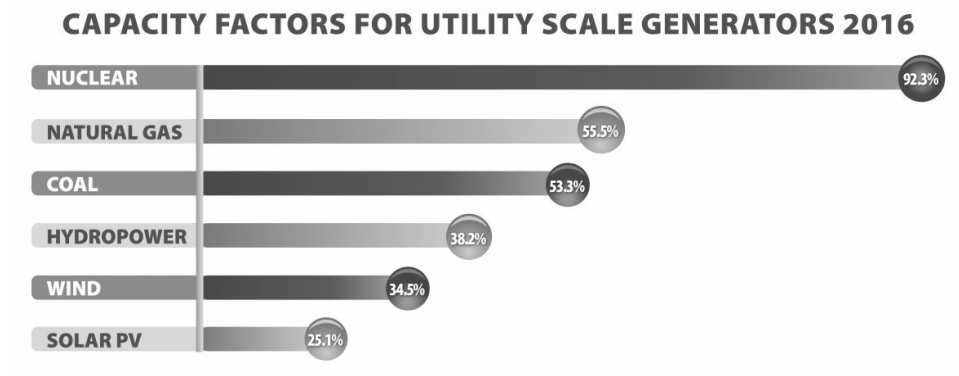


Fig. 5.1 Capacity Factors for Utility Scale Generators

Source: "What Is Generation Capacity?" *Department of Energy*, n.d., www.energy.gov/ne/articles/what-generation-capacity. Accessed February 6 2019.

The US has 98 operating nuclear power reactors in 30 states ("Nuclear Power in the USA"). Despite public fear, nuclear power has proved to be among the safest energy resources, with few injuries and fatalities among workers in more than seven decades. Since commercial operation of nuclear reactors in 1960, nuclear power in the US has not been responsible for a single death among the public (See Fig 5.2). Carbon based energy fuels are responsible for producing air pollution. When carbon emissions pollute our atmosphere, the result is an increase in deaths due to the negative environmental effects of climate change. Nuclear energy has reliable safety records because it is non-carbon and therefore does not contribute to air pollution.

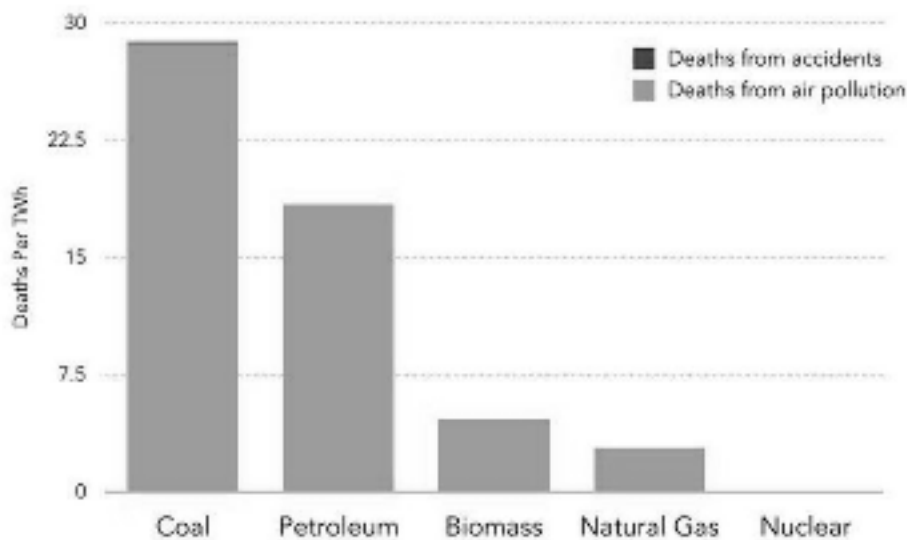


Fig. 5.2 Deaths per TWh by Energy Source

Source: "The Complete Case for Nuclear." *Environmental Progress*, n.d., environmentalprogress.org/the-complete-case-for-nuclear. Accessed February 6 2019.

Nuclear energy produces large amounts of power from relatively small amounts of land. Wind farms require up to 360 times as much land area to produce the same amount of electricity as a nuclear energy facility (“Land Needs for Wind, Solar Dwarf Nuclear Plant’s Footprint”). This in turn minimizes a nuclear plant’s environmental footprint. Furthermore, nuclear plants generate 63% of US carbon-free electricity (“Nuclear Power in the USA”). These factors paired with an unmatched capacity factor, highlights nuclear as capable of producing long term carbon-free power.

	Average lifecycle GHG emissions (tonnes/GWh)	Emissions produced from generating 2518 TWh of electricity	Additional emissions avoided through use of nuclear electricity in place of fossil fuel
Lignite	1054	2654 million tonnes CO ₂	2581 million tonnes CO ₂
Coal	888	2236 million tonnes CO ₂	2163 million tonnes CO ₂
Oil	733	1846 million tonnes CO ₂	1773 million tonnes CO ₂
Natural Gas	499	1256 million tonnes CO ₂	1183 million tonnes CO ₂
Nuclear	29	73 million tonnes CO ₂	-

Fig. 5.3 Greenhouse Gas Emissions Avoided Using Nuclear Energy

Source: “Greenhouse Gas Emissions Avoided through Use of Nuclear Energy.” *World Nuclear Association*, n.d., www.world-nuclear.org/nuclear-basics/greenhouse-gas-emissions-avoided.aspx. Accessed February 11 2019.

Role of Government

Section 123 of the US Atomic Energy Act of 1954 sets up conditions under which the US can prevent diversion of commercial nuclear materials and technology from their intended peaceful purpose (“Nuclear Cooperation Agreements”). Stringent guidelines under the Atomic Energy Act furthers the US mission of non-proliferation and national security. However, U.S. businesses cannot conduct business with countries that do not have a 123 agreement and are required “for U.S. companies to export to foreign markets” (“Nuclear Cooperation Agreements”). This limits the countries that the US can export nuclear technology to, creating a major economic disadvantage for the nuclear energy sector. China and Russia are actively pursuing nuclear projects in countries without US 123 agreements (“Nuclear Cooperation Agreements”). Russia and China are able to secure exports to these countries with no competition from the U.S. Cooperation with other nations is necessary for the US to secure access to all nuclear energy markets. Accessing international nuclear energy markets gives the U.S. the opportunity to export nuclear technology, resulting in economic gains.

The U.S. nuclear industry is currently at a crossroads. It has the lowest carbon output but at the highest cost. Federal involvement has helped the industry face several major hurdles. Economically, nuclear has very high upfront capital costs. Natural gas is a primary competitor to nuclear energy because natural gas makes up 34% of US electricity generation (AEO2019 22). At \$34/MWh in 2017, nuclear is expensive compared to natural gas, but is decreasing— from \$40/MWh in 2012 (“Nuclear Power in the USA”). As of 2016, there were about 2,462 trillion cubic feet (Tcf) of dry natural gas in the US. At the rate of consumption of 27.5 Tcf per year, the United States has enough natural gas to last about 90 years (“Natural Gas”). Because of this abundance, natural gas is cheap compared to nuclear energy. In addition, renewables have been selectively subsidized federally, and also by individual states. There is no comparative support for nuclear. Lack of support branches from the public as well, where misinformation about nuclear energy has produced fear and therefore diminished state level support. Nuclear disasters are the key component to public fear. However, there have been no nuclear disasters in the US. Increased occurrence of reactor closures have been caused by these issues, and are expected to continue to increase. This will further erode US leadership in nuclear energy, risking a turnover of global influence to China and Russia in this sector.

In 2016, The New York Department of Public Service (NYDPS) proposed zero-emission credits (ZECs) for nuclear generators that would work in parallel with the tax credits that renewable sources receive (“Nuclear Power in the USA”). Zero emission tax credits allow electricity generators to receive compensation for not emitting greenhouse gases in the production of electricity (“Nuclear Power in the USA”). This helped keep reactors economically viable in New York and Illinois. Zero emission tax credits supported the continued operation of the plants to capitalize on clean energy. The zero-emission credits “would generate \$2.8 billion in benefits, or two-thirds of the entire clean energy standard program” (“Nuclear Power in the USA”). It is feasible for other states to benefit if the US nuclear industry continues to develop.

Future Outlook

A new nuclear era is beginning. The US is being quickly approached by energy rivals such as China and Russia. Both of these nations are not developing their nuclear sectors for purely energy production. The US Russia is taking advantage of export markets that surround new reactor designs. Russia’s nuclear industry has projects in Belarus, China, Hungary, India, Iran and Turkey, and to varying degrees as an investor in Algeria, Bangladesh, Bolivia, Indonesia, Jordan, Kazakhstan, Nigeria, South Africa, Tajikistan and Uzbekistan among others (Nuclear Power in the World Today, WNA). Through these nuclear projects Russia is able to benefit its own economy in the short term and also seed long term nuclear market relationships. The spread of reactors to countries who have not implemented nuclear power, gives Russia an advantage in international influence over the US. China has taken advantage of the manufacturing of nuclear reactors and continues to dominate the market for new nuclear build. At the start of 2019, “13 of the 57 reactors under construction globally were in China. In 2018 China became the first country to commission two new designs” (Nuclear Power in the World Today). The US must become more than a leading producer of nuclear energy, they must compete with Russia and China in nuclear development. If the US is surpassed by Russian and

Chinese nuclear development, the US will suffer economic losses in exports and in country electricity generation.

The future outlook of US nuclear energy highlights a steady decline in generation, capacity, state support and reliance. "22% of current nuclear capacity retires by 2050" (AEO2019 96). Reactor capacity is the maximum energy output possible. As more plants close, there will be fewer active reactors contributing to US nuclear energy output. The obvious consequence of fewer reactors will be that energy capacity will decline. In addition, reactor closures will decrease the already limited quantities of state implemented subsidies and tax credits. This is not only an energy projection, it is an ongoing occurrence. As early as the mid 2020s we will see a "scheduled expiration of renewable tax credits[...] as well as the retirement of coal fired and nuclear generation capacity during the projection period" (AEO2019 82). If the minimal support already in place for nuclear energy decreases, the nuclear energy sector will lose traction economically and in research and development.

New Reactor Designs

New reactor designs are in progress, such as the Small Modular Reactor (SMR), which are the primary source of streamlining nuclear reactor production and efficiency. Not only are they physically smaller, but their modified technology offers "lower overall costs, shorter construction periods, and simplified designs that enhance safety." (Benefits, NUSCALE). An assembly-line approach in production, reduced meltdown risks and location flexibility are few of many benefits. The US benefits not only from efficient electricity production because "advanced SMRs can provide to the Nation's economic, energy security, and environmental outlook" ("Advanced Small Modular Nuclear Reactors"). The US is not the only nation that is developing SMR technology. China is active with manufacturing of nuclear technology, including SMRs, contributing to competition between companies. If the US continues to develop nuclear technology, they will remain competitive in the energy market provided that federal support for nuclear technology expands.

Conclusion

- The US is a leading nation in nuclear energy and must expand to remain competitive.
- Nuclear energy is desirable because of its safety, reliability, capacity, market, and non-carbon properties.
- Nuclear energy generation is projected to decrease by 2050 due to competition with natural gas, closure of existing reactors, and lack of federal and public support.
- China and Russia are surging forward in development and exportation of nuclear technology, securing their place in the energy market.

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US Energy Usage

Tom McGahern, Shaun Kuo & Geneviève Goutzioulis

Six

Energy Efficiency

The Power of Market Transformation

Thomas McGahern

Introduction

Energy efficiency efforts have proven to be significant in advancing a number of national goals, including economic productivity, environmental protection, and energy security. The central focus of government policy in this area is market transformation. Through incentives and mandates, such policy seeks to help lower barriers to energy efficient choices made by consumers and businesses. Efficiency improvements lower costs and improve quality for everything from power plants to laptops. As a key means of reducing energy intensity (consumption per unit GDP or per capita) they reduce costs and improve system resilience, whether for manufacturing, transportation, or residences. Indeed, reducing energy intensity defines an essential pathway to reducing emissions and thus mitigating climate change. Success in promoting energy efficiency hinges on cooperation between federal, state, and local jurisdictions, as well as partnership with the private sector. This report will focus on the central role of the federal government in three key areas of this important domain: The power sector, buildings, and the transportation sector. Together, these account for nearly half of all carbon emissions in the U.S. (EPA).

Power Sector

Efficiency-related policy in the power sector has targeted both the production and consumption of electricity. However, because direct authority over power generation (i.e. utilities) lies at the state level, the sway of federal policy measures are aimed at end-user efficiency. There are two primary approaches employed by the federal government in this respect: legislation that requires states to consider certain policies, and funding for state energy-efficiency programs. The federal government also supports research and development related to many aspects of energy efficiency (United States, Dept. of Energy, Office of Energy Efficiency and Renewable Energy, National Renewable Energy Laboratory).

End-user Approaches to Efficiency: Load Management

One common approach to increasing end-user efficiency at the state level is “Load Management”, which aims to reduce demand at peak hours. The most common forms of load management are Demand Response programs. Demand Response functions by incentivizing customers to decrease energy use during peak consumption hours, and can be facilitated automatically through the use of Smart Grid technologies (United States, Department of Energy). A couple companies, such as California based AutoGrid, are pioneering the use of this technology. AutoGrid’s “Demand Response Optimization and Management System™

(DROMS™) automatically sends a signal to its program participants if California Independent System Operator (CAISO) electricity market prices go above a certain threshold. This signal then triggers these smart thermostats to unobtrusively reduce the amount of energy being used during peak hours without impacting participants' comfort (MCE Selects AutoGrid Flex™ for Demand Response and Distributed Energy Resource Management).

One federal approach to incentivizing load response programs can be witnessed in the 2009 Recovery Act of the Obama administration. As part of the Recovery Act the Obama administration allocated 4.5 billion dollars to upgrading the energy grid. Much of this money went to implementing smart grid technology in participating states. The introduction of smart grid technology makes facilitating demand response programs more seamless for state utility companies and consumers as it automatically adjusts consumer consumption according to demand. According to a government funded study by the Electric Power Research Institute "The Smart Grid, combined with a portfolio of generation and end-use options, could reduce 2030 overall CO2 emissions from the electric sector by 58% relative to 2005 emissions" (Estimating the Costs and Benefits of the Smart Grid: A Preliminary Estimate of the Investment Requirements and the Resultant Benefits of a Fully Functioning Smart Grid). Fig 6.1 below is taken from a study done by the Lawrence Berkeley National laboratory which outlines the estimated benefit-cost ratio of investing in the Smart Grid over 20 years.

	20-Year Total (\$billion)
Net Investment Required	338 – 476
Net Benefit	1,294 – 2,028
Benefit-to-Cost Ratio	2.8 – 6.0

Fig 6.1: Summary of Estimated Cost and Benefits of the Smart Grid

Source: Cappers, P., A. Todd, and C. Goldman. 2013. Summary of Utility Studies: Smart Grid Investment Grant Consumer Behavior Study Analysis. Lawrence Berkeley National Laboratory, LBNL-6248E.

It must be reiterated that these numbers are only projections. The potential for the smart grid seems bright, but it is currently in early stages of implementation and research on its efficacy thus far provides mixed reviews. Part of this could be because as shown above, only a modicum of the necessary investment to fully establish this technology has been allocated to its progress. It may take a substantial increase in government funding to the smart grid before any conclusions can be made on its promise or shortcomings. As the nation's sources of electric power generation continue to diversify, more and more sectors will engage in "electrification" (i.e. transitioning from carbon fuel sources to electricity) as electric power becomes more efficient and cost effective (Molina). This steadily increasing load on our power grid will make the transition to smart technology increasingly essential.

Buildings: Labeling Programs and Appliance Efficiency

Buildings consume 40% of U.S. primary energy, including 72% of U.S. electricity consumption and 36% of natural gas consumption. The building sector drives the growth for new power plants— 87% of the growth in electricity sales between 1985 and 2006 is attributable to building sector demand. Similar to the power sector, the federal government doesn't have direct authority over building codes and regulations, but it can transform the market, again, by focusing on end-user efficiency. By using its uniquely broad reaching authority it can increase the use of energy efficient appliances nationwide through federal standards, incentives, and programs. Due to the fact that appliances contribute to a significant portion of building emissions, this is an indirect way to improve building energy efficiency in residential, commercial, and industrial sectors. One of the most prominent examples of such a program is ENERGY STAR®. ENERGY STAR is a labeling program introduced in 1992 by the EPA, that helps consumers identify what appliances are energy efficient. It has been enormously successful in both saving money and reducing CO₂ emissions. Here are some facts that demonstrate the yearly efficacy of ENERGY STAR.

- \$34 billion/year energy bill savings (net)
- \$575 in energy bill savings/ year for typical family with all new ENERGY STAR products and insulation
- 370 billion kWh/year electricity savings (≈ electricity use of 30 million homes)
- 300 MMT CO₂ /year emissions reduction (≈ emissions of 60 million cars)

Perhaps the most remarkable thing about ENERGY STAR is how seamlessly it achieves these successes. In 2017 it was funded by the EPA at roughly 41 million dollars. This minimal investment spurred a substantial transformation in the market of appliances. Appliance companies now voluntarily strive for ENERGY STAR standards knowing that consumers associate that logo with more money in their pockets (Majdi).

Technical Assistance

Despite the fact that the federal government doesn't have direct authority over building policy at the state level, the DOE in particular plays an important role in these state or local policies as an advisor and technical assistant. The first step of the federal government's role in state building policy is for the DOE to review model building codes submitted by the American National Standards Institute, the American Society of Heating Refrigerating and Air Conditioning Engineers, and the Illuminating Engineer Society (ANSI/ASHRAE/IES) or the International Energy Conservation Code (IECC). After approving a new model code, state legislatures are then required to *review* these new codes, and at their own discretion, either set a date to incorporate these new models or disregard them. The adoption of these codes varies substantially from state to state as shown by Fig 6.2 below (United States, Department of Energy, Energy Efficiency and Renewable Energy).

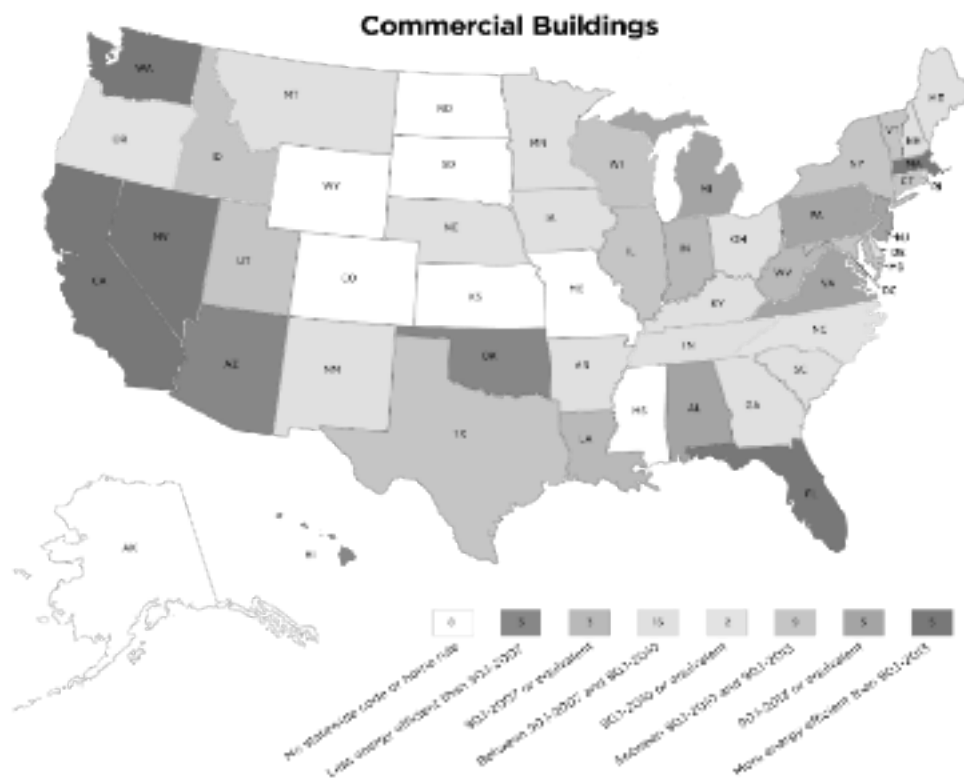


Fig 6.2: Map of State Adoption of Commercial Building Energy Codes

Source: "Status of State Energy Code Adoption Map - Commercial." *Building Energy Codes Program*,

www.energycodes.gov/status-state-energy-code-adoption-map-commercial.

Accessed 4 February 2019.

After submitting codes for consideration to state and local governments, the DOE employs several other methods to increase energy efficiency. Each update in model codes put forth by DOE results in substantial increases in efficiency from an energy and cost savings perspective so the DOE works to increase adoption of these new codes through several different approaches.

New Model Codes

The DOE releases analyses of each new model code in an effort to convince state and local governments of the energy and cost savings available to them. Fig 6.3, taken from a 2015 IECC analysis, documents the increase in consumer cash flow that occurs between the 2009, 2012, and 2015 IECC building codes.

Table ES.3. Impacts on Consumers' Cash Flow from Compliance with the 2015 IECC

Climate Zone	Compared to the 2012 IECC		Compared to the 2009 IECC	
	Net Annual Cash Flow Savings (for Year 1)	Years to Cumulative Positive Cash Flow	Net Annual Cash Flow Savings (for Year 1)	Years to Cumulative Positive Cash Flow
1	+\$ 13	0	+\$ 103	1
2	+\$ 5	1	+\$ 103	2
3	+\$ 6	0	+\$ 125	2
4	+\$ 7	0	+\$ 236	1
5	+\$ 5	0	+\$ 263	1
6	+\$ 6	0	+\$ 340	1
7	+\$ 8	0	+\$ 672	0
8	+\$ 18	0	+\$ 1,024	0

Fig 6.3: Impacts of Consumers' Cash Flow from Compliance with the 2015 IECC

Source: United States, Congress, "National Cost-Effectiveness Analysis of the Residential Provisions of the 2015 IECC." *National Cost-Effectiveness Analysis of the Residential Provisions of the 2015 IECC*, United States. Dept. of Energy., 2015.

Transportation

The transportation sector represents the largest sector (28%) of U.S. primary energy consumption and in 2016 emitted 6,511 million metric tons of CO₂. Unlike the other sectors addressed in this report, the federal government holds primary jurisdiction on energy efficiency in transportation as shown in Fig 6.4.

Table 9: Map of Transportation Policies to Jurisdiction

	Federal	State	Local
Fuel efficiency standards ¹⁸	Yes	Some	None
Labeling	Yes	None	None
Incentives	Yes	Half	Some
Technical assistance	Yes	Half	None
Urban planning and behavior change	No	Some	Some
Research and development	Yes	Some	None

Fig 6.4: Map of Transportation Policies to Jurisdiction

Source: United States, Congress, Office of Energy Efficiency and Renewable Energy, et al. "Energy Efficiency Policy in the United States: Overview of Trends at Different Levels of Government." *Energy Efficiency Policy in the United States: Overview of Trends at Different Levels of Government*, National Renewable Energy Laboratory, U.S. Dept. of Energy, Office of Energy Efficiency and Renewable Energy, 2009.

Fuel Efficiency Standards: Corporate Average Fuel Economy (CAFE)

Fuel efficiency standards encourage innovation across the transportation sector. Due to the fact that cars remain in service for an average of 9 years (a climbing statistic), it is essential

that fuel efficiency standards are introduced to reduce fuel demand in the long-term (United States, Department of Transportation/Federal Highway Administration). The history of the CAFE dates back to 1975 when it was established largely in response to the 1973 oil embargo. The Obama administration revisited CAFE and proposed to increase fuel economy to the equivalent of 54.5 mpg for cars and light-duty trucks by Model Year 2025. This proposed national program to improve fuel economy and reduce greenhouse gas emissions sought to save consumers more than \$1.7 trillion at the gas pump and reduce U.S. oil consumption by 12 billion barrels. As of 2016 the model year adjusted average fuel economy is 24.7 mpg. This does not meet the goals set by the Obama administration's 2012 CAFE standards, but it is the highest fuel economy up to that date. As evidenced by Fig 6.5 below, a marked improvement on transportation based emissions and adjusted fuel economy can be observed during the very years these standards went into effect (United States, Environmental Protection Agency).

Adjusted CO₂ Emissions for MY 1975-2017¹ Adjusted Fuel Economy for MY 1975-2017¹

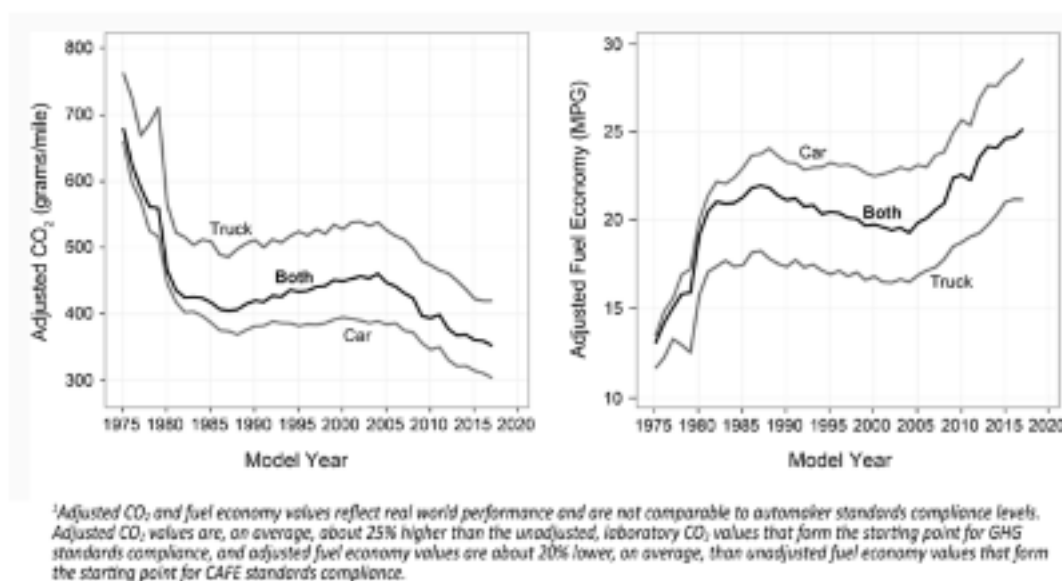


Fig 6.5 Adjusted CO₂ Emissions and Fuel Economy for Model Years (MY) 1975-2017

Source: "Highlights of CO₂ and Fuel Economy Trends." EPA, Environmental Protection Agency, 11 Jan. 2018,

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Labeling Programs

The Fuel Economy Label was introduced in 1974 and has continuously evolved to offer consumers more detail on the efficiency of the vehicles they purchase (United States, EPA). The success of the EPA's Fuel Economy Label is particularly important given the Trump administration's concern over consumer access to affordable safe vehicles in the face of increasing fuel economy standards. A 2018 study by consumer reports found that "On average, car buyers are willing to pay about \$690 more for each additional mile per gallon (MPG) – or

roughly \$5,050 for each gallon saved per 100 miles (gal./100 miles).” This points to the fact that consumer interests are in line with tightened regulations regarding fuel economy. When presented with the relevant information, buyers are willing to pay more for a long-term payoff (Friedman).

Fig 6.6 below indicates that the Fuel Economy Label was by far the most effective metric in encouraging consumers to pay more for efficiency.

Willingness-to-Pay in purchase price for fuel economy (one MPG)

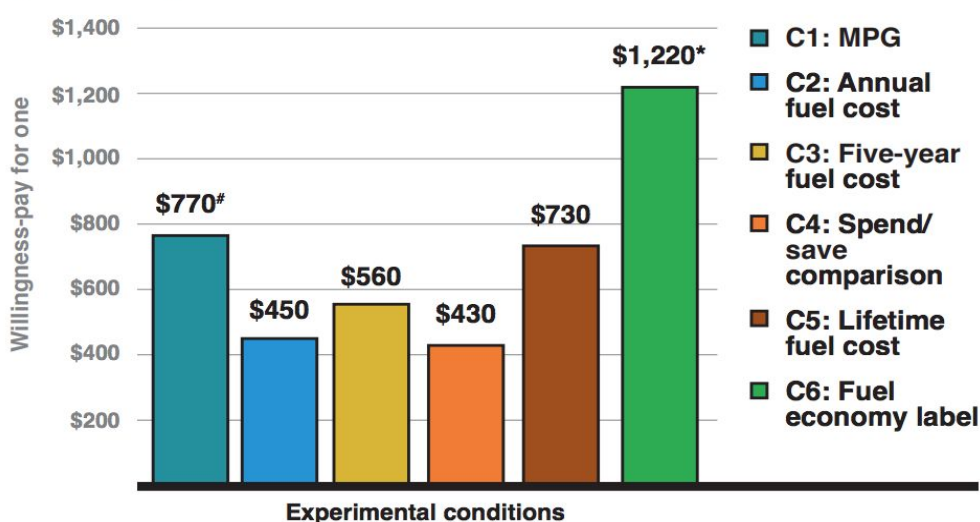


Fig. 6.6 Willingness-to-Pay in purchase price for fuel economy (one MPG)

Source: Friedman, David, et al. *Key Findings from “Auto Buyers’ Valuation of Fuel Economy.”* *Key Findings from “Auto Buyers’ Valuation of Fuel Economy,”* The Advocacy Division of Consumer Reports, 2018.

Conclusion

The most important thing to note about energy efficiency policy over the years is that when implemented correctly, a relatively minimal upfront investment has a tendency to result in substantial long term payoff. This payoff comes not only in the form of dollars saved at the gas-tank and on energy bills, but also in reducing the long-term cost associated with increasing greenhouse gases in the atmosphere. While acknowledging the fact that the federal government has reduced power in state jurisdictions, what is perhaps more important to note is the power it has to inform consumers on a broad scale. As shown through both Energy Star, and the Fuel Economy Label, consumers respond accordingly when given information to inform energy efficient decisions. These examples show that by making energy efficient choices easily accessible, long-term transformations in the market can be made at rather low cost. For the sake of both remaining competitive economically, and also leading the global effort against climate change, the U.S. has a strong incentive to continue investing in energy efficiency solutions.

- Energy Efficient policy is negotiated between jurisdictions, the federal government has a specific role in these negotiations
- The federal government has the power to transform the market and consumer behavior on a broad scale unlike any other jurisdiction
- Consumers choose efficiency when given the information (e.g. ENERGY STAR, Fuel Economy Labels)
- When not in direct authority of a jurisdiction, the federal government still has power to promote efficiency by acting as an advisor to state/local policy

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Seven

Infrastructure and Energy Usage

How Infrastructure Change Can Reduce US Energy Usage

Shaun Kuo

Introduction

Infrastructure includes the physical and organizational structures and facilities that shape the operation of American society. This makes it a core issue for energy distribution. Change in infrastructure presents the opportunity for change in energy consumption patterns. The US can change the infrastructure change to improve energy reliability and security as well as decrease energy demand. Key examples in this respect are the US Grid, urban design, and transportation. Together, these infrastructural domains present the best opportunities for reductions in energy usage, as well as for advancing energy security and therefore national security in aspects of daily life.

The US Grid

The US Electrical Grid is a combination of electricity generators, transmitters, distribution units, and end use mechanisms. Currently, electricity delivery in the US is over an aging and complex electrical grid system, some parts predating the 20th century. Most US transmission and distribution lines were constructed in the 1950s and 1960s with a life expectancy of around 50 years. The system is connected by over 640,000 miles of high-voltage transmission lines across three connected transmission systems, the Eastern, Western, and Texas Interconnection. The lower 48 states' power grid and the grids of Alaska and Hawaii are at full capacity ("2017 Infrastructure Report Card"). Simultaneously, electricity generation and end use mechanism are changing to include a greater mix of renewables, micro-generated power and electric devices.

Compounding these challenges are, lack of sufficient funding, changing weather patterns, complexities of integrating variable sources (wind, solar), and evolving behaviors of its end users. In its current condition, The American Society of Civil Engineers (ASCE) has characterized the grid as a patchwork system, which has bandaged together 3 subgrids, and that is operating at a congested full capacity (Campbell 18). "The resulting congestion raises concerns with distribution, reliability, and cost of service, producing constraints for delivering power from remote generation sites, specifically from renewable sources, to consumers." ("2017 Infrastructure Report Card") This congestion means that a single line cannot be taken out of service to perform maintenance as it will overload other interconnected lines in operation. Being at capacity is extremely problematic when T&D lines are disrupted.

In 2017, seven blackouts were caused by over demand (“Eaton Blackout and Power Outage Tracker”). If changes to the grid are not made, continued electrification of the American automotive fleet and other devices will increase peak energy usages in the US. Greater temperature variance from climate change will increase heating and cooling energy usage. Those 7 outages there were among 3,526 outages that affected 36.7 million people. That year, 1,159 outages were caused by weather/trees, 791 by faulty equipment/human error, and 444 by vehicle accident. The majority of the remain outages have unknown causes (“Eaton Blackout and Power Outage Tracker”).

Some of the issues that caused outages in 2017 are bound to become more frequent without infrastructure updates to the grid. Over demand is bound to become a greater contributor to blackouts if current practices and infrastructure do not accommodate increasing electricity demand. In 2018, US electric vehicles sales increased by 81%, which is just a slice of the transfer in US demand from oil to electricity (Pyper). Heating and cooling will likely also increase as climate change brings more extreme temperature variance. With the changing climate, the United States can expect more severe weather events and climate related disasters. Stronger hurricanes, and wildfires are among the many severe weather events or weather-related events that threaten the reliability of the US electrical grid. After Hurricanes Irma and Maria struck Puerto Rico in 2017, the entire island was blacked out, and power was only restored after an over \$3 billion cost and 11 months. Blackouts have left critical life supporting mechanisms without power, causing serious risk to life for some affected by outages. A six-minute outage in Colorado on March 11, 2017, caused a refinery to dramatically drop regional air quality when it emitted hundreds of pounds of hydrogen sulfide and sulfur dioxide into the air after the blackout triggered automatic and manual safety shutdowns (“Eaton Blackout and Power Outage Tracker”). These issues reflect heavy integration and dependency of electricity in American society that makes grid reliability a public safety concern. Economic and public safety implications of blackouts warrant investments to modernize the US electrical grid. A successful modernization of the US’s patchwork system would have to take measures to accommodate an evolving energy market (Sullivan).

Modernizing the US electrical grid will have to involve improving its resiliency, adaptability, and security. To protect from severe weather events and other incidents harmful to the physical infrastructure, the grid should be hardened for greater protection. Hardening the grid involves building more resiliency into the electrical grid. Basic improvements include replacing wooden utility poles with those made of durable metals, installing guy wires to help anchor poles, and increasing vegetation management and grid capacity. Storm and wildfire related outages are caused by the trees they affect, so pruning, watering, inoculating trees from pests, and removing unstable trees would reduce the risk of outages from severe weather-related events. More situation solutions include, undergrounding of transmission and distribution cables, and improving transmission lines materials, but they have different risk factors. Ideally every region in the US would have a threat assessment done and have catered grid hardening improvements applied to improve the resilience of the US grid overall.

A smarter grid can better identify issues with the grid, adapt to changing energy demands, and accommodate changes in energy supply. Much of existing US grid infrastructure predates the digital technologies that now permeate the fabric of US society. Digitizing the grid, or “applying recent advances in digital technology such as electronic devices or data and information systems,” offers energy efficiency and reliability improvements to both the supplier and consumer. Industry can benefit in asset lifecycle management, grid optimization and aggregation, integrated customer services, and a new market for related services (Greenwald and Smith 6). Better asset management helps alleviate blackouts related to faulty equipment and human error by monitoring and increasing the efficiency of generation, transmission, and distribution assets. A smart grid offers greater capacity for utilities to “give consumers more options for managing consumption and payments, switching between different energy resources, and self-generating electricity”, which enables better integration of microgrids, distributed generation, and energy storage (Greenwald and Smith 6).

Consumers, whether it be individuals or large organizations, have increased investments in their own smart grid technology, energy storage, isolated microgrids, and microgeneration. They enable better integration and efficiencies of energy storage like battery technologies, and microgeneration like residential solar panels by dynamically accessing them rather than allowing them to idle. Residences with a smart meter, solar panels, and energy storage have already allowed their owners to opt into time-based rates offered by utilities to buy cheap energy, use stored energy during periods of high demand, and decide on how their generated energy is stored or sold. Localizing microgeneration and energy storage with basic grid infrastructure, can form a microgrid that can operate outside of the US Grid. With smart technologies, a locality can seamlessly transition to one of these microgrids when there’s a disruption in the wider grid. Hospitals across the US have deployed microgrids to increase power reliability for their critical services. A layered and smart US grid improves upon the reliance and general efficiency of the electrical grid.

Complex grids brings new vulnerabilities. Cyber threats are of special concern with a digital/smart grid. Russia has positioned itself a major threat with its attacks on Ukraine, and penetration of computers of several US electrical utilities. The WSJ even reported that the degree of Russian infiltration to US electrical system was enough to gain the capacity to cause blackouts. According to some experts on grid security, current federal regulations mandate standards that are sufficient for observed cybersecurity threats. While large utilities can meet or surpass those standards, smaller and mid-sized companies often cannot invest in full cybersecurity protections (Govindarasu and Hahn). All utilities should adopt or receive aid to adopt basic security states and engage in a cybersecurity system that adapts with changes and additions to US energy infrastructure to stay ahead of threats. Grid security has become more paramount as the US population becomes more clustered in urban areas and more dependent on reliable electricity.

Urban Design and Infrastructure

Continued urbanization of the United States remains the trend for the foreseeable future. This direction grants urban planners an opportunity to greatly affect the energy usage of the US by way of reducing the energy inefficiencies in the current infrastructure. According to 2014 projections by the United Nations Department of Economic and Social Affairs, American urban planners will be able to shape the energy behaviors of 87.4% of the country's population by 2050 ("World Urbanization Prospects"). Urban centers utilize directly consume energy with motor vehicles, buildings, and industry within urban limits. They will also indirectly expend energy from electricity purchases and the production of imported goods and services. Energy-minded urban planning would be concerned with creating efficiencies that reduce the energy usage of city dwellers. A major contributor to energy usage in the US is the automobile industry.

An automobile's energy expenditure comes from its manufacturing process and the energy it uses to do work. Before a car has rolled off the assembly line, its global supply chain has already produced tons of CO₂. Raw material extraction, component manufacturing and shipping, and assembly produce 6 tons of CO₂ for a Citroen C1 to 35 tons of CO₂ for a Land Rover Discovery (Berners-Lee and Clark). For the rest of a vehicle's lifecycle a standard gasoline vehicle will utilize energy equal to emission of 18-19 tons for CO₂, according LowCVP's report on Lifecycle emissions from cars ("Lifecycle emissions from cars"). A similar report by the Union of Concerned Scientist, also found that battery manufacturing for EVs results in a 15-30% jump in emissions for EV manufacturing when compared to gasoline vehicles. This increase also comes with a decrease of lifetime emissions by over 50% (Anair et. al). A reduction of driving hours and car ownership should be targets for the reduction of the average American's energy usage, whether it be electricity or carbon fuels.

Energy-oriented urban planning has the tools to change a population's behavior regarding the reduction of Vehicle Miles Traveled (VMT) and car ownership. Land use policy is a key tool for urban planning to wean urbanites off car usage and ownership. Currents policies enable many urban polities to sprawl in a manner that increase the transportation energy usages of its residents. Sprawl is characterized by single use development, low-density, disperse activity, and poor street accessibility. Researchers found that less sprawling areas had higher rates of walking, transit use, and less car ownership and VMT (Ewing et. al). Successful land use policy decisions reduce the need for the use of automotive by setting development regulations that encourages more multi-use development, greater population density, and the localization of production.

Single use development dominants urban areas. This kind of development comes in the form of purely residential, commercial, industrial, or institutional areas. In contrast, multi-use development creates communities that integrate housing, providers of goods and services, and employment centers. This proximity creates more walkable neighborhoods that open walking as an alternative to driving vehicles in many scenarios. In a study done in King County by Larry Frank found that residents in the most walkable neighborhoods drive 26 percent less than

residents in the country's most sprawling neighborhoods (Ewing 17). Increasing the proximity of goods and services to its consumers reduces the need for residents to drive and own a vehicle.

Low-density development also permeates US urban landscapes. Liberalizing zoning laws to raise allowed building height can encourage developers to create dense neighborhoods. Density works in tandem with multi-use development to bring consumers and suppliers close together. "A meta analysis of urban design/energy usage studies finds that households living in developments with twice the density, diversity of uses, accessible destinations, and interconnected streets when compared to low-density sprawl drive about 33 percent less." (Ewing 17) Population density is core to embedding energy efficiency into America's ever-growing urban population. Conversion of low to high density neighborhoods also provides municipal lawmakers an opportunity to mandate or incentivize the usage of energy efficient appliances, solar panels, energy storage, smart meters or other methods of energy reduction of cities in new buildings.

Technological advances are making urban energy production and storage, urban agriculture and manufacturing more relevant variables in urban energy use calculus. Today, those technologies play minor roles in affecting a city's energy realities, but advances in solar panel and energy storage affordability have already enabled the spread of local microgeneration and microgrids. This phenomenon can be observed in residences, where 581 MW of new solar was installed in Q3 2018, up 11% from the previous year ("Solar Market Insight") and residential energy storage additions grew by 202% from 2016-2017 (Maloney 2018). Urban agriculture and manufacturing both present an opportunity to reduce VMT in the US by locating means of production and employment closer to population centers. Urban agriculture currently operates in small community farms on designated patches of land. Urban manufacturing also takes the form of small establishments where specialty products are made. Their current small scales could be transformed by advances and proliferation of vertical farming and 3-D printing manufacturing. Deploying those technologies at reasonable scales of economies in the United States require more R&D investment to improve their affordability and applicability. The USDA has allocated funds available for vertical farming in their Agriculture and Food Research Initiative Competitive Grants Program and private companies have rushed to develop and supply 3-D printers. These technologies provide urban planners with more tools to reduce indirect energy usage of their city's inhabitants.

Transportation Infrastructure

In 2016, 28% of U.S. greenhouse gas emissions came from the transportation sector, which represents very high levels of energy usage. ("Sources of Greenhouse Gas Emissions") This energy usage is mostly carbon fuels combusted by cars, trucks, trains, ships, airplanes and other vehicles. The prior section tackled how car VMT can be reduced through energy-oriented land use policy. In concert with land use planning, transportation planning is also core to urban planning. Connecting distant communities presents its own energy challenges, at those distances, aviation, rail, or waterway become the only realistic options.

Smart growth in the city integrates transportation and land use planning and gives people more choices for mobility. Locating residences, commerce, institutions, and workplaces near transit stations and close to each other boosts convenience for walking, bicycling, or taking transit. (“Smart Growth and Transportation”). Infrastructure improvements starting on the street level can be smartly designed to provide appealing alternatives to SOVs. Walkable communities typically utilize physical barriers between vehicles and the sidewalk to alleviate safety concerns and incentivize walking. Inclusion of bike lanes in US streets would also make city streets more accessible. A study done by the National Association of City Transportation Officials (NACTO) shows that offering bike lanes increases the interest and usage of bicycles in a city. Furthermore, that usage and interest increase with protected/separated bike lanes, which can also be extrapolated to pedestrians and sidewalk safety. Scooters and other last mile transportation can take advantage of accommodating streets. In addition to building density into US cities with skyscrapers, the private sector has taken advantage of this infrastructure and density to introduce shared transportation services like Limebike, and Byrd. Providing a range of transportation choices and the walkable neighborhoods that support them can help improve air quality and reduce greenhouse gas emissions and energy usage.

Within cities, high-density environments provide scales of economies required for many VMT reducing technology. High capacity vehicles, such as urban rail transit, and buses become more economically efficient and VMT reducing with density. At full capacity, bus transit and rail transit can reduce SOV emissions by 80-90%, translating to similar energy savings (“Public Transportation’s Role”). To maximize occupancy, this kind of transportation should be planned in coordination with land use to gain access to the largest markets. Transit-oriented development and sustainable transportation planning ensures that compact development occurs around transit stations and that transit stations are delivered to compact development, while examining the effects of transportation projects on future growth, development, long-range economic goals, and on air and water quality and other environmental resources. These urban high capacity vehicles can also be electrified rather easily, with rail transit using railway electrification systems and buses deploying overhead wires and/or battery electric buses. Increases in route and vehicles energy efficiencies drive down energy usage within urban areas.

For the US, long-haul transportation options are heavy trucks, heavy rail, and aviation. Increasing the fuel economy of heavy trucks can be done by federally mandated CAFÉ standards. Electrification is also possible and seems likely to occur over time, yet challenge is much greater than for light-duty vehicles and will almost certainly require several or more decades to become commercial. Energy efficiency of heavy rail is possible through electrification, but the process is complicated by U.S. railroads being a regulated private sector industry. Under 1 percent of US tracks are electrified. Electrification has “high upfront capitalization costs, an obstacle that publicly owned railroads in other nations do not face. Railroads in other countries also do not have to pay property taxes on electrification infrastructure, which U.S. railroads do” (Mazza). Unlike Europe and East Asia, the US’s unique mix of low density, strong property rights, and culture maybe the reason why high-speed rail has not come to the US. Our allies in East Asia and Europe, and China have all demonstrated the

ability to construct and implement high speed rail, which acts as an energy efficient alternative to flight and car. In China, researchers found that introduction of rail between areas that had high air travel demand decreased that demand (Mazza).

Electrification of modern passenger aircraft is “simply not physically possible yet. ... it’s quite another thing to move an aircraft weighing tons across thousands of miles using electric propulsion” (“Electrifying the Aviation Industry”). R&D from NASA and private companies into electric plane technology remains at an early stage. Full electrification of passenger and cargo aviation may not arrive until after 2050. The FAA does have plans to implement Performance Based Navigation, which is an advanced satellite-enabled form of air navigation to create precise 3-D paths. PBN offers increased efficiency, reduced carbon footprint, and reduced costs.

Key Challenges in Infrastructure Change

Reducing energy usage through infrastructure change is a costly task that requires the engagement of all levels of government. Counties, states, and the federal government all have the power to fund projects and R&D, to influence improvements through regulation and tax incentives. While modernizing the electrical grid just needs proper funding, funds alone will not guarantee proper action from localities. Cities require the political will of its inhabitants and leaders to change zoning laws and fund public transportation. Public awareness of infrastructure improvements to reduce energy usage and carbon footprint is needed. Urban development has its fair share of creative destruction. Buildings get torn down, new ones are built, population density may increase, traffic lanes are converted to public transit, and so forth. Disturbances caused by large construction projects and the fear of altered characters of neighborhoods also incentivize residents to resist construction of energy-reducing infrastructure. These residents contribute to strong anti-development voting bloc in city politics and are active in slowing or blocking up-zoning around the country.

Conclusion

In 2013 and 2017, the US was granted a cumulative infrastructure GPA of a D+ by the American Society of Civil Engineers’ Infrastructure Report Card This grade reminds the US to pick some low hanging infrastructure fruit that reduce energy usage. The United States is very much behind much of the developed world and China when it comes to infrastructure. However, its position does grant it the ability make infrastructure improvements in its electrical grid, urban environments, and transportation infrastructure to create energy efficiencies.

- The US Grid is out of date, modernizing it will involve hardening it, preparing it for future demand and smart grid technology, and securing it with greater cybersecurity.
- Land use policy can be used to decrease energy usage of cities by adopting more multi-use development and increasing population density.
- Transportation planning in concert with land use policy can also decrease VMT by increasing the efficiencies of transportation systems.
- Infrastructure change requires coordination and cooperation of all levels of government.

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Eight

Major Demographic Changes & Future Energy Consumption

Impacts on Future Policymaking

Geneviève Goutzioulis

Introduction

When considering potential policies for energy and environment in the United States, some of the most important topics to consider are the United State's population demographics and energy consumption projections. This information helps shape policies and predict future data, energy needs and voting trends. The correlation between different generations--birth dates, retirement rate, dominance of a particular generation cohort--all have an influence on a population's energy needs and usage. This section provides projected data of the United States' domestic energy markets given certain assumptions, vital for U.S. policymakers.

Major Demographic Trends

The mass human migration from Northern states and Canada to the South of the U.S. for the winter months of each year is commonly dubbed as the 'Snowbird migration'. During these months, the southern states of the U.S. experience a sharp increase in their populations, which leads to increased energy usage, production of human waste and consumption of petrol, food and energy. Most of these 'Snowbirds' are either near or over retirement age and tend to belong to a higher economic class (Smith). Whether they drive or fly to their southern getaways, the increase in emissions and petrol from transportation and travel has notably increased. Most higher class and older generations tend to use vehicles that are poor for the environment and are classic traditional gasoline vehicles, dubbed: 'gas guzzlers' (Smith). In addition to emissions, electricity usage is also expected to increase each year because most Snowbirds will use air conditioning to moderate the warm Southern weather (Smith). According to the Annual Energy Outlook, throughout the projection period of 2015-2019, residential housing stocks will continue to grow, especially in warmer areas where space cooling demand is higher, due in part to this domestic migration. "Cooling dominated West South Central, South Atlantic, and East South Central census divisions all experience average annual stock growth that exceeds the national average" (United States, Dept. of Energy, Energy Information Administration 136). This problem will only continue to increase as southern cities become more densely populated without supporting infrastructure and the US population becomes dominated by elderly dependents. Not only will the US have to come to terms with a rapidly changing population but climate change and an increasing global temperature will compound the need for cooling in the South.

Over the course of the next 40 years, the United States' workforce is expected to shift towards the elderly. The old-age dependency ratio is projected to nearly double by 2060, there will be 41 people aged 65 and older for every 100 work-age adults between 18 and 64 years,

and on the other end there will only be 35 youths (peoples under the age of 18) for every 100 work-age adults (United States, Dept. of Commerce, Economics and Statistics Administration 4). This is due to the average life expectancy increasing and better medical and elderly care in the U.S. along with declining mortality rates per year. This demographic crisis is not unique to the US. Japan is farther along in experiencing this crisis and the consequences are becoming critical for the nation's course. As their elderly population increases, resource priorities will tilt towards elderly care, hospitals and medicine rather than infrastructure, energy efficiency and so forth (Weller). Birth rates are also dwindling alarmingly. This will reduce the number of capable adults who can participate in a productive workforce, needed to meet the nation's growing needs. The energy sector is no exception. As the US shifts towards an elderly dependent and dominant population, more focus will be directed towards supporting public health rather than devoting funding and time towards environmental legislation and energy efficiency. While there is still time, it would be prudent to focus on developing infrastructure to better support the projected increase in elderly population in Southern states while also that infrastructure's efficiency. Finding ways to either deter or shift vehicle transportation away from gasoline powered vehicles and instead to either more efficient or non-carbon vehicles, is another aspect that would need to be developed before it is too late.

Despite the increase in the global refugee population, since 2016 the refugee arrivals have declined. Most of the refugees coming to the U.S. towards the end of 2017 were from the Middle East and Africa, and these Sub-Saharan African nations account for "eight of the 10 fastest growing international migrant populations since 2010" (Cilluffo 2018). The number of foreign students enrolling at U.S. colleges and universities has doubled since 2008: growing from 179,000 to 364,000 in 2016. These students are coming primarily from China, India and South Korea and account for "more than half (54%) of all new foreign students pursuing higher education degrees in the US" (Cilluffo). Immigrants from El Salvador, Guatemala and Honduras are also rising, 25% from 2007 to 2015. And the U.S.' black immigrant population had increased "fivefold since 1980", reaching 4.2 million in 2016. The number of these immigrants seeking and becoming citizens and naturalization have increased to 19.8 million in 2015. And these numbers are not about to decrease or plateau within the next decades (Cilluffo). Some claim that these immigrants will be the ones to save the U.S. population from its impending demographic crisis (McArdle). The U.S. needs to begin thinking about how it will support an increasingly diverse population while also considering environmental repercussions. Similarly, the U.S. should be modernizing and increasing the efficiency of energy infrastructure: from the grid to more efficient house-ware products, to be able to deal with the population spike while curbing emissions.

Family size is also expected to increase. This differs from Japan's situation. Japan is scrambling to accommodate their elderly population while simultaneously trying to incentivize women to have children. The United States is already expecting a slight bump in its birth rate and will need to accommodate larger families as well as an expanding elderly and retired population. Despite the slight increase in birth rates, the 'graying of America' is assured. This will only add to resource consumption and energy usage due to both children and the elderly needing more resources and energy to survive. More women are having a child before the end

of their childbearing years (40-44 years) as well as having more of them. In 2006, the U.S. was experiencing their lowest birthrate yet, averaging 1.86 children per woman, whereas in 2016 women are having 2.07 children during their lifetime. Over the past two decades there has also been an increase in motherhood in general: in 2014, 55% of women who have never been married have still given birth, where as only 31% had in 1994 (Cilluffo). The United States' energy infrastructure will have to fundamentally change to support a future U.S. population that will be as diverse as projected.

Voting Trends and Generational Rifts

Just as the U.S. population becomes more diverse in terms of race, age and political beliefs, voting trends and generational rifts are expected to shift. Millennials (born between 1981-1996) and Generation Z-ers (born after 1996) are proving to be more liberal than older generations. Generation Z-ers are holding similar views to Millennials when it comes to political views and attitudes to the environment: 56% and 54% of Millennials and Generation Z-ers respectively agree that the Earth is getting warmer due to human activity, 61% and 62% of Millennials and Generation Z-ers also see that “increased diversity is a good thing for our society” (Parker). This upcoming generation of new, young voters are “diverse and on track to be the most well-educated generation and is moving toward adulthood with a liberal set of attitudes and an openness to emerging social trends” (Parker). Research shows a growing gap among younger and older Republicans: on some key issues they tend to be more polarized. Younger generation Republicans stand apart in terms of the causes of climate change and a more government control: “they are less likely than their older counterparts to attribute the earth’s warming temperatures to natural patterns, as opposed to human activity” (Parker). As these younger generations move into U.S. leadership and authoritative positions in the near future, it is almost certain that their policies and voting patterns will reflect their new attitude and promote liberal ideals. That being said, Millennials and Generation Z-ers are not as likely to vote or participate in elections, even though they would generate the most change (Parker). To stimulate environmental legislation and energy as a national priority, more public outreach and informational campaigns could be implemented to engage young voters

Energy Production Growth Variables & Conditions

The AEO’s 2019 Reference case refers to the EIA’s “best assessment of how U.S. and world energy markets will operate through 2050 [...] it assumes improvement in known energy production, delivery and consumption of technology trends” (United States, Dept. of Energy, Energy Information Administration 5). This permits the EIA to utilize this case as a benchmark and compare policy-based modeling⁹. This case should just be interpreted as a reasonable baseline used in comparison with other alternative cases. Some of the key takeaways that the AEO expressed from the Reference case were that fossil fuels, natural gas and natural gas plant liquids (NGPLs) are projected to have the highest projection growth throughout the period (from 2019 to 2050) and will account for nearly a third of U.S.’ cumulative liquid production. The

⁹ The potential impacts of proposed legislation, regulations and/or standards are not included in the Annual Energy Outlook’s 2019 Reference case.

US power sector is expected to shift and increase natural gas-fired electricity generation due to low natural gas prices. Increase energy efficiency across end-use sectors, like the residential, transportation, commercial and industrial sectors, is projected to keep U.S. energy consumption relatively flat despite an expanding economy (United States, Dept. of Energy, Energy Information Administration 4-6).

In the AEO's 2019 Reference case, the U.S. production of crude oil and NGPLs continues to grow through 2025 until slowly tapering off through 2050. However, in the case of High Oil and Gas Resource and Technology, the U.S.' crude oil production will increase from a little over 11 million barrels per day in 2019 to 20 million barrels per day between 2040-2045. This case represents a "potential upper bound for crude oil and NGPL production, as additional resources and high levels of technological advancement result in continued growth" in these sectors (United States, Dept. of Energy, Energy Information Administration 15-16). While this is not the most appropriate scenario, it is still a possibility for the United States. With growing public distaste for fossil fuels, technological advances should be diverted to non-carbon and NGPL development and sourcing.

Critical Drivers & Uncertainty

Policies, technology and economics all affect fuel consumption and production. In the Reference case, electrical power is still the number one sector in terms of energy consumption within the projection period, with the industrial sector coming in second after FY 2025. Oil and natural gas are projected to remain the leading energy sources, with natural gas growing rapidly and coal declining. Solar and wind power are also forecast to rise significantly, reaching 30% or more of total electricity generation by 2050. Yet all other forms of non-carbon energy (nuclear, hydroelectricity and liquid biofuels) stay relatively unchanged over the course of the projection period. That being said, several states have enacted new policies since the publication of AEO's 2018 projections. These new policies plan to increase non-carbon electric generation, and in cities like New Jersey, "to support operation of existing nuclear generators" (United States, Dept. of Energy, Energy Information Administration 50). Looking at fig 8.1, the required U.S. renewable portfolio standards (RPS) is 704 billion kilowatt hours by 2050. However these new policies in California, New Jersey and Massachusetts see nearly double the requirement for 2050 in the Reference Case. While this information is comforting to see, and growing support for non-carbon energy sources at the state level is slowly growing, consumption of crude oil and NGPL increasing into the early 2020s and then plateauing or only slightly decreasing to mid-century, according to AEO projections (United States, Dept. of Energy, Energy Information Administration 49-50). Key reasons for this include a growing demand for petrochemical products and continued need for petroleum fuels in transport. Electrification of light vehicles is unlikely by 2050 and will take longer for heavier vehicles, trains, airplanes, and off-road equipment (construction, agriculture, mining, etc.).

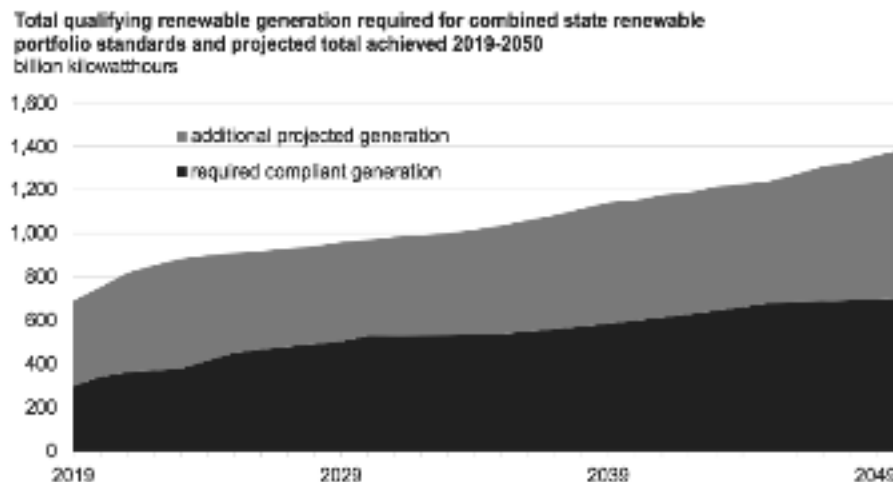


Figure 8. 1: Total qualifying renewable generation that is required vs. total qualifying renewable generation with new, additional standards from California, New Jersey and Massachusetts through to 2050

Source: United States, Dept. of Energy, Energy Information Administration. "Annual Energy Outlook 2019 with Projections to 2050." Jan. 24 2019. Pg 49.

Petroleum & Other Liquids

The AEO specifies that in all cases, crude oil and NGPL production will continue to increase until 2022. Already has crude oil production hit its peak in 2018 from its previous peak in 1970. And this production is also predicted to continue to rise through 2030 at 14 million barrels per day before plateauing. NGPL production reaches 6 million barrels per day by 2030, increasing 38% from 2018. These production predictions are very variable under different assumptions about resources, technology and oil prices. It is possible to greatly influence the future consumption of crude oil and petroleum as well as its production through legislation and policies at local, state and federal levels. Tight oil development (See Fig. 8.2) lead by the Southwest region, in all cases, is projected to primarily drive U.S. crude oil production throughout the projected period and finding a way to target or dissuade this development specifically in the Southwestern states (Texas and New Mexico) as well as the Gulf Coast states (Louisiana to Florida), those actions would seriously decrease the United States' involvement in its production, thus improving its environmental impact.

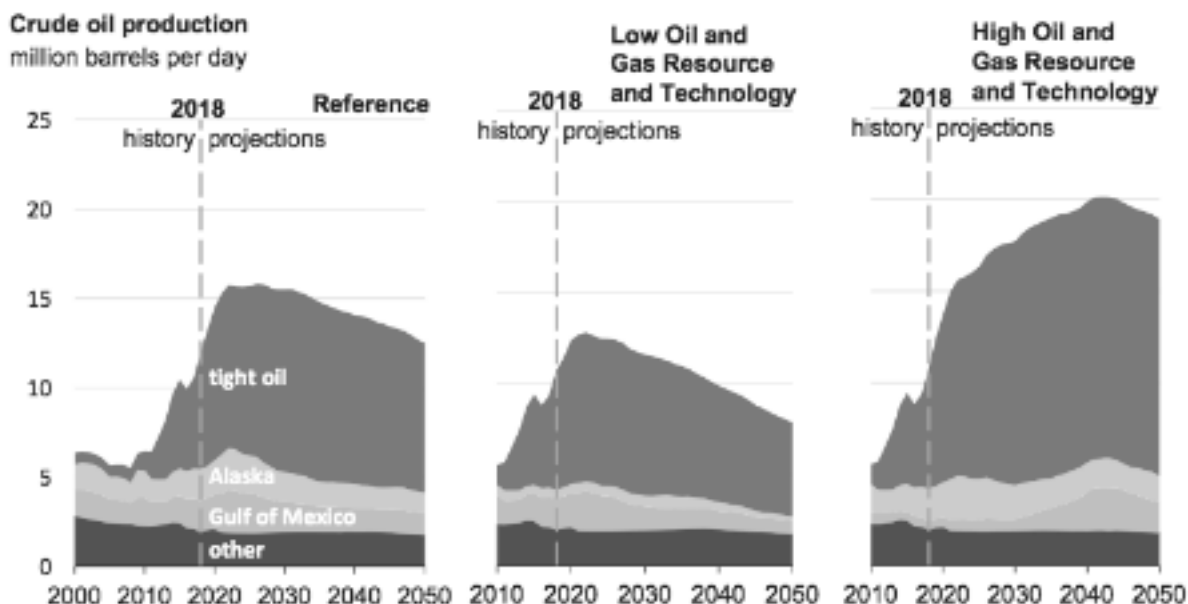


Figure 8.2: Crude oil production projections through different cases through to 2050
 Source: United States, Dept. of Energy, Energy Information Administration. “Annual Energy Outlook 2019 with Projections to 2050.” Jan. 24 2019. Pg 55.

Despite the projected increase in crude oil and petrol production, domestic consumption is predicted to fall in the Reference case as the U.S. becomes a new exporter of petroleum and other liquids. Motor gasoline and diesel fuel prices are projected to increase by “76 cents per gallon and 82 cents per gallon, respectively, from 2018 to 2020 and gradually phase out of the market by 2026” (United States, Dept. of Energy, Energy Information Administration 53).

Natural Gas

Natural gas production is predicted to grow at 7% per year from 2018 to 2020, from then on growth slows to only 1% per year as domestic consumption and demand for U.S. natural gas exports slow dramatically in the Reference case. To support demand for natural gas production and consumption, an “environment of relatively low and stable prices supports growing demand from large natural gas- and capital-intensive projects currently under construction” (United States, Dept. of Energy, Energy Information Administration 71). Focusing on natural gas production and deterring crude oil would provide the transition into non-carbon sources.

The industrial sector and electric power sector are the two primary sectors that will drive the demand for natural gas consumption throughout the projected period. This increase is due to “the scheduled expiration of renewable tax credits in the mid-2020s, as well as the retirement of coal-fired and nuclear generation capacity” (United States, Dept. of Energy, Energy Information Administration 81-81). While natural gas consumption does not increase in residential, commercial or transportation sectors for a variety of reasons, creating solutions to those challenges could facilitate the expansion of natural gas usage and further move the nation away from petroleum and other carbon intensive sources.

Electricity

Demand for electricity is predictably increasing throughout the projected period in all sectors. Economic growth tends to be the primary driver of electricity demand, although weather patterns as well as electricity efficient also have an impact. In the past, demand has slowed due to new more efficient products on the market and efficient production, even as the economy continued to grow. In the future, developing more efficient appliances, heating, cooling, ventilation and other equipment could decrease electricity production even further, thus decreasing the average electricity bill for the average citizen.

In all cases, the AEO predicts coal-fired generation to decline. However, due to the popularity and the abundance of natural gas, all other forms of energy generation lag behind (non-carbon, nuclear...). Looking at figure 4, the only case in which non-carbon sources emerge as a primary source of electricity generation is the case in which oil and gas resource, technology advancement and production are low. While natural gas prices are current low and compete with coal-fired power generation. Being too fixed on natural gas production will lead to completely side-lining all other forms of energy sources, especially non-carbon. While it is a positive that natural gas is not nearly as harmful neither does it generate as much carbon, it is not a long term solution to lowering carbon emissions. The side-lining of these energy generation sources will not be beneficial to the United States in the long run as natural gas still both emits carbon and has a poor reputation throughout the U.S. populace.

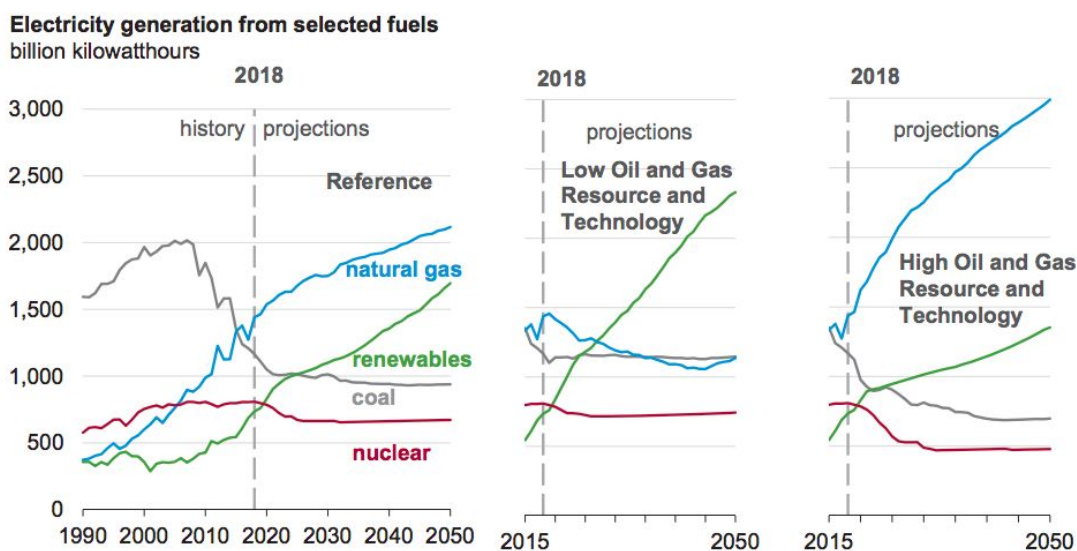


Figure 8.3: Electricity generation from different fuels through different cases through to 2050
Source: United States, Dept. of Energy, Energy Information Administration. "Annual Energy Outlook 2019 with Projections to 2050.", Jan. 24 2019. Pg 91.

Transportation

In the Reference case, due to increases in fuel economy standards, U.S. motor gasoline consumption decreases by 26% between 2018 and 2050. However, in terms of heavy-duty

vehicle energy and other diesel use, consumption stays approximately at the same level throughout the projection period. “Continued growth of road travel increases energy use later in the projection period because current fuel economy and greenhouse gas standards require no additional efficiency increases for new light-duty vehicles after 2025 and for new heavy-duty vehicles after 2027” (United States, Dept. of Energy, Energy Information Administration 118). To get ahead of these future consumption increases, various industries should begin to invest and develop more efficient products, and incentives from local, state or federal government could help that along.

Light duty vehicles will continue to lead the way in terms of on-road passenger travel, increasing from 2.5 trillion miles per year in 2010, to nearly 3.5 trillion miles per year by 2050. While heavy-duty vehicles burn through diesel fuel, the increase in vehicles miles is less than .25 trillion miles. In terms of passenger travel, air travel is projected to increase to nearly 1,800 billion revenue passenger miles per year by 2050 from only 1,000 per year in 2018. Bus and passenger rail barely increase at all, due in part to the United State’s lack of passenger rail systems and the unpopularity as well as slowness of bus travel. Domestic shipping due to economic growth is expected to increase as well but only in freight rail, in contrast domestic marine shipping plummets from 500 billion ton miles traveled per year in 2010 to only 250 billion ton miles per year by 2050. Despite the huge increases in travel across all sectors, sales of more fuel-efficient cars and light-truck crossover vehicles in crease over the projection period by about 10% and alternative/electric vehicles gain market shares in the Reference case through to 2050. However, gasoline and traditional vehicles maintain both significant market share and the dominant vehicle type through 2050 (United States, Dept. of Energy, Energy Information Administration 117-120). While the transition and the rise in popularity of these vehicles is slowly increasing, more can be done to facilitate this and further transition away from traditional vehicle and truck types. To further stimulate decreasing carbon emissions, air quality standards could be put in place in large urban areas and port cities. Using natural gas as an alternative to oil or coal to power U.S. modes of transportation (especially barges) would also decrease emissions while being economically.

Conclusion

Using current economic and demographic trends in many different scenarios, these projections show that the United State’s total energy consumption could increase from 100 quadrillion British thermal units a year to nearly 120 units by 2050 if the country enjoys high economic growth (United States, Dept. of Energy, Energy Information Administration 11-12). The data and information from the studies and projections within the United States’ *Annual Energy Outlook 2019* would provide much needed direction to policy makers. The energy needs for a large nation, like the United States must be met. The correlation between the population and energy needs is obvious but vital when thinking about the future of American energy.

- The U.S. population is shifting, it is becoming graying, which has many negative implications in terms of energy consumption and carbon emissions.
- The upcoming voters and youngest generation are the United States best educated and most liberal generation yet. They are prone to be more agreeable

with pro-environmental policies and other liberal agendas, and as they enter the voting pool, they should be used to push for the right policies.

- Energy consumption, electricity demand and passenger travel will only increase in the future, how to best support that increase while still decrease carbon emissions is still up for decision.
- Natural gas is increasing in popularity and consumption. While it is a good way to transition away from crude oil, coal and other fossil fuels it is not the end-all solution, it should be considered as a stepping stone to non-carbon energy sources.

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Central Energy and Climate-Related Concerns

Sofia Soto & Madisen McKenzie

Nine

Energy and National Security

Public Safety, Economic Stability, and Infrastructure

Sofia Soto

Introduction

The discussion and debate surrounding energy usage in the US and abroad has and will continue to be at the forefront of politics for centuries to come. International and domestic pressures have made it imperative that the US re-evaluate the key security issues related to energy. This chapter determines the major vulnerabilities and threats that harm US energy infrastructure and overall national security. The first vulnerability the US faces is the risks related to our energy resource supply in addition to the current weaknesses of our country's energy infrastructure system. To ensure our energy resource supply is reliable the US should consider the dangers associated with imported oil. The second major vulnerability, is the fact that the current US energy producing systems are outdated and in major need of repair as various infrastructure has begun to pose serious environmental, economic, and public safety threats. Moving forward from vulnerabilities are the external threats that have recently prompted government systems to rethink their security. Namely, the overwhelming effects of climate change on increasing security threats as extreme weather poses new hazards to US military installations and the domestic energy grid. As the scale and sophistication of cyber attacks to the energy grid have increased our energy and ultimately our national security has come into question. By first laying out the major vulnerabilities of US energy infrastructure and secondly assessing the threats posed to national security we come to understand that these risks are no longer up for consideration, they are urgent—having major impacts on public safety, economic stability, and the overall infrastructure of the country.

Ensuring the Reliability of Resource Supply

There is no doubt that the oil market has changed dramatically in the past decade. The US has begun a transition to reduce its international oil dependence by producing its oil domestically. According to the American Geosciences Institute, nearly 20% of US oil demands are still being met from international producers (AGI). This leaves us vulnerable to outside hazards that can not be controlled, further prompting us to reevaluate the reliability of our energy resource supply. Stanford University in 2016 published a risk assessment of oil market disruption risks, the assessment concluded that there exists approximately an 80% probability of a net disruption of two MMBD (million barrels per day) or more lasting at least one month (Beccue and Huntington).

Comparison of Duration Probabilities by Region

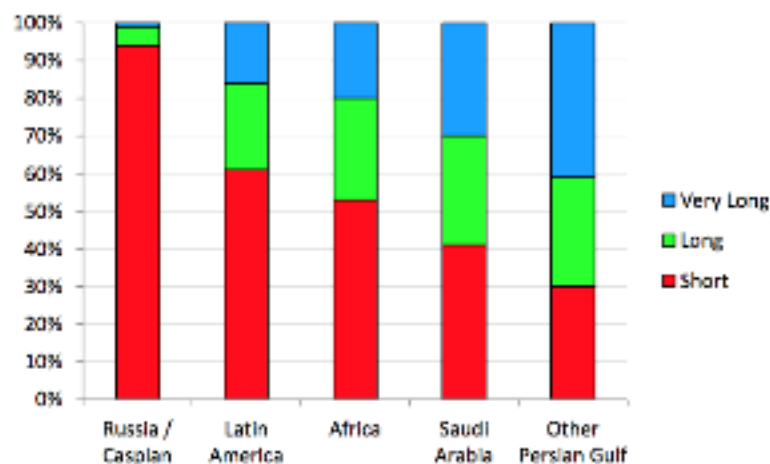


Fig. 9.1 Likelihood of Oil-market Disruption Durations by Region

Source: Beccue, Phillip, and Huntington, Hillard. "An Updated Assessment of Oil Market Disruption Risks". *Energy Modeling Forum Stanford University*. 1 Oct. 2016.

https://web.stanford.edu/group/emf-research/docs/special_reports/EMF_SR10.pdf. Accessed 14 February 2019.

This alone should motivate the US government to consider the effects of a disruption of this scale on economic and national security. From 2016 to 2017 alone, the US Navy has said that there was an average of 2.5 "unsafe" or "unprofessional" interactions per month between the Navy and Iranian maritime forces of the Gulf Coast. An Iranian military officer is quoted as saying, "their security and the security of their interests in the region are in our hands" (Hafezi, Saul, and Sharafedin). These instances of aggression time and time again require attention from the US Navy and prove that this is not a reliable source of oil. Even though US oil production has rapidly increased, it still can not run on domestic production alone. The current situation in Venezuela underscores American dependence on politically unstable petrostates. According to journalist Matt Egan, Gulf Coast refiners can not operate entirely on domestic oil alone. To churn out a plethora of petroleum products, American refineries require a constant and large supply of crude oil. Venezuela has therefore become a main foreign petroleum supplier to the US (Egan). And because Venezuela has such a vast amount of oil reserves the political instability of the region has peaked the interest of outside parties. This has implications on national security due to the fact that both President Trump and Russia are attempting to gain access to these reserves. This geopolitical crisis threatens US control over oil prices, opening the door for a hike in price (Smith).

Energy Infrastructure Weaknesses

In 2017, 59.8% of total US energy consumption came from petroleum and natural gas (US Energy Information Administration). Being that the US utilizes so much oil and gas it is imperative that these systems are regulated. The infrastructure of oil and gas storage must prioritize the protection of public health and safety, conservation of air and water quality, and the reduction of wasted resources. A study conducted by the US Department of Energy (DOE), highlights risk considerations related to electric, petroleum, and natural gas infrastructure across all regions of the US. The study found that the Gulf Coast was most at risk for hazards affecting petroleum storage costing the equivalent of 216.5 thousand barrels a day. This is the result of corrosion, damage, and equipment failure of pipelines in the region (DOE). Not only are these pipelines susceptible to the hazards of poor maintenance, but they also exist in an area prone to hurricanes, flooding, and storms which in turn make them even more vulnerable. Below are important figures to consider.

Top Events Affecting Crude Oil and Refined Product Pipelines (1986–2014)

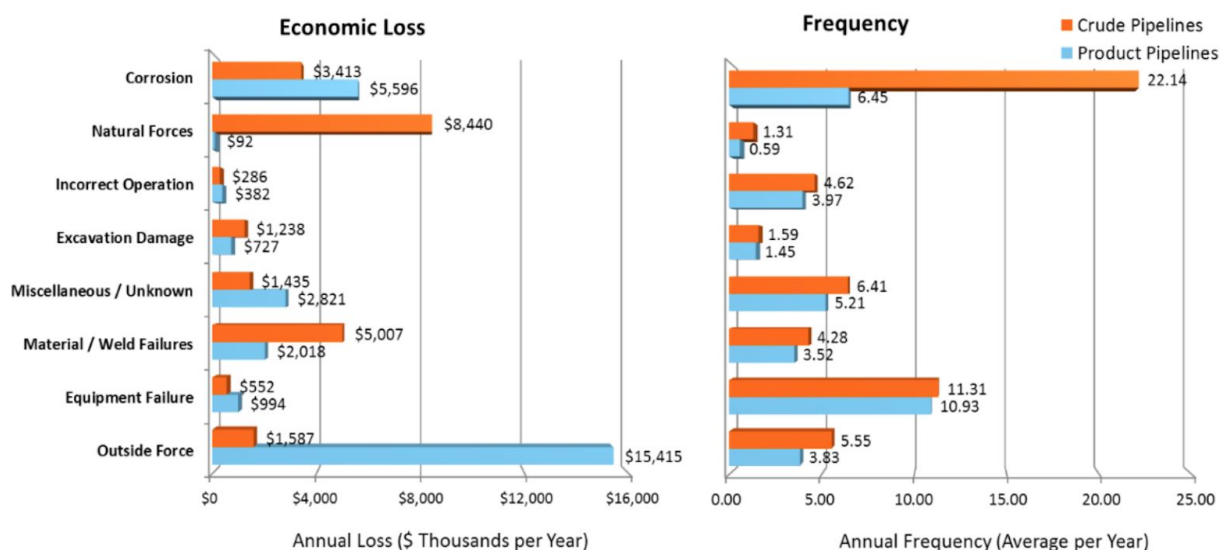


Fig 9.2 Accelerating costs & instances of oil storage malfunctions in the Gulf Coast.

Source: US Department of Energy. "Gulf Coast Region: Energy Sector Risk Profile." *The Office of Cybersecurity, Energy Security, and Emergency Response*. pp 4. <https://bit.ly/2WWc2NH>.

Accessed 13 February 2019.

Since 2004, oil pipelines off the coast of New Orleans have been spilling oil into the Gulf Mexico daily, equating to between 300 to 700 barrels of oil a day (Fears). This should most definitely be a national security concern as it is an extremely poorly regulated area that demands more oversight. The neglect of spills like these across the country make for a huge expense lost and a massive threat to public and environmental safety. The threats to the environment include contamination of marine food chains resulting in the poison and eventual death of marine life. Given that oil can contaminate fish, crab, and shellfish meat, this poses

threats to human consumers. Many energy industries outside tourism also require clean water to function. Power plants, nuclear or desalination plants for example, require clean water to function. Once contaminated, the piping systems of said plants would not function properly forcing these plants to shut down (Global Marine Oil Pollution Information Gateway). If hazards - like those illustrated by the EIA - continue to be ignored by future administrations, the US risks detrimental damages to the environment as well as the economy. We must see to our infrastructure weaknesses in attempts to fix major vulnerabilities and ultimately ensure our energy security.

Hydropower dams across the country provide electricity to the grid almost immediately. In the event of an energy blackout hydropower dams across the country have the ability to provide essential emergency power. Beyond electricity they also provide flood control benefits, irrigation and water supply. In 2017, Hydropower produced about 7% of total US electricity generation and about 44% of total US renewable energy (EIA). While hydroelectric power is a great source of renewable energy, due to lack of investment and the age of the dams, hydropower dams are in major need of repair. By 2020, 70% of dams in the US will be more than 50 years old leaving them vulnerable to the dangers caused by deterioration of old infrastructure. If ignored we risk the loss of human lives, flooding, property loss, and environmental damages. According to the Association of State Dam Safety Officials (ASDSO), by 2020 there will be over 10,000 state-regulated high-hazard¹⁰ dams in the country.

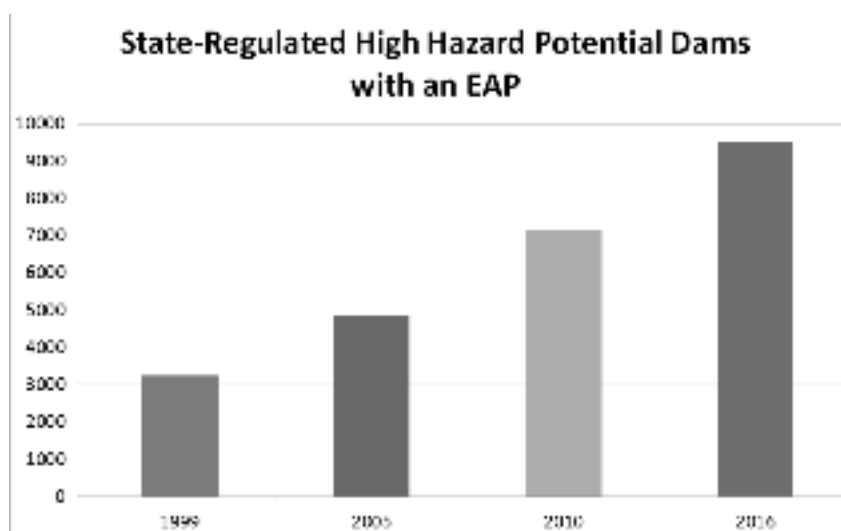


Fig. 9.3 The growing threat of high hazard dams in the U.S.

Source: ASDSO. "Are Emergency Actions Required?" *Frequently Asked Questions* | Association of State Dam Safety, ASDSO, <https://bit.ly/2tkVwJt>. Accessed 12 February 2019.

¹⁰Dams assigned to the high hazard classification refers to dams where failure or mis-operation will probably cause loss of human life. See [ASDSO].

The need for dam repair or shutdown is urgent to national security and accelerating every year. In 2017, heavy rains caused a twenty one mile low hazard¹¹ dam in Nevada to burst. The dam---having been built in the early 1900's---could not withstand the pressure and burst. This large-scale incident cost Nevada thousands of dollars of property damage due to flash flooding. In considering the damage and potential costs, this low hazard dam had on the area it further highlights how imperative dam repair is to national security considering the vast amount of high hazard facilities. In order to ensure energy infrastructure coincides with security the US must shift their focus on investing more into our current energy infrastructure.

Role of Climate Change in Increasing Security Risks

As the projections of climate change continue to increase, the risks posed to national security accelerate accordingly. The US has suffered extreme weather events, rising sea level, and increased episodes of extreme heat and extreme cold as a result of climate change. It is necessary that we assess the effects of these scenarios to national security as it relates to weakened military infrastructure, increasing demand of US aid, and the geopolitics of newly-created Arctic Sea trade routes. We may better incorporate the threats climate change pose into our national protection procedures.

As a result of climate change, extreme climate events are changing the way in which the US military must assess their security. In response to the security risks of these events, in January of 2019, the Department of Defense (DoD) published a report titled "Report on Effects of a Changing Climate to the Department of Defense." The DoD concluded that across all of the US military departments of the country 79 military installations are vulnerable to climate effects that could inhibit them from functioning properly (DoD 5). As a result of worsening sea level rise, many Navy Bases have been left susceptible to flooding and increasing storm surge impacts that cause logistic issues for the bases. The US military manages property in all 50 states, seven US territories, and 40 foreign countries, comprising almost 300,000 individual buildings around the globe worth roughly \$590 billion. About 10% of DoD coastal installations and facilities are located at or near sea level and are vulnerable to flooding and inundation (Houser et al.). In 2018, Hurricane Michael ravaged the coast of the Florida ripping apart Tyndall Air Force Base. The effects of this hurricane alone cost this base over 5 billion dollars in damages (McKenna). These weather events have not only proven to be extremely costly for the US government, and overall inhibit military readiness and affect base resilience.

As the climate continues to change the arctic remains susceptible to warming. Along with the detrimental ecological and environmental damage caused by warming, it also opens the door for new pressures on the military, specifically the US Navy. If the ice continues to melt at its current rate it will open two passages through the region; the Northern Sea route and the Northwest Passage. These are two possible trade routes that have the potential to cause major geopolitical competition as a result of the possible economic advantages. Russia and Canada

¹¹Dams assigned to the low hazard classification refer to those where there will be economic and environmental losses but no probable human lives lost. See [ASDSO].

have each claimed a passage, while the US claims the waters as international. Another aspect of concern is the control of the potential petroleum reserves in the area that were previously not accessible. If the ice continues to melt, exposing more oil reserves and offering new trade routes, the US military will be confronted with new problems that will be costly and extremely demanding.

Cyber Security Threats to the U.S. Energy Grid

Ensuring US energy systems are protected from cyber security risks is of utmost importance to national security as the sophistication and scale of cyber threats have increased. Overlooking cyber security relative to the energy industry is no longer an option, as threats to the energy grid have become more and more prominent. According to Daniel R. Coats, Director of National Intelligence, US competitors have and will continue to use cyber capabilities to seek political, economic and military advantage over the US government and its allies (Coats 5). There has been an increase in occurrences of these parties probing energy systems to better understand U.S. grid vulnerabilities. This would allow for potential disruptions in the U.S. energy supply chain which can have detrimental effects on US public and private infrastructure.

The energy grid makes up thousands of power plants, substations, miles of high-voltage transmission lines, and millions of miles of low-voltage distribution lines (Smith 374). Americans rely almost entirely on the grid to function. The US Department of Defense depends on the commercial energy grid for 99% of the energy they consume (McGrail). The idea that the energy grid could be disabled as a result of a cyber attack is one that did not seem like a reality until recently. Specifically, The Journal of Energy & Natural Resources Law highlights that over the last year, Russia's military intelligence has infiltrated the control rooms of power plants across the United States. It is suspected that this would allow Russia to "control parts of the grid by remote control" (Smith 374). According to federal officials in 2017, Russian hackers participated in an ongoing and sophisticated infiltration that could have allowed them to cause blackouts across the country. This would be extremely dangerous as it could completely dismantle US infrastructure in a matter of seconds. When it comes to the energy grid, stakes are so high due to the fact that military and public welfare concerns are so vast.

In December 2018, The President's National Infrastructure Advisory Council (NIAC), published a study assessing the nation's preparedness for a catastrophic power outage. The study *Surviving a Catastrophic Power Outage* came to the conclusion that the US is nowhere near being prepared for a large scale power outage. This report allows us to better understand the infrastructure vulnerabilities of the public and private sector in the event of an energy blackout. A energy blackout would cause a breakdown in critical infrastructure affecting drinking water and wastewater systems, communications, transportation, healthcare, and financial services: these sectors are critical to public health and safety and our national and economic security (NIAC 3). Not only are power outages a risk to public safety they are also very expensive for the companies which supply energy. In 2015 alone, The Department of Defense reported 127 outages that cost the US an astonishing \$26 billion annually, some outages even costing companies upwards of \$17,000 per minute (McGrail). The vulnerabilities of the US

energy grid to cyber attacks can no longer be ignored as the risks to public safety, military infrastructure, and the economy are far too great.

It is critical that the US government re evaluate the threat of cyber threats to the energy sector as it has proven to be matter of national security. Being that the 90% of the nation's energy infrastructure is privately held, the US government must align with the private sector to ensure the correct measures are taken (CESER). Because it can be very difficult to trace hackers, it is imperative that the US takes preemptive protection. US dependence on the energy grid leaves national security susceptible to the manipulation of nation-states, terrorist organizations, and competitors. Moving forward, ensuring the energy industry is protected from cyber threats is critical to national security.

Concluding Remarks

The goal of national security when it comes to energy should be that energy systems are providing safe, reliable, and protected forms of energy. In order to meet this criteria, US energy systems require a reevaluation of the reliability of our energy sources. This chapter highlights the following conclusions:

- The US government must see to its energy infrastructure weaknesses in attempts to fix major vulnerabilities and ultimately ensure our energy security.
- The risks associated with imported oil present security challenges related to the reliability of US energy sources.
- Climate change poses a new threat to security as extreme weather events introduce new problems to the US military.
- An increase in the sophistication and scale of cyber-attacks to energy grids require the DoD to reevaluate the preparedness of current energy distribution systems.
- In order to ensure public safety, environmental sustainability, and economic security an assessment of current US energy infrastructures is urgent.

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Ten

The Costs of Climate Change

An Analysis of Past, Present, and Future Consequences

Madisen McKenzie

Introduction

Starting in the late 2010s, the growing impacts of climate change have brought costly, damaging, and lethal consequences to the United States. Extreme weather, massive wildfires, drought, flooding, and sea level rise together are costing the nation many billions of dollars each year, while lost neighborhoods and businesses, widespread damage to essential infrastructure, and a growing number of climate-related deaths are impacting public well-being. These realities are headlined in the most recent National Climate Assessment (NCA) delivered to Congress and the President at the end of 2018. Alarming, this report identifies that “atmospheric carbon dioxide (CO₂) concentrations are now higher than at any time in the last 3 million years, when both global average temperature and sea level were significantly higher than today” (USGCRP II, ch. 2). Furthermore, in their most recent report, the Intergovernmental Panel on Climate Change (IPCC) insists that the world remain below 1.5°C of warming, yet with human activity “adding around 0.2°C to global average temperatures every decade,” the IPCC predicts that between 2030 and 2052 the 1.5°C level will have already been reached (Carbon Brief Staff). Current indications are not encouraging a rapid decrease in global carbon emissions, and thus exhibit the failure of the US to act as a moral leader on addressing the climate threat (Hausfather).

It is imperative that at this time the US drastically decreases its greenhouse gas emissions due to the cumulative effects of climate change. The future risks of climate change are directly tied to decisions made today as greenhouse gases remain in the atmosphere for hundreds of years. As such, when choices today disregard lowering greenhouse gas emissions, “decision-makers put in place processes that increase overall risks tomorrow,” and further push climate change’s disastrous effects on future generations (Risky Business Project 22). To promote a new US energy policy that focuses on reducing greenhouse gas emissions within the US, this report will focus on both the current and projected costs of climate change under an unmitigated climate change scenario. The topics of discussion include: hurricanes, wildfires, agriculture, labor, public health, energy, and national security. The report will conclude with a discussion on the implementation of various mitigation and adaptation techniques that can be used to decrease the economic and social losses attributed to climate change.

Unmitigated Climate Change Scenario

The current effects of climate change have occurred primarily due to the growing accumulation of manmade greenhouse gases in the atmosphere and their capacity to increase global mean temperature and produce specific climate-related events (USGCRP I & II). In order

to understand the future of greenhouse gas emissions, the Integrated Assessment Modeling Consortium created four possible scenarios to identify a range of atmospheric greenhouse gas concentrations (see figure 8.1). These scenarios are titled “Representative Concentration Pathways” (RCPs) and have been used in the IPCC’s Fifth Assessment Report to identify the possible effects of climate change for each variation in greenhouse gas levels. Each scenario represents a different emissions pathway related to the rate at which the world decreases its fossil fuel uses. The RCP8.5 scenario -used in this report- exhibits a scenario where global emission growth rates moderately increase as fossil fuels remain the prominent factor in global economic growth. This scenario is deemed the closest to “business-as-usual,” whereas major emitting countries continue to utilize fossil fuels to promote their economic growth with little policy enacted to reduce their emissions (Houser et al 18). The RCP8.5 pathway has been chosen as the focus for projections included in this report in order to draw attention to the severe ways in which climate change will harm US economic and social stability, and thus promote a new energy policy that limits fossil fuel emissions.

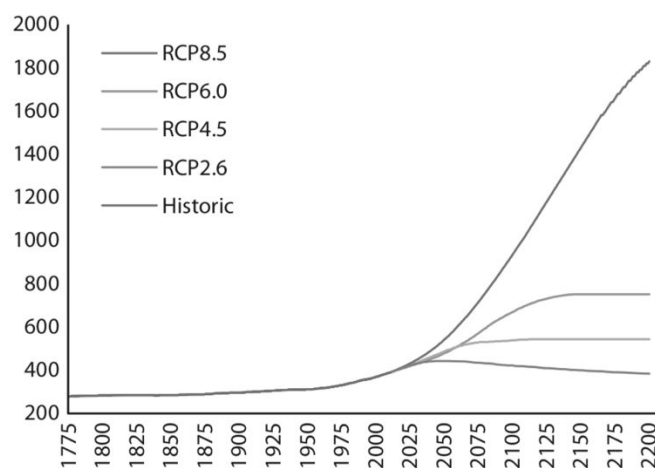


Fig. 8.1: RCPs for atmospheric CO₂ concentration in parts per million

Source: Houser, Trevor et al. *Economic Risks of Climate Change: An American Prospectus*. Columbia University Press, 2015.

Coastal Storms

Since the 1970s, hurricane activity has increased in the Atlantic, along with a rise in hurricane severity due to aspects of climate change, specifically warmer sea temperatures and sea level rise¹² (Watson 1; Dinan 186). When a hurricane hits, rising sea levels paired with heavy precipitation results in severe flooding, causing damages that far outlast the initial storm (USGCRP I, ch. 8; Hsiang et al 3). Accordingly, by 2050 the influence of rising sea levels on hurricane activity are predicted to increase annual hurricane losses by \$5.8 billion to \$13 billion (Houser et al 111). The 2017 Atlantic hurricane season was the first time on record that “three

¹²As of 1900, there is high confidence that the global mean sea level “has risen by about 7-8 inches... with about 3 of those inches occurring since 1993.” See *Climate Science Special Report: Fourth National Climate Assessment, Volume I*.

category 4 hurricanes made landfall in the US (Harvey, Irma and Maria) and six category 5 landfalls occurred across the Caribbean basin from Irma and Maria” (“WMO Hurricane Committee”). The economic losses incurred from these hurricanes exceeded more than \$300 billion, which is more than double the total damage wrought by Hurricanes Katrina and Rita in 2005 (United States. Cong. Senate 5). These hurricanes affected multiple states and territories, costing upwards of hundreds of people to lose their lives while the lives of millions were severely impacted. Hurricane Harvey, with estimated damages of \$125 billion became the second costliest hurricane in US history, with Maria following behind as the third costliest at \$90 billion.¹³ Maria’s devastation to Puerto Rico far outlasted the initial effects of the storm, with power outages encompassing the entire island, followed by severely diminished water supplies and communications. Three months after the storm, power had only been restored to over half of the population (“WMO Hurricane Committee”). In addressing both the Atlantic hurricane season and the California wildfires which occurred around the same time, it is estimated that over 25 million Americans were impacted by these extreme weather events (United States. Cong. Senate 7). Events such as these and their accumulating economic losses will only continue to grow under the RCP8.5 scenario if the US fails to reduce its greenhouse gas emissions.

When storms, such as the preceding, devastate coastal communities, the Federal government provides disaster relief aid to assist in addressing the damages. Currently, between the years 2000 and 2016 the government has spent over \$200 billion in disaster relief aid to damaged coastal communities, while future projections suggest these numbers will continue to rise (EOP 26-27). In discussing both known and predicted economic losses, it is important to keep in mind that these estimations often remain conservative due to their inability to fully integrate indirect economic losses. Indirect losses can include destroyed businesses and the socio-psychological impacts that often follow extreme weather events (USGCRP II). Other losses come from a decrease in an area’s economic revenue as populations permanently leave the area following a disastrous event, as was the case in New Orleans after Hurricane Katrina (“Announcement: Moody’s: Climate Change is Forecast”).

Wildfires

On the coasts, global temperature increase plays a role in strengthening hurricanes, while more inland it is a factor in increased wildfires, another costly extreme weather event. There is persuasive scientific evidence that the frequency of wildfires across the western US and Alaska has increased since the 1980s (USGCRP I, ch. 8). Scientific research has shown that an increase in forest fire activity is largely due to a combination of interrelating factors which are a product of temperature increases¹⁴ (USGCRP I, ch. 8). Climate change also further complicates wildfire management by limiting water available for fire suppression and

¹³ Katrina (2005) remains as the first costliest hurricane in US history. See “WMO Hurricane Committee Reviews Devastating 2017 Season.”

¹⁴ Rising temperatures create warmer and drier climates where increased drought frequency, minimal precipitation, dry soils, and increased fuel flammability all contribute to more frequent and severe fires. See *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*.

lengthening the fire season (EOP 23). These factors all contribute to the recent drastic events of the California wildfires. In accounting for the fires' total loss in property, taxes, jobs, business, and health, Dr. Joel Meyers estimates California's economic loss to be \$400 billion in 2018, which is equivalent to 2% of the nation's GDP ("AccuWeather Predicts 2018 Wildfires"). Wildfire management is also costly for the Federal government. As of 2017, the US spent \$34 billion on fire management over the last decade, while future estimates predict annually costs to reach \$1.3 billion by mid-century (GAO 1; EOP 24).

Additionally, forest fires incur external costs that are not evident after the immediate damage has occurred. A prime example is California's Pacific Gas and Electric Works (PG&E) company's recent filing for bankruptcy, making it "the largest company to seek protection while blaming the effects of a warming planet" (Eckhouse & Roston). The company faces billions of dollars in liability claims that far exceed its insurance and assets, and thus sees bankruptcy as their only option (Penn et al). Currently PG&E stands as the first example of a crucial financial causality from the effects of climate change, yet climate expert Michael Wara,¹⁵ speaking on the economic effects of wildfires and other extreme weather events, claims that "tomorrow it could be insurance companies or state governments that are overwhelmed after an unexpectedly intense hurricane or series of hurricanes" (Penn et al).

Aside from hurricanes and wildfires, increased greenhouse gas emissions will produce other extreme weather events that incur economic losses. Hurricanes and wildfires have been chosen as topics of discussion due to their ability to produce significant resulting damage that often cross state borders, causing severe regional economic and social losses that impact the national level. Other extreme weather events that range in levels of severity, frequency, and total economic losses include tornados, thunderstorms, snowstorms, atmospheric rivers, droughts, and flooding¹⁶ (USGCRP I, ch. 9). Since 1980, these events, including coastal storms and wildfires, have totaled 241 and have cost the US over \$1.6 trillion in economic losses ("Billion-Dollar Weather and Climate Disasters").

Agriculture

Agriculture, which is dependent on precipitation levels, temperature, and carbon dioxide amounts in the atmosphere and soil, makes this sector of the US economy highly susceptible to climate change (Houser et al, USGCRP II, ch. 10). Since 2011, the US has experienced a number of significant droughts induced through direct human interaction with the soil and changing weather patterns (USGCRP I, ch. 8). Since 2012, these droughts have accounted for crop failure across hundreds of thousands of acres in many US states,¹⁷ producing \$56 billion in economic losses for these farmers within the last five years (Watson et al 3). Although these

¹⁵Michael Wara is the director of the Climate and Energy Policy Program at the Woods Institute for the Environment at Stanford University. See "PG&E Bankruptcy Tests Who Will Pay for California Wildfires."

¹⁶ Unrelated to other extreme weather activity, namely hurricanes. See *Climate Science Special Report: Fourth National Climate Assessment, Volume I*.

¹⁷These states include California, Texas, Oregon, Washington, Idaho, Montana, and New Mexico. See "The Economic Case for Climate Action in the United States."

losses currently do not threaten the economy on a national scale, they significantly hurt the livelihood of farmers and rural communities whose economies are closely interconnected with agricultural production (USGCRP II, ch. 10).

Aside from direct weather changes, agriculture yields are predicted to suffer increased losses due to limited water availability for irrigating crops and increased levels of pests as temperatures rise (USGCRP II, ch. 10; Houser et al 61-64). Livestock accounts for half of the overall US agriculture production, and will suffer losses under diminished water availability, rising temperatures, and increased diseases, putting animals under stress and at higher risk for death (USGCRP II, ch. 10). Furthermore, US agriculture relies heavily on subsidized crop insurance by the federal government to reduce risk management. Under an unmitigated climate change scenario, by 2080 the cost for annual crop insurance premium subsidies for corn, soybeans, and wheat could increase by 40 percent. Reduced output in various economic sectors of the US, including agriculture, will result in less revenue for the federal government, creating difficulties for the government to provide necessary subsidized crop insurance and other amenities¹⁸ (EOP 15, 7).

The drought the US experienced in 2012 affected both livestock and agricultural production severely and remains one of the worst droughts in US history since record keeping began in 1895 (Schnoor). During the drought two-thirds of US counties were declared as disaster areas, while crop losses were estimated at \$18 billion (USGCRP II, ch. 10; Schnoor). The drought largely affected yields in livestock, wheat, corn, and soybean production which “accounted for \$14.5 billion in loss payments by the federal crop insurance program” (USGCRP II, ch. 10). These loss payments costed taxpayers billions as the federal government pays only 60 percent of them (Schnoor). Without a reduction in atmospheric greenhouse gas concentrations, a warming climate will further exacerbate drought severity and frequency as well as its ensuing costs. In the past, farmers have been able to implement technological advancement and adaptation practices to offset the losses incurred by changing weather (USGCRP II, ch. 10). However, strategies used in the past may not be effective in dealing with the predicted changes a shifting climate will bring, or they will remain too costly to implement (Houser et al 54).

Labor

The US workforce is the backbone of the American economy, and as such even minimal changes in worker productivity can have a powerful effect on the economy’s total yield. In the past, extreme weather events have decreased worker productivity due to its damages obstructing business and production in various areas (Houser et al 67). As climate change increases the severity and possible frequency of extreme weather events, economic losses will grow as labor productivity declines in the areas of impact. Yet extreme weather events do not pose a daily risk to the labor force, unlike rising temperatures. As the overall US climate warms,

¹⁸These amenities include federal revenue spent on disaster relief, flood insurance payouts, investments in at risk federal infrastructure, federal fire suppression resources, and federal healthcare programs. See “Climate Change: The Fiscal Risks Facing the Federal Government.”

laborers will be more prone to decreased productivity, affecting economic output and causing economic losses (Houser et al 67). Workers within the agriculture, construction, utilities, and manufacturing sectors of the US economy are at high-risk for decreased productivity due to the amount of time they spend in outdoor environments. In addition, workers in stores and offices also face a decrease in productivity due to difficulty in maintaining optimal thermal conditions inside as outdoor temperatures change, but their changes in productivity remain significantly lower than high-risk sectors (Houser et al 68). Combining both high-risk and low-risk sectors of the economy, with limited greenhouse gas emissions annual labor productivity costs are predicted to grow by \$0.1 billion to \$22 billion between the years 2020 and 2039 (Houser et al 131).

Aside from labor productivity, rising temperatures are anticipated to increase heat-related deaths and cause a decline in the labor supply. Moreover, heat-related deaths are predicted to offset cold-related deaths as temperatures rise across the nation, causing the national mortality rate to rise by an average 5.4 deaths per 100,000 for each incremental rise in temperature (Hsiang et al 3). By 2090 this will account for a total of \$155 billion in economic damages (USGCRP II, ch. 29). Also, by the year 2090, taking into account both a decrease in labor productivity and rise in mortality rate, two billion labor hours are predicted to be lost yearly, incurring “an estimated \$160 billion¹⁹ in lost wages” (USGCRP II, ch. 11). The above estimates solely focus on the ability of rising temperatures to decrease labor productivity and labor availability, and thus fail to assess the impact of related heat induced illnesses on the workforce. As such, it is important to consider that estimates for a decline in both labor productivity and availability will be much higher once climate induced public health consequences are considered.

Public Health

Climate change is an important factor within human health, as its impacts generate both economic and social losses. Currently there is high confidence that both physical and mental ailments will intensify as average temperature and precipitation levels increase alongside the dynamic patterns of extreme weather events (Houser et al 74 & USGCRP II, ch. 14). Many sectors of the American population are predicted to suffer from the psychological consequences of climate change, fluctuating from immediate to long-term negative impacts. The NCA states that “mental health consequences, ranging from minimal stress and distress symptoms to clinical disorders... can result from exposures to short-lived or prolonged climate- or weather-related events” (USGCRP II, ch. 14). Similarly, individuals who have experienced climate induced disasters are at a higher risk of developing depression, post-traumatic stress disorder, and reduction in cognitive functioning (Bergh & Pillay 582; Patz et al 370; USGCRP II, ch. 14).

Increasingly the US is experiencing more hot days than cold ones due to temperatures rising. Larger accumulations of warmer days hold the potential to create heat waves, such as

¹⁹In terms of 2015 dollars. See *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*.

the one that California experienced in 2006. This two week-long heat wave caused an estimated 16,000 emergency room visits, 1,620 hospitalizations, and 655 premature deaths, resulting in an estimated total of \$6 billion in health costs (Watson 4). As previously mentioned, higher temperatures will increase the overall mortality rate within the US, affecting mainly older adults, pregnant women, and children, with people living in urban areas at a higher risk of heat-related illness or death (USGCRP II, ch. 14; Patz et al 370). Rising temperatures also increase the US population's exposure to vector-borne and water related illnesses. Patz et al states that "most vector borne diseases exhibit a distinct seasonal pattern which clearly suggests that they are weather sensitive" (373). Hence, as climate change disrupts weather patterns and temperatures, new conditions will be created "that favor the movement of vector-borne disease into new geographical regions," placing populations previously safe in danger of obtaining a disease (USGCRP II, ch. 14). Rising temperatures and changing precipitation levels are predicted to increase the introduction of pathogens and toxic algal blooms in both recreational waters and sources of drinking water, further putting the public at risk (Patz et al 372; USGCRP II, ch. 14).

Energy

Energy availability, dependability and security affects nearly every sector of the US economy from its financial security for businesses and households to its importance in maintaining national security for the nation (USGCRP II, ch. 4; Houser et al 95). Overtime climate change is predicted to rise electricity demand as warmer days become more frequent and populations increase their use of air conditioning (Houser et al 95; Hsiang et al 3). Under an unmitigated climate change scenario, "average nationwide demand in the residential and commercial sectors will likely increase by 0.7 to 2.2 percent by 2020-2039" (Houser et al 97). Currently electrical grids are designed to accommodate peak demand days in accordance to a particular area's number of hottest days. Yet as a warmer climate rises the number of days experiencing extreme heat, additional investments will be required in the electrical grid to accommodate peak generation capacity, transmission, or storage (Auffhammer et al 1886).

Aside from demand, climate change also directly impacts energy transmission, generation, and supply. As temperatures increase, they will intensify current losses in electricity transmission (USGCRP II, ch. 4; Houser et al 101). Likewise, an increase in hurricane severity directly threatens US energy production and generation as "more than half of total US energy production and three quarters of electricity generation takes place in coastal states" (Houser et al 99-103). When hurricane Katrina and Irma hit coastal states in 2005, "more than 100 oil and gas production platforms were destroyed," and caused the Louisiana Offshore Oil Port, which is the only US deep-water oil import facility, to halt production for several days. These damages compelled three million barrels, or 20 percent of the country's daily refinery throughput, to remain unavailable for three months after the hurricane passed. The damages incurred caused retail gasoline prices to increase by 30 percent around the US and caused widespread public panic (Chow & Elkind 146). Without a decrease in greenhouse gas emissions, climate-induced events like hurricanes Katrina and Irma are estimated to produce \$9 billion in economic losses by 2090 due to climate change's impact on energy supply and demand (USGCRP II, ch. 29).

National Security

Another issue of concern that climate change threatens is the stability of US national security. Climate change is predicted to “have significant geopolitical impacts around the world,” as its environmental degradation causes food and water scarcity, worsens poverty, increases the spread of disease, and heightens mass migrations (Houser et al 190). The aforementioned geopolitical impacts will affect developing nations more so than developed ones, causing a likely raise in the demand for US humanitarian and disaster aid (USGCRP II, ch. 16; Houser et al 190; DOD 9). Furthermore, these geopolitical impacts often hold the ability to undermine weak governments in certain areas, allowing for instability and conflict to arise which may require US military intervention to stabilize the region (Houser et al 190). In addition, as individuals both domestically and abroad increasingly experience displacement due to rising sea levels, extreme storms, and decreased agricultural production, they will be forced to cross state borders or leave their home countries in search of shelter and a sustained well-being. These migrations may overwhelm unprepared states and further strain diminishing resources (USGCRP II, ch. 16; Houser et al 193).

As temperatures rise, precipitation levels change, and water resources become scarce, maintaining US food security will grow in difficulty (USGCRP II, ch. 16). Considering that the US is a major exporter of agricultural goods, as other parts of the world face threatening food scarcity, the US will be strained in its needs of providing for its citizens as well as its commitments abroad (USGCRP II, ch. 10; Houser et al 63). Additionally, by 2050, the IPCC predicts that food prices could rise as high as 84 percent, which places stress on both US and global food security and holds indirect impacts for both economies as uncertainty in prices affects exports and imports (Houser et al 63). In terms of the global economy, climate change is predicted to directly affect the US economy and trade through its effects on US services, infrastructure, and resources in climate vulnerable countries, while it will indirectly affect the economy through large-scale shifts in the availability and prices of a wide array of imported goods (USGCRP II, ch. 16).

Adaptation, Mitigation, and Resilience

Thus far, this report has identified both past and present costs of climate change, as well as providing estimates for future costs. Yet the implementation of adaptation and mitigation techniques ranging from the local to national level hold the solution to decrease climate change’s overall costs on US economic and social stability. Mitigation involves measures to reduce the severity and speed of climate change’s impacts through reducing greenhouse gas emissions. Mitigation often involves investments in renewable, or non-carbon, energy sources, carbon capture and storage techniques, and changing current high emitting technologies and practices. As Figure 8.2 shows, if the US engages in vigorously applying mitigation techniques that move it away from the RCP8.5 pathway and ideally towards the RCP2.6 pathway, there are significant reductions in both the median damage (dots) to the US economy and the possibility for potential negative impacts (lines) (USGCRP II, ch. 29). In comparison, adaptation involves risk management, and is where the individual, local, regional, and national levels assess climate

change risk and take steps to neutralize it through both short-term and long-term goals. The US is currently investing in various adaptation strategies to mitigate the effects of climate change, but more must be undertaken in order to reduce climate change's devastating projected impacts (USGCRP II, ch. 28). When combined and implemented together, adaptation and mitigation strategies hold the possibility to reduce many of climate change projected impacts and costs (USGCRP II, ch. 29). However, for implementation to be successful, adaptation and mitigation strategies must be met with public and private resilience.

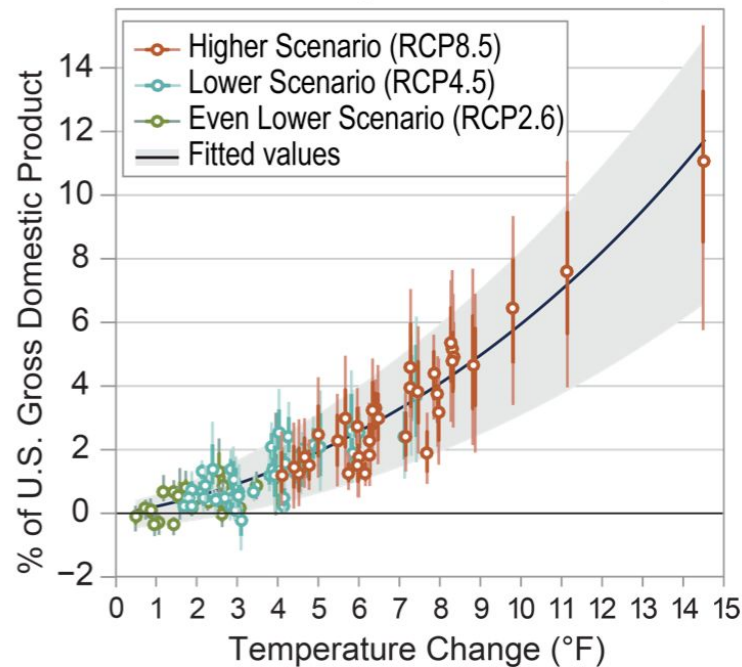


Fig. 8.2 Estimated US Economic Damage Within Different RCP Scenarios

Source: U.S. Global Change Research Program (USGCRP). *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*. U.S. Global Change Research Program, Washington, DC, USA, 2018, <https://nca2018.globalchange.gov>. Accessed 9 Feb. 2019.

Conclusion

While there are multiple risks and effects associated with climate change, this report has discussed the most pressing and concerning factors. Attention has been given to the past, present, and future costs of climate change on the US economy and social stability in the following sectors: coastal storms, wildfires, agriculture, labor, public health, energy, and national security. Accordingly, the report concludes with five key takeaways in regard to climate change and its effects:

- The US is and will continue to be vulnerable to a full range of climate change impacts due to its continental size and various climate regions.

- Climate change's impacts will not be equally distributed across the US, causing variable regional and local losses while further exacerbating existing inequalities amongst vulnerable populations and areas.
- Climate change will further aggravate resources within the US and abroad, creating both domestic and international security challenges for the US.
- If the US continues "business-as-usual," and follows the RCP8.5 pathway, there will be severe losses for both the economy and social stability.
- By applying both adaptation and mitigation techniques through the local to national level, the US may be able to reduce overall emissions and their ensuing economic and social losses as it moves away from the RCP8.5 pathway.

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The Global Role for US Energy

Serena Baserman, Liam Casey & Akshara Kumar

Eleven

Considering US Energy Leadership Abroad

Geopolitical Dimensions of Energy

Serena Baserman

Introduction

Following the end of the Cold War, the United States emerged as a global hegemonic leader, and became an economic force with the ability to sway other nation's decisions through international institutions. US leaders, for example, have had the ability to influence configurations of other nation's economies. In a more contemporary context, other countries looked to the US during the Paris Climate Accord delegation, and signed only after one of the leading global emitters had signed on. With the most recent Presidential Administration, several years of US climate leadership has been undone, with global repercussions. By taking regressive steps and slowing the transition to non-carbon sources, the US has lost substantial credibility when it comes to suggesting that other nations slow their own processes of industrialization in order to take climate action. This report will briefly name some of the current issues the US faces that present obstacles to U.S. leadership ability, and conclude with a future outlook.

Current

At present, the United States faces several challenges when it comes to improving energy policy in a global context. For one, many of the US's European allies are plagued by an over-dependence on Russian oil, and lack sufficient alternatives or influence over the price for the oil that underpins so many sectors' success. This dependency has economic repercussions with the price of oil underpinning so much of the economy, and has implications for national security: for example, Russia demonstrated in 2009 that it has the ability and willingness to shut off all gas supplies to Europe through Ukraine as a bargaining tool in a dispute (Associated Press).

Another avenue where the United States must improve comes with how it is perceived abroad based on the messages the United States sends internationally both explicitly and implicitly. Any message that US policymakers try to send today will rest on top of a long legacy of the US's multi-century exploitation and use of fossil fuels as it industrialized. With its political and economic dominance, the US was able to industrialize faster than many of today's Less Economically Developed Countries or LEDC's (EIA). With several of them facing some of the most drastic effects of climate change, it is unfair that they be held to a stricter standard than larger, more developed nations (Trenberth).

Furthermore, the US will face increased impacts of climate change as global carbon emissions are compounded by the development due to take place as LEDC's develop further. This impending increase in energy use is not going to be sourced by clean technologies. One other obstacle to US leadership comes from the substantial partisanship in our own nation and politicization of energy policy. These debates surrounding nuclear power, for example, have dramatically stalled the US's ability to commit to non-carbon sources. With no repercussions for emitting over the standards set by international accords like Paris or Kyoto, partisan policies have inhibited climate leaders from effectively influencing US emission policy.

Future

For the US future in energy leadership, leaders should take every opportunity to collaboratively facilitate the reduction of carbon emissions domestically. This will allow the US to set a global example for how a nation can achieve low emissions and national security while simultaneously protecting public welfare and serving as an ally. As for the security of the US's national energy resources, it is important to iterate that energy "dominance," as promoted our current President, is not a goal. "Dominance" may refer to dominating global oil or LNG markets, adopting an aggressive zero-sum perspective that fosters competition with Russia and or China, or attempting to use energy resources to extort other countries for political motivations. Ultimately, achieving the more noble and urgent goals of mitigating the extent of climate change and transitioning to non-carbon sources will only come with collaboration. As such, the US should adopt an approach that more closely aligns with the goals of self-reliance and resilience, which enables leaders to encourage other countries to do the same .

This two-fold method of both self-reliance and resilience in the name of national security can include several transformations of the contemporary reality. For one, Secondly, resilience domestically requires improvements towards grid technology and other mitigation efforts as detailed in Chapter 7. Resiliency without a need for international aid will become increasingly important in the coming decades as the US in the face of hazards compounded by climate change, as detailed in Chapter 10. The US can refer to Japan's acknowledgement and work towards energy self sufficiency in the face of a strong reliance on international oil. For Japan, this investment takes the form of utilizing renewable energy, nuclear power, and methane hydrate and offshore resources found in Japan's Exclusive Economic Zone or EEZ (FECP). For the US, the fracking boom of the early 2000's has drastically reduced our nation's reliance on foreign oil (Cox). Transitioning away from this affordable source towards non-carbon sources will take time and a strong political effort. The US should retain a focus on self-reliance and a strong integration of non-carbon energy into its economy, and should refrain from relying on energy as geopolitical weapon or rhetoric that asserts energy "dominance."

The US has the resources to invest in new technologies and retire old ones, and with this ability comes responsibility. As policymakers move forward with US energy policy and decide how or to extent to invest in new tech, the US needs to understand the implications of our place and our policies. To this end, it is important that the US energy future serves as a

model that leaders can export. In the face of a burgeoning population in the developing world, resources spent on a model that LEDC's can adopt will further the work done by each dollar spent. Acting on this may involve a greater emphasis on loans to allies for the up-front costs of nuclear reactor construction, for example.

Providing support abroad for an international switch towards non-carbon sources could involve more nations than simply LEDC's. For example, in the face of Russian efforts to control the European energy market, the US should consider reinvigorating existing partnerships. For example, the US already participates in the International Thermonuclear Experimental Reactor or ITER project, contributing only 9% of its annual funding. An increased embrace of nuclear power has the potential to help European countries meet their goals of self reliance and an affordable transition to non-carbon energy sourcing.

Conclusion

In conclusion, the US should take opportunities to transition away from the policies it has undertaken during the most recent Presidential term, and make steps to rectify the legacy of geopolitical dominance it cultivated prior to the most recent administration. The US must make it clear internationally that it is not only going to be involved in reducing carbon emissions with domestic policies, but that it will serve as a leader and facilitator of an efficient transition towards non-carbon energy sourcing abroad. The US future needs to include a stronger emphasis on self-reliance on non-carbon energy sources, and then ask other countries to do the same. This can take the form of hosting international climate summits, with the articulated goal of creating binding agreements with supervision bodies that can identify and penalize countries that fail to meet necessary emissions reductions. International agreements must incorporate successes from binding agreements like the Non-Proliferation Treaty and learn from the failures of the Kyoto and Paris climate accords. Moreover, it is important that the U.S. acknowledge that there is a lot of work to go into reaching these goals, and re-adjust current policy humbly. As an overarching goal, U.S. policies must demonstrate that the US is committed to extended decarbonization and climate action.

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Twelve

Energy Relationships Between the United States and Asia *Current Ties, Obstacles to Further Integration, and Our Joint Energy Future* Liam Casey

Introduction

Any discourse on world energy politics would be incomplete without a more narrow conversation on US-Asia energy relations. Asia has become--and will remain for decades--the center of worldwide demand growth for energy resources. As such, the continent will become a major destination for exports and an essential factor in global supply, prices, and geopolitics. Having undergone massive economic growth for two decades, Asian nations will increasingly turn to foreign sources to meet rapidly increasing demand for energy. The United States--with its newfound oil and gas capabilities--has the potential to become an integral economic and diplomatic partner.

Given Asia's massive size and over four billion residents, one must simplify energy geopolitics to include major allies and rivals of the United States. Key regional American energy "allies" include Japan, South Korea, India, and Vietnam. The main energy "adversary" of the United States in Asia is none other than the Russian Federation, whose growing energy exports and authoritarianism threatens international stability. Russia would prefer global affairs be divided into appropriate "spheres of interest" and thus sees "energy dominance" as a way to execute this vision (Tenin 15). China---for its part--occupies a complex role as both a major customer of American fossil fuels and a challenger to the American-led liberal world order. Strong relationships built on energy will both mitigate growing Russian and Chinese influences and offer clear benefits for America and her Asian "allies." After all, when countries develop stronger trade relationships, it facilitates deeper economic and diplomatic ties. This paper will first discuss current Asian-American energy linkages, analyze obstacles inhibiting future integration, and finish by outlining potential trade agreements.

Current US-Asia Energy Partnerships

Crude Oil

The most highly-traded commodity on the planet petroleum serves as the cornerstone for any functioning, modern economy and military. With 34 billion barrels of oil extracted annually, this vital energy resource has a plethora of uses ("Total Petroleum and Other Liquids Production"). Asian nations--with their growing demand for power due to a rising middle class--now demand more crude oil than ever to power their vibrant economies. A number of them, moreover, have been expanding their military capabilities to bolster national security in a region where adversarial relations are the norm (Raymond). The United States only began to capitalize upon Asia's growing petroleum needs in 2016, after former President Obama lifted a

40-year ban on petroleum exports mandated under the Energy Conservation Policy Act (ECPA) (Friedman and Kenneally). Previously, US crude oil exports had traditionally been limited mostly to Canada due to (1) said draconian export restrictions and (2) the geographic proximity--and hence lower prices--of various petrostates. A surge in offshore drilling in the Gulf of Mexico and the fracking revolution have led to a robust American petroleum sector. American crude oil output rose from five million barrels per day (mbd) in 2008 to roughly 11.3 mbd ten years later ("Today in Energy: Crude Oil"). Further catalyzing American petroleum growth, the Organization of Petroleum Exporting Countries (OPEC) and Russia both agreed to limit supply to 1.8 mbd in 2017 in an effort to maintain price stability (Friedman and Kenneally). American petroleum---with comparatively low prices and new supply discoveries---slowly became the most reliable, stable option for non-Canadian oil importers.

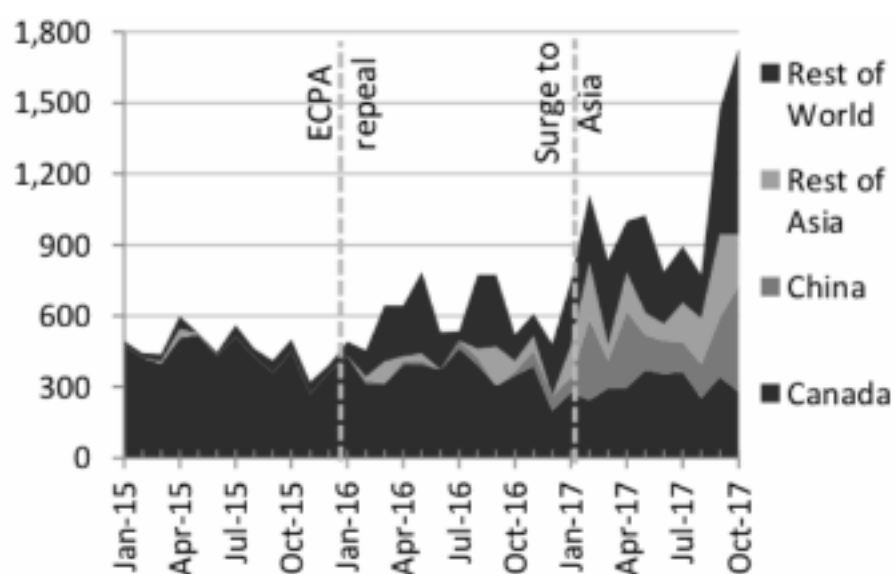


Fig. 12.1 Diagram of US Oil Exports by Destination (mbd), 2012-2017

Source: "Petroleum & Other Liquids." *US Energy Information Administration*, 1 Nov. 2018, <https://bit.ly/2hZjLun>. Accessed 12 February 2019.

As seen in Fig. 12.1, the repeal of petroleum export restrictions under the ECPA--and the price increase in OPEC and Russian crude--led to an increase in petroleum exports to non-Asian and non-Canadian countries. However, these factors alone do not explain the so-called "surge to Asia." The first major factor undergirding growing American petroleum expansion in Asia involves contango pricing. Contango pricing manifests when the future spot price runs below the current market price and customers are willing to buy a good for more than its market value. Second, economic prosperity in Asian countries translates into increased demand for energy resources. These nations will collectively require 1.9 billion tonnes of oil per year to meet expected doubling of oil demand by 2030 (Friedman and Kenneally). In 2018, China became the leading Asian importer of American crude, purchasing 376 thousand barrels per day (bpd). South Korea was the next largest customer at 111 thousand bpd, followed by India at 89 thousand bpd (Friedman and Kenneally). Two persistent areas of concern

nevertheless project uncertainty on this newly-developed petroleum connection. First, environmentalists and climate change advocates fear that increased American exports of petroleum will translate into higher rates of use and higher carbon emissions. Also, while the United States has become an important oil supplier to Asia, our country contributes only a fraction of Asia's total petroleum resources. A vast majority of oil imports to major Asian countries in 2017 came from OPEC members and Russia, with other oil exporters comprising a relatively small market share. This implies limited American influence and inroads into an already well-defined crude oil market.

US Coal Sales to Asia

Often derided by activists as the dirtiest of fossil fuels, coal has a conflicted reputation as both hazardous to human health and a necessary component to economic development. During the Industrial Revolution, Western nations utilized coal as an inexpensive, reliable way to generate electricity and produce steel before later diversifying their energy portfolios. Asian nations--mimicking the West--now utilize coal for the two reasons: (1) coal deposits are roughly evenly geographically distributed within the continent and (2) it is relatively inexpensive when not accounting for negative environmental externalities (Montgomery 95). Developing Asian countries first began burning coal in massive quantities in 2000 and now account for over 80% of global coal usage ("Today in Energy"). China, Japan, South Korea, and India in particular have garnered a reputation for their ever-increasing dependence on coal. While all of these countries have all promised to lower carbon emissions by 1.5°C under Paris Agreement requirements, decarbonization has proved more difficult than expected. China and India plan to build coal-fired plants to stimulate local economies ("India and China Continue to Build Coal Plants"). Meanwhile, Japan--having suffered through the 2009 Fukushima-Daiichi disaster--is now turning away from clean nuclear power to build new coal-fired plants (Kuo).

The United States--for its part--possesses the largest coal reserves of any country, with enough reserves to meet current domestic resource demand for the next 300 years. The United States exported 32.8 million short tons of coal to Asia alone in 2017 ("Today in Energy"). Given our abundance in this energy-rich mineral, many right-wing partisans have encouraged the continued export of American coal to energy-hungry countries. This is a bad idea for a number of reasons. Perhaps most obviously, coal has deleterious environmental effects. Several harmful emission forms result directly from coal combustion: sulfur dioxide, nitrogen oxides, particulate matter, carbon dioxide, mercury, and fly ash ("Coal and the Environment"). Coal's high carbon dioxide emissions²⁰--compared to other fossil fuels--accentuates global climate change via the greenhouse effect. And despite robust exports, production and employment in the coal industry during 2016 dropped to record lows (Patterson). Simply put, coal is not the most cost-effective fuel source available. Rather than allow coal to be pollute the environment elsewhere, the next administration should prioritize trade of cleaner fossil fuels and renewables.

²⁰Anthracite coal generates 228.6 pounds of CO₂ per Btu compared to 157.2 pounds per Btu for gasoline and 117.0 pounds per Btu for natural gas. See "Frequently Asked Questions."

US LNG Sales to Asia

In contrast to long-term appetite for petroleum resources, natural gas--for much of the last century--was highly undervalued as a potential energy resource. Previously, natural gas was seen as a useless byproduct of petroleum extraction to be burned off rather than carefully harvested (Montgomery 81). A growing need for a clean, abundant source of energy has led to shifting attitudes in natural gas. This fossil fuel is now used for various forms of heating and electricity generation. Due to its abundant fossil fuel resources, the United States recently surpassed Russia as the world's largest natural gas producer, generating an aggregate 766 million cubic tons last year alone ("Country Comparison: Natural Gas"). In fact, the United States currently out-produces what its domestic customer base can feasibly consume. This leads investors to worry that long-term oversupply and stagnant demand will force firms to exit the market, leading to a contraction this clean, abundant fuel industry. As such, it is imperative that the United States is able to find foreign customers for its natural gas. Asia--with its growing energy demand--could solve this logistical problem.

Asia has become a focal point in the American government's efforts to increase exports of natural gas. American natural gas sold abroad is pressurized as liquified natural gas (LNG) at -165°C and shipped via tanker ("What is LNG?").²¹ Roughly 70% of global LNG cargoes are destined for Asian nations, and continental demand for LNG is expected rise by the same percentage by the year 2030. This explosive rise in demand offers the United States plenty of new customers. The United States currently exports roughly nine million cubic tons of LNG each day to its top customers South Korea, China, and Japan. The main inhibitor of current LNG exports rests upon the inability of American producers to ship out the fuel resource. Currently, the United States has but two LNG terminals in Louisiana and Maryland that produce roughly 3.8 billion cubic feet of natural gas per day (Bcf/d) (Morris). By the end of 2019, however, American energy companies are expected to triple export capacity by adding additional LNG terminals along the Gulf and Pacific coasts (Morris). The expansion of American LNG into Asia represents a strong step to furthering constructive energy relationship, regardless of temporary infrastructure limitations. The United States can use this opportunity to display moral leadership by exporting a relatively clean fossil fuel. In addition, growing US LNG exports benefit the economies of all involved (reduced trade deficit for the United States combined with access to a reliable energy resource for Asian countries).

Obstacles Preventing Further Market Integration

Territorial Disputes in the South China Sea

Due to its role as a rising geopolitical competitor to the United States, the Chinese government has begun to lay claim to strategically important regions in an effort to counterbalance American influence and isolate nearby states. To this effect, China has engrossed itself in a long-term territorial expansion into the South China Sea since 2012. To

²¹Despite new technical innovations regarding LNG, this shipping process still has high capital expenditures and transportation costs that pass directly to consumers.

secure its claim, the East Asian superpower has built a number of artificial island bases in the sea and has maintained a strong naval presence in the region. Neighboring Asian states have bristled at China's territorial grab. Leaders from the Philippines, Taiwan, Malaysia, Brunei, and Vietnam have all contested Chinese takeover of the region to various degrees; many have even turned to the United States to intervene directly in the conflict. Unfortunately for our Southeast Asian partners, the current administration has avoided strengthening regional partnerships in favor of nationalist rhetoric. Although non-Chinese media outlets emphasize these two issues, the concept of energy security is just as important to understanding this conflict.



Fig. 12.2 Oil Reserves and Territorial Claims in the South China Sea

Source: "Beijing Keeps Busy in East China Sea Oil and Gas." *Center for Strategic and International Studies*, 23 Aug. 2018, <https://bit.ly/2DFiZcT>. Accessed 12 February 2019.

Unknown to many outside observers, the South China Sea is home to abundant fossil fuel resources. In particular, the sea is home to rich deposits of petroleum and natural gas; the US Energy Information Administration (EIA) estimates that the waterway harbors roughly 11 billion barrels of oil and 190 trillion cubic feet of natural gas as proven or probable reserves ("South China Sea Energy Exploration and Development.") The U.S. Geological Survey further projected in 2012 that the South China Sea may contain an additional 12 billion barrels of oil and 160 trillion cubic feet of natural gas classified as *possible* reserves ("South China Sea Energy Exploration and Development"). As seen in Fig. 12.2, much of China's self-imposed territorial claims cut directly through the richest oil and gas deposits in the region. The Chinese government's willingness to violate international maritime laws comes at the expense of neighboring states. For example, the Chinese government recently authorized the construction of oil rigs within Vietnam's exclusive economic zone (EEZ)²², prompting mass protests in the

²²An exclusive economic zone (EEZ) is 200 nautical mile zone over which a state has special rights regarding the exploration and use of maritime resources. See Green et al.

latter nation (Green et. al). This particular conflict over fossil fuel resources demonstrates that energy security feeds directly into notions of patriotism.

Ultimately, Chinese foreign policy forgoes the modern-day collaborative approach favored by previous American administrations (Heath). China disputes the territorial claims of smaller regional actors because it believes that said claims suppress its self-identified right to political and economic hegemony (Heath). In response to a Pacific theater increasingly dominated by Chinese influence, the United States must commit to economic, military, and diplomatic re-engagement with Southeast Asian for two key reasons. First, the South China Sea's fossil fuel resources could be successfully extracted by American companies after fairly compensating local governments. And second, the United States must maintain strong regional partnerships to push back against the hyper-nationalist Chinese world vision.

China's Belt and Road Initiative (BRI)

An increasingly militarized Chinese presence in the South China Sea is actually part of a much broader development strategy adopted by the Chinese government to expand the country's influence over global politics and trade. With its name stemming from the Ancient Chinese Silk Road, this 21st century foreign policy strategy is lumped under the umbrella term the Belt and Road Initiative (BRI). The BRI remains geographically segmented between several land corridors spanning 60 countries and a maritime silk road (Hillmann). The Land "Belt" includes the New Eurasian Land Bridge, China-Mongolia-Russia Corridor, China-Central Asia Corridor, China-Indochina Peninsula Corridor, Bangladesh-China Corridor, and China-Pakistan Corridor (Hillmann). The Maritime Silk "Road" supplements said land routes by a maintaining a strong military presence and investing heavily in the Indian Ocean Region (IOR) (Hillmann). Currently, BRI foreign direct investment has focused primarily on construction projects, education, railway and road construction, and materials support for developing nations (Hillmann). China has used the BRI to vastly improve diplomatic relationships with its neighbors and expand Chinese influence into these countries (Hillmann).



Fig 12.3 Map of the One Belt and Road Initiative

Source: "China's Belt-Road Plans are to be Welcomed and Worried About." *The Economist*, 26 Jul. 2018, <https://econ.st/2JXXfdx>. Accessed 14 February 2019.

One underlooked aspect of the BRI relates specifically to foreign direct investment in energy. Energy investment serves China as a vital economic tool to expand its geopolitical hold over the IOR. In 2018, China invested \$50 billion (¥338.66 billion) in Pakistan to fund the construction of coal-fired power plants ("China-Pakistan Economic Corridor"). The BRI has also invested in two oil and gas pipelines between Myanmar and mainland China that carry Arabian oil to Yunnan province. Finally, China has also acquired the Sri Lankan Hambantota port: a major trade center for fossil fuels for IOR countries (Abi-Habib). The BRI as a whole acts as a counterweight to American influence in the developing world and strengthens the Chinese position (Clarke). However, one part of the BRI that goes quietly unmentioned by the Chinese media is the control that the Chinese government maintains over these development projects. Given that these infrastructure programs are paid for and executed largely by the Chinese government alone, it retains great leverage over the use of said projects. The fundamental problem with the BRI--and with nation-building in general--is that it manifests inequitable relationships between developed and developing nations. To roll-back Chinese expansion, the United States must collaborate with developing nations to tackle their growing energy needs in a manner that does not compromise their sovereignty.

Russian Energy Expansion

In addition to a Chinese resurgence on the world stage, the Russian Federation also acts as a major inhibitor of improved US-Asia energy ties. As stated previously, Russia does not seek to project global economic and military hegemony. Rather, Russia's leaders would rather the world be divided into appropriate spheres of interest (Tenin 5). One way the former Soviet state puts this into action is through the sale of fossil fuels to adjacent Asian countries. In 2017, mineral fuels were the Russian Federation's top export, comprising 48.5% of all exports at \$173.3 billion (or, □11,488 trillion) ("Russian Exports"). Russia's largest trading partner is none other than China, with the latter nation purchasing 300 million barrels of oil from Russia last year alone ("Russian Exports"). Most of Russia's fossil fuel exports to China come from ships sent via Kozmino Bay (464,000 bpd) (Downs et. al 19). In addition, the Eastern Siberia-Pacific Ocean (ESPO) pipeline supplies Daqing, China 355,000 bpd (Downs et. al 46). Ultimately, China has more leverage in its relationship with the Russian Federation; the former nation could procure fossil fuels from other countries if absolutely necessary, leaving the undiversified Russian economy vulnerable to a potential downturn.

Today's Russo-Chinese energy relationship first took root in 2008, following the financial crisis. The temporary drop in oil demand--brought about by the onset of the recession--left Russian energy companies short on liquidity necessary to pay workers and fund future contracts. The Chinese Development Bank--a state-run institution--took advantage of this moment by providing Russian companies with loans in exchange for long-term contracts with China at a discounted price (Downs et. al 3). In 2013, Russian annexation of Crimea--and subsequent Western sanctions--triggered a currency crisis for the ruble (Downs et. al 3).

Chinese state banks yet again supplied the country with access to capital in exchange for new oil infrastructure projects to China, including Yamal LNG and Power of Siberia (Downs et. al 41). The Russo-Chinese energy relationship proves problematic for American interests in Asia for two key reasons. First, the sanctions relief brought on Chinese investment allows the Putin regime to escape culpability for its invasion of Ukraine and destabilizing actions taken around the world. In addition, a stronger Russian economy means that the northernmost state is more capable of exporting additional fuel resources to other Asian states. An expanded Russian presence in Asia would undoubtedly undermine American influence in the region.

Future Potential Partnerships

Trans-Pacific Partnership

The Trans-Pacific Partnership (TPP) was a proposed trade agreement signed by 12 Pacific nations in 2016 but never took effect. Shortly after his inauguration in 2017, American President Donald Trump withdrew the United States from the agreement, effectively ending the trade agreement altogether. The TPP included measures to lower non-tariff and tariff barriers to trade and created a dispute resolution mechanism (Livingston). American government agencies and think tanks largely agreed that the final TPP agreement would have generated net economic benefits for all 12 member-states. Following the failure of the original TPP, seven of the original TPP signatories ratified a similar comprehensive trade agreement called the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CP-TPP). Some academics have argued that--in addition to the economic dimension of TPP--the Obama Administration sought to contain rising Chinese economic influence in the Asia-Pacific region. It believed that the key to mitigating said expansion rested with deeper economic US-Asia economic integration.

Renewable energy is currently the largest destination for capital expenditure in Asia, and the proposed trade deal would have saved American companies \$24 million per year due to the reduction of tariffs (Livingston). Because the United States pulled out of the trade deal, China has filled the United States' role as clean energy provider for its Asian neighbors. China has now assumed the mantle as the largest global investor in clean energy, accounting for 40% of global investment (Livingston). In addition to benefiting American renewables, TPP would have also had a net positive effect on our LNG exports. The final agreement would have automatically approved exports to TPP members. Under regulations outlined by the Natural Gas Act of 1938, any company wishing to export natural gas first needs authorization from the Department of Energy (Levi). The TPP would have waived this requirement, giving blanket approval to member-states and thereby reducing export wait-times (Levi). Ultimately, said waiver would have given fellow TPP members confidence in America's role as a reliable energy partner. Given the importance of energy and the necessity of trade deals, the next American president ought to join the new CP-TPP or draft a new trade agreement altogether.

Conclusion

Energy sits at the crux of any significant relationship between two or more countries. Based on this discussion, the United States has a clear opportunity to develop strong alliances with crucial regional partners in the region. Major takeaways of US-Asia relationships include:

- US petroleum exports to Asia represent a small but growing share of Asian petroleum imports.
- Coal exports to Asia have negative environmental effects both in Asia and worldwide and will not save the American coal industry.
- US LNG exports are also a small but growing sector of Asian energy development.
- Chinese territorial grabs in the South China Sea and the development of the BRI translates into weakened American influence abroad.
- Russian energy development is part of its larger strategy to divide the world into geographically-appropriate spheres of interest, and its growing energy ties with China undermine efforts to isolate the Putin government.
- Trade deals are the best way to ensure that the United States maintains strong ties to Asia and mitigates Chinese and Russian threats.

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Thirteen

US Leadership in Energy Innovation

Technological Capabilities, Obstacles and Emerging Opportunities

Akshara Kumar

Introduction

Innovation is the key for efficient energy products and services and to reduce detrimental impacts on the environment. The United States has long been a pioneer in energy innovation, from nuclear technology and solar photovoltaics to hydraulic fracturing and offshore drilling. Such innovation has added greatly to economic vitality, given that energy is the third largest public sector, preceded only by defense and education (Amadeo 2018). While U.S. energy demand is not expected to increase a large amount between today and 2040, a growth of almost 30% is expected in global energy needs (International Energy Outlook 2018), suggesting a large potential market for U.S. technologies. It has been estimated that the clean (non-carbon) energy industry could attract as much as \$60 trillion of investment worldwide in the next 20-30 years (Moniz and Yergin 38). As Low Economic Development Countries (LEDCs) seek access to more energy, it is unlikely that efficiency and CO₂ emissions will be priorities in many cases unless relevant, affordable technologies are readily available. Accelerated development of clean energy technologies is both lucrative as well as vital to address growing concerns of climate change and national security. The United States must provide incentives and utilize public and private sectors to maintain its status as a leader on the energy innovation front. Some energy innovation projects with international partners are underway. For the future, the US should rely on extensive collaboration as it fast tracks technology transfer, commercialization and presents leadership opportunities.

Potential for Energy Innovation

The United States has a plethora of resources, foundational systems and technological capabilities to spur energy innovation. The chain of innovation--research, development, demonstration and commercialization--is funded by key stakeholders starting at the federal level from the Department of Energy to private companies. In addition to setting up national laboratories, research centers and collaborating with universities, the Department of Energy also drives comprehensive public policies to encourage investment in the private sector. Breakthrough potential technologies are technologies that have high technical merit, market viability, compatibility with existing energy systems and consumer value (Moniz and Yergin 16). If funded adequately, breakthrough technologies have great potential for commercial success. These parameters for success, address the end goals of key stakeholders involved in energy innovation. Amongst the key stakeholders is the Breakthrough Energy Coalition. This coalition consists of 28 private high-net worth individuals who are interested in funding clean energy initiatives and willing to tolerate high risks. The Coalition narrowed down battery technologies,

advanced nuclear reactors, smart cities, grid modernization and deep decarbonization- via expansion of renewables and carbon storage, as high impact areas of interest.

The DoE has set up a number of programs and agencies to direct energy priorities to breakthrough potential technologies. The Advanced Research Projects Agency–Energy (ARPA-E) was set up by the DoE in 2009 to improve US competitiveness and remodel power generation and consumption (Pew Research Center 14). Commercialization and economic viability and success are key to increasing private sector investment. ARPA-E requires grantees to devise a tech-to-market plan to accelerate innovation, streamline investments and optimize end use. The ARPA-E has helped many US companies to establish their energy technologies in the market and incentivizes high potential R&D with high reward. 1336 Technologies received \$4 million in ARPA-E funding in 2014 to develop solar wafers used to convert sunlight to electricity. It attracted a follow-on funding of \$60 million from the private sector. The company sought to provide cost effective solar energy and compete with coal. It went on to receive recognition as Massachusetts Institute of Technology's Top 50 Most Innovative Companies (Pew Research Center 16). The ARPA-E Energy Innovation Summit is another initiative held annually to bring together entrepreneurs, influential investors, government and academia to facilitate collaborative innovation projects.

The DoE also has the Loan Programs Office to assist capital-intensive prototype research in emerging energy industries. As of September 2018, the interest paid by entrepreneurs was \$2.41 billion which is used to offset the losses incurred in high risk energy projects (Investing in American Energy 2018). The LPO fills in the gap created by for-profit private investment in clean energy innovation. Tesla Motors, the world-renowned electric vehicle company, received \$465 million from the LPO as a starter fund in 2010 under the Advanced Technology Manufacturing Program. Tesla has progressed to incredible success today, with the help of LPO loans, and sells its designs in Europe and Asia, employing over 45,000 globally and strengthening the US economy (Lambert 2018). To best address decarbonization concerns, the DoE has utilized a revolutionary program called the Carbon Capture, Utilization, and Storage (CCUS). Program goals include determining CO₂ storage potential on and off shore, increasing storing efficiency, evaluate the environmental risks of CO₂ storage and information sharing to stakeholders. Regional Carbon Sequestration Partnership Programs have helped capture or inject 16 million metric tons of CO₂ in a time when global emissions escalated to record highs of 37.1 gigatons (Carbon Storage Research).

The model of innovation based on public-private partnerships gives the US a competitive edge in the clean energy race. Private investment depends on many factors such as tax credits, securing patents, risk assessment, return on investment, etc. However, current developments in clean energy is operating in a contentious and uncertain political environment (Moniz and Yergin 38). For example, tax credits extended to solar, wind and geothermal renewables expired in 2016. The Tax Cuts and Jobs Act, passed in 2017, left these tax credits unchanged. However, not updating them does not fully capture the market value of these renewable sources and hinders private investment. Also note that these credits are not applicable for fuel cells, new

nuclear power plants, and combined heat and power projects that are just as important as the other sources as discussed in the breakthrough potential technologies (Moniz and Yergin 210). A setback in one or more of the factors affecting private investment creates a “valley of death” at each stage of the innovation chain and limits technological capabilities.²³ The recognition that software solutions are on the forefront of innovation in recent decades has also contributed to the declining investment in hardware based clean technologies (Moniz and Yergin 15). Software solutions are relatively more flexible, less capital intensive in production and easily transferable, hence capturing a large market. Smart cities, for example, are based on an integrated approach to software solutions and electrification for greater efficiency and reduced emissions. In addition, Infosys--a prominent IT company--reduced its per capita energy consumption by a whopping 49% from 2008 to 2016. Infosys owes its success to data driven efficiency designs, optimized by software systems (Sastry).

Nonetheless, every stage of innovation requires special technical assistance and tends to become progressively capital intensive. The most common challenge is a lack of test beds that is compatible with the innovators requirements to carry out demonstration, with demonstration being critical to assess end use (Moniz and Yergin 55). Federal agencies aim to address these gaps by providing support to innovators and private stakeholders with policies and programs to incentivize the innovation process. The DoE, for its part, provides demonstration facilities and technological assistance by collaborating with universities, national laboratories, and research centers. For example, the Manufacturing Demonstration Facility is a DoE initiative based at Oak Ridge National Laboratory. It aims to cut the costs of production and manufacturing while also reducing electricity consumption and greenhouse emissions. These technologies also serve the clean energy sector by innovating on lightweight materials, new techniques for solar power production and other sophisticated battery devices (Pew Research Center 27). The Wind Technology Testing Center with more than \$25 million in DoE funding opened in 2011 as the world’s first facility to test wind blades up to 295 feet in length (Massachusetts Clean Energy Center).

Obstacles to Leadership, Contending China

The energy innovation sector seems to be vibrant and teeming with potential. A 2018 U.S. Energy and Employment Report indicates that more than 1.9 million workers were directly employed in 2017 in the Electric Power Generation and Fuels technologies; 800,000 of them worked in low-carbon-emission generation technologies, renewables and nuclear sector, and advanced/low-emission natural gas (Moniz and Yergin 33). However, “energy dominance” as pursued by the current administration, is neither a reality nor possibility. Energy innovation is a far less priority than defense and national security. Federal budget allocated in 2017 for defense was \$584.2 billion. In comparison, the DoE received a mere \$37.6 billion (Amadeo). Out of the DoE’s total budget only \$4.8 billion was spent to clean energy technologies. The total federal budget for clean energy tech was not far off with a total of \$6.4 billion (Moniz and Yergin 125).

²³ Valley of death refers to the declining investment at each successive stage of innovation as a consequence increasing risks, time and capital needs for a certain innovative product/service. See *Advancing the Landscape of Clean Energy Innovation* 71.

Moreover, caps on discretionary spending for the DoE has increased significantly as of 2018 (Amadeo). Additionally, DoE's budget portfolios are categorized by fuel source rather than breakthrough potential of energy technologies. So, energy technologies on the brink of success, in terms of efficiency and economic viability, are woefully underfunded.

Also, implicit in "dominance" is the ability to supply energy to other countries without any competition, in addition to being completely energy independent. Evident in the budget cuts, dominance as sought after by the current administration, is expanding the fossil fuel sector and slashing regulations which is environmentally and economically unsustainable. The political implications of "dominance" would also not bode well with potential buyers of US energy. Dominance in the renewable industry is also not practical because of resource constraints, underfunding and lag in energy innovation chain.

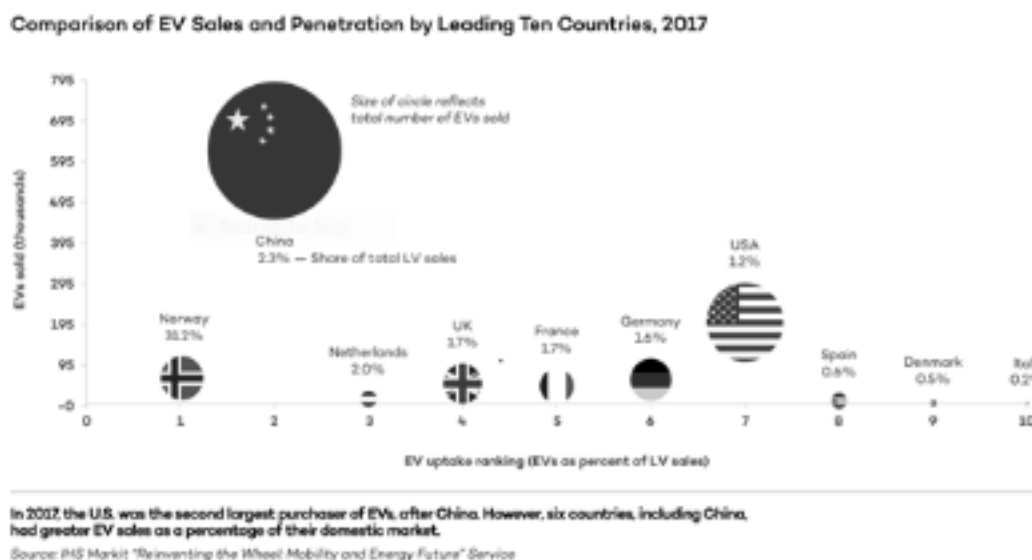


Fig. 13.1 Comparison of Electric Vehicles Sales by Top 10 Countries

Source: Yergin, Daniel, and Ernest Moniz. "Advancing the Landscape of Clean Energy Innovation." *Breakthrough Energy*, IHS Markit and Energy Futures Initiative, Feb. 2019.

In addition to being the global leader in EV sales as seen in figure 13.1, China is also leading in solar, hydro and wind production and construction of nuclear power plants. According to the International Energy Agency, China leads with one third of global wind power, one fourth of global solar power, six of the top ten solar panel manufacturers and four of the top ten wind turbine manufacturers (China Is Rapidly Developing Its Clean-Energy Technology 2018). These technologies have kick started the journey for what might be one of the world's largest carbon trading scheme by China.²⁴ The US does not produce much of the minerals needed for renewables and relies on exports. 70% of the lithium used in US energy technologies have been imported while demand has only been increasing 1970s. China is responsible for producing of

²⁴ Carbon trading scheme is a market solution to control pollution with economic incentives for reduced emissions. See *What is Emissions Trading* 2011.

85% of the world's rare earth materials that are used for renewable devices, such as lithium, germanium and indium ("A Scramble for the Minerals Used in Renewable Energy"). However, China is not entirely self-sufficient either. The energy supply from renewables accounts for only about 12% of its total energy mix ("China Is Rapidly Developing Its Clean-Energy Technology"). Heating across the country is mostly from coal and China is trying to switch to LNG to lower emissions and set a precedent for the Paris Climate Agreement. The United States has an abundance of cheap natural gas that can be exported to China because of the early R&D investment in gas exploration and production during the 1980s.

With China becoming a rising competitor in energy innovation, the United States has made several policy mistakes that threaten its clean energy future. The US raised import duties on Chinese solar-panels in 2014 citing concerns for weak regulations in production and quality. In January 2018, the Trump administration imposed more tariffs on imported solar panels, most of which come from China ("China Is Rapidly Developing Its Clean-Energy Technology"). China also made steep cuts in export quotas for rare earth minerals used in renewable energy devices in 2010 ("A Scramble for the Minerals Used in Renewable Energy"). The US imported nearly 60% of the total rare earth minerals from China in 2017 and with no reliable US alternative, threats to the supply chain will slow down clean energy innovation and have serious political consequences (Bray). Additionally, U.S. trade balance in advanced technology products went from \$6.6 billion in 2001 to a deficit of \$110 billion in 2017 (Atkinson). Increased barriers for technology transfer amongst countries will cause a lag in energy innovation overall and ultimately affect the race to innovation leadership.

Partnerships as the Future

The United States and other countries will stand to benefit immensely from trading technologies rather than putting up protectionist barriers. Innovation potential increases exponentially not only when national stakeholders collaborate, but also when international cooperation and knowledge sharing is prioritized. Mission Innovation (MI) is a multinational collaboration—formed during the 2015 Paris Climate Conference—consisting of 20 countries that represent more than 80% of the world's R&D investment. The one of the goals of MI is to increase bilateral and multinational collaboration to encourage joint technology development programs in addition to boosting public and private investment levels at the national level. The United States has benefited immensely from international engagement. A recent venture of MI is the Carbon Capture Innovation Challenge led by the US, in partnership with Saudi Arabia, in 2017. The two objectives were to identify breakthrough potential technologies and identify collaborative pathways for research, development and demonstration. The project set up an Expert's workshop with representatives from 17 different countries to deliberate on research direct for the future. Mexico also led a similar project in 2017 named the Clean Energy Materials Innovation Challenge. This new program addressed one of the key issues of the energy landscape, the gap between next generation software solutions, and energy technologies. Recommendations for stakeholders was the to integrate software developments like machine learning, artificial intelligence, and robotics in energy innovation. As mentioned earlier, the

energy landscape is shifting, and key concerns of efficiency can be addressed by incorporating software-based solutions.

International Thermonuclear Experimental Reactor (ITER) is another highly anticipated multinational collaborative project in France. There are 35 participating countries, including the US, EU, China, India and Russia. The project is a reiteration that strong foundations in basic science will innovate energy solutions that have commercial potential. It is “a magnetic fusion device that has been designed to prove the feasibility of fusion as a large-scale and carbon-free source of energy based on the same principle that powers our Sun and stars” (ITER Official). Founded in 2005, commercial operations are set to begin in 2035. It will be the first and largest fusion device to use integrated technologies to commercially produce fusion-based energy. Unlike conventional nuclear fission, nuclear fusion is a hydrogen directed, natural process that powers the Sun. Fusion remains one of the most sought-after innovation in clean energy for two key reasons. For one, mimicking the Sun ITER would be a steady source of inexpensive energy if commercialized. Second, emissions would be almost negligible compared to ITER’s non-carbon counterparts (ITER Official). ITER is expected to produce 500 MW of fusion power from 50 MW of input heating power unlike ever before. In comparison, the European made JET, which holds the world record for fusion power since 1997, produced 16 MW of fusion power from 24 MW of input heating power. What this means for energy production is that “an amount of hydrogen the size of a pineapple could be used to produce as much energy as 10,000 tonnes of coal” (The Guardian 2017). The potential for energy innovation and efficiency is in such collaborative projects. Partnerships facilitate cost sharing, fast track technology transfer, set realistic yet desirable goals for clean energy and increase commercial viability.

Conclusion

Innovation and energy efficiency go hand in hand. The United States has the intellectual and financial potential for energy innovation and leadership. There are many programs, research centers and agencies that assist and reward innovation. Collaboration between different stakeholders has been played a major role in incentivizing innovation. However, the US is no longer at the forefront of renewable energy. Fall in federal R&D investment and insufficient incentives through policies for private sector investment has stifled the United States’ potential for leadership in energy innovation. A dire need to streamline efforts in energy efficiency, to technologies with breakthrough potential, is important to assert leadership, support cost saving energy infrastructure and curb emissions. “Energy dominance” is neither a possibility neither a reality because of capital and resource constraints. Many international collaborations on energy innovation show that partnerships are the most effective way to address challenges in the changing energy landscape.

- The United States has the technological capabilities to innovate extensively in the renewable sector.
- However, “energy dominance” is not possible in practice because currently China is at the forefront of energy innovation.
- In the current political climate, private and public investment for R&D is seriously lacking.

- Many successful energy innovation projects based on international partnerships are underway.
- The US should take a collaborative approach to energy innovation, broaden opportunities and quickly address the looming threat of climate change.

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Role for Government in Energy and Climate Change

Mikayla Werner, Jenne Lawrence & Yookyeong (Jenny) Do

Fourteen

Role of Government on Energy Research and Development

History of Federal Support, Investments in Private Sector and Current Role

Mikayla Werner

Introduction

US Government support for energy R&D has had an irreplaceable role in advancing innovation and in making America a global leader in related technology. The rationale for significant federal support in this area is clear: energy is the basis for modern society and its support contributes to key national goals such as national security and public welfare. Energy innovation is essential for addressing climate change, an issue that directly impacts the the national goals mentioned above. At present, however, federal support fails to address these issues and sustain leadership standards. Moreover, funding for energy programs in the future is uncertain. Even with both public and private funding, the US currently invests less in research than other developed countries. This has been the case for well over a decade. With rising concerns over climate change, however, and the need for deep decarbonisation of the energy system, there is new urgency for prioritizing energy innovation. The history of energy R&D shows a decline in government support after the 1970s that was largely echoed by the private industry. Tax incentives, public-private partnerships, grants, and more stimulate private investment. Increasing investment in the US is important for innovative strategies and global market security.

History of Federal Support and Funding on Energy R&D

Federal support for energy R&D shows a major decline and shifting government priorities to defense and national security (See Fig. 14.1). Funding for research, development, and demonstration of advanced energy technologies grew rapidly during the 1970s in the wake of the oil crises. Crude oil prices increased significantly during the Arab Oil Embargo of 1973 and the Iranian Revolution in the late 1970s. These events empowered the International Energy Agency (IEA) to establish the framework for advancing non-carbon energy sources, rational energy policies, and multinational energy technology co-operation. The total public energy R&D budget in the US increased rapidly, from \$2.45 billion under President Ford in 1947 to \$7.47 billion in 1980 under the Carter Administration (Bennett 2017). Funding was distributed across many sources including fossil fuels, nuclear power, energy efficiency, and newly vitalized technologies of solar and geothermal power.

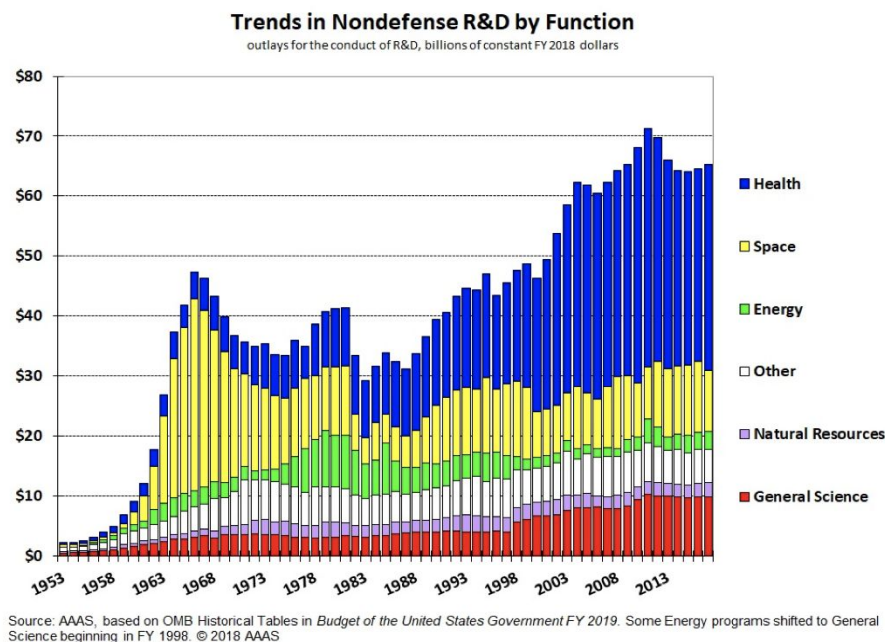


Fig 14.1 Federal funding towards R&D sectors without defense trends.

Source: "Historical Trends in Federal R&D." *American Association for the Advancement of Science*, <https://www.aaas.org/programs/r-d-budget-and-policy/historical-trends-federal-rd>, April 2018. Accessed January 29, 2019.

After the peak of the 1970s, federal energy R&D was cut more than 50% from \$6.64 billion in 1981 to 3.15 billion in 1988. Under the Reagan Administration, the federal energy R&D budget, some funding for basic research was kept, but most support for technology development projects was eliminated (Dooley 9). Reasons for the withdrawal of government involvement were related to a change in philosophy favoring private industry and free markets as the proper determinants of energy advancement. A second factor was a collapse in oil prices in 1986, followed by nearly two decades of cheaper oil, which eliminated the context of urgency that had led to funding increases in the 1970s (See Fig. 14.2). An important new area of R&D, however, was launched in nuclear fusion, in the form of the International Thermonuclear Experimental Reactor program (ITER) by the Reagan Administration.²⁵

As shown in Fig. 14.1, federal support continued to decline in the 1990s and 2000s. Funding priorities shifted away from non-carbon sources and nuclear power in the 1970s to fossil fuel technologies, and energy efficiency, with some attention to new technologies under the second Bush Administration. After the accidents of Three Mile Island and Chernobyl, federal support largely evaporated for nuclear power and nuclear engineering. Starting in the late 1990s, new funding concentrated on coal technologies. Overall, non-defense energy R&D reached a minimum under the Clinton and Bush Administrations (Fig 14.1). This was in spite of

²⁵ ITER is an international nuclear fusion research and engineering mega project to prove the feasibility of fusion as a large-scale and carbon-free source of energy. See *Glossary*.

a declared goal for federal investment to develop commercial technologies that would advance the nation's economic competitiveness (Kammen and Nemet, 84).

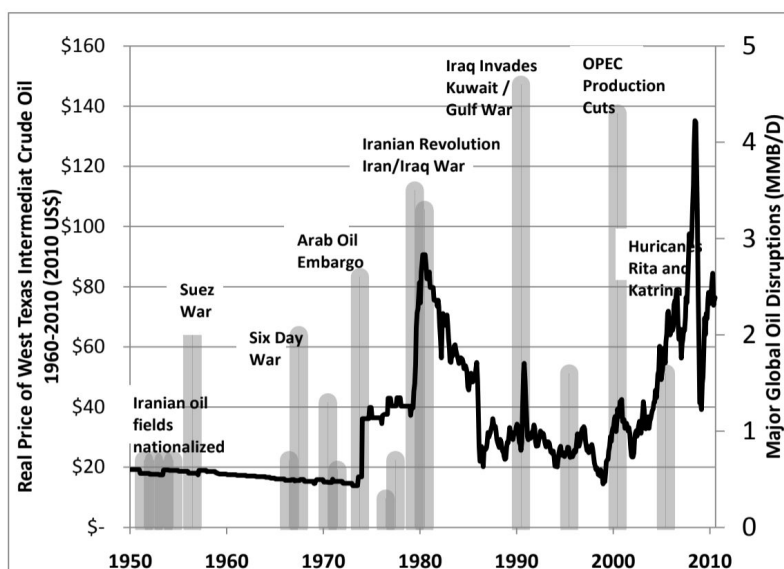


Figure 1 Real Price of U.S. Crude Oil (2010 U.S.\$ per BBL) and Selected Major Disruptions to World Oil Markets (MMB/D)²

Fig. 14.2 The graph indicates events of significance that influenced the real price of crude oil distributions to the world oil markets.

Source: Dooley, James. "The Rise and Decline of U.S. Private Sector Investments in Energy R&D since the Arab Oil Embargo of 1972," *Research Gate*, January 2010. Accessed February 8th, 2019.

Under the Obama Administration, relief programs were implemented to encourage better investment and secure jobs in infrastructure, education, health, and non-carbon energy. The Recovery Act totaled to \$27.2 billion towards energy efficiency and non-carbon energy research and investment. This plan prioritized energy efficiency with the expansion of hydropower and solar power among other non-carbon sources. The Clean Power Plan (CPP) set the nation's first limits on carbon pollution from power plants, the US's largest source of emissions. It intended to create new economic and investment opportunities in developing efficient, non-carbon energy sources. However, these implementations achieved were far below the peak R&D funding attained in 1979. Oil prices were as high as in the 1990s although CPP aimed for stimulating the non-carbon energy sector. The private sector was encouraged to invest in energy R&D during the Obama Administration for a short period that made up for lost activity under Reagan's Administration.

History of Private (non-government) Spending on R&D

Trends for private investment in energy innovation have largely followed those of the federal government for the past 50 years (Fig 14.3). Private sector funding has risen again after several decades following the oil crisis, in response to federal subsidies and tax-credit support

for non-carbon technologies. The National Science Fund (NSF) surveyed US industry support for energy R&D of two large nonprofit energy research organizations, the Electric Power Research Institute and the Gas Research Institute.²⁶ These organizations reached a peak of \$6.7 billion in 1980, in response to the oil crisis. When the collapse of oil prices occurred in the 1980s, liberation of the oil, gas, and electric power industries put substantial pressure on the private sector's support for energy R&D into the 1990s. Eventually investment plummeted to \$1.8 billion in 1999, but inclined to \$3.4 billion in 2005 (Dooley 2010). Hence, the private sector R&D budgets are affected by both government investment and incentives in R&D as well as oil prices. (See fig 14.3).

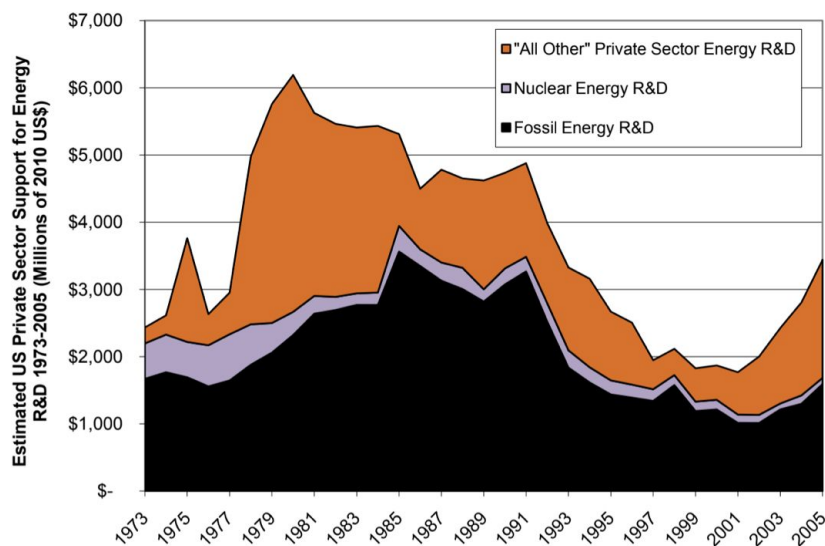


Fig 14.3 Figure represents the private sector specific support for energy R&D in reference to changing oil prices.

Source: Dooley, James. "The Rise and Decline of U.S. Private Sector Investments in Energy R&D since the Arab Oil Embargo of 1972," *Research Gate*, January 2010. Accessed February 8th, 2019.

Private sector investments in energy R&D was devoted to nuclear fission during the 1970s, reaching 20% of overall private investment, in response to a desperate alternate energy source. After new designs developed and deployed at nuclear power plants around the US, the focus of the private sector's investment for nuclear energy R&D diminished to 4%-8% of the overall private sector budget of \$6 billion, to focus on life-extensions technologies for existing nuclear power plants. Fossil fuel investment has a given alignment with oil prices. Diverse energy investment decreased in the 1970s in response to increased oil prices, while technologies of fossil fuels increased in the 1980s and 1990s, due to affordable development

²⁶ National Science Foundation, broad-based US Government survey of industrial R&D expenditures with data of more than 20,000 firms assessed over the period between 1973-2005. See *Historical Trends in Federal R&D* 2019.

and consumption. Since the 1970s, investment has significantly dropped in non-carbon energy technologies, shifting back to amplifying oil. The Major Energy Producers²⁷ finalized exits from solar energy in 1995, when Mobil sold its solar division in 1993 and Amoco spun its solar industry off into a joint project with Enron. Focus on oil and gas industry investment was less rational for others to continue to support energy R&D of non-carbon energy divisions.

New cost-effective technologies were adopted by the Major Energy Producers to increase energy demand. Successful developments include: offshore exploration and production in the Gulf of Mexico, Shell's 1990 half a mile water depth production, 1980s horizontal drilling techniques, CO₂ pipelines in the 1980s, expanding domestic supplies, oil production territory, and hydraulic fracturing. These technologies facilitated easy access and cheap production, creating an even greater gap between oil and all other energy resources. With more profit from the oil industry investments, private sector popularity increased due to economic viability. Private sector R&D core investments became business oriented around refining petroleum and natural gas. The US private sector has dominated fossil energy R&D with domestic oil and gas industries. The correlation of 1970s and 1980s oil price range and private sector investment has been tightly linked. However, the weakening of non-carbon energy development is calling for more investment despite cheap and stable oil prices.

Current Support

The private and public sectors are both attempting to increase their investments in non-carbon energy R&D. The nation's ability to respond to climate change and challenges in energy distribution and innovation is considerably weakened by the lack of long term investment available in expanding non-carbon energy. In 2017, non-carbon funding in the US remained less than the oil and gas industry. However, global energy investment was \$1.8 trillion USD, the highest since the 1970s. Without any subsidies and patents incentivizing energy diversity, there is no drive for energy innovation. Currently the House and Senate appropriation committees have requested greater funds for energy than what is allocated currently. The increase of 2017-2018 national energy budget has only been 2%, with the exception of the nuclear division. Fossil energy budget increases in 2017-2018 were 0.8% and larger than all other budget sectors for other energy subdivisions. Technology expenditure increased to \$740 million towards fossil fuel R&D such as CCS, unconventional oil and gas development.

The final budget for 2018 for efficiency and non-carbon is \$2,379 million, which was \$1.7 billion above the request. Funding for non-carbon technologies have a 4.3% increase in hydro technology and a 4.9% increase in Advanced Manufacturing Office (AMO).²⁸ Research and

²⁷Major Energy Producers: Influential US private sector companies producing and investing in energy, primarily in the oil and gas industry. Such as: Mobil, NextEra, Duke Energy, Dominion Resources, The Southern Company, etc. See *The Rise and Decline of U.S. Private Sector Investments in Energy R&D since the Arab Oil Embargo of 1972* 8.

²⁸ Advanced Manufacturing Office (AMO) supports R&D projects and technical partnerships with national laboratories, companies (for-profit and not-for profit), governments, and universities through funding opportunities to investigate new manufacturing technologies.

materials for advanced wind technology doubled by \$30 million with a \$20 million office-wide cybersecurity effort to protect the limited resources received from wind and hydro energy. Hopefully, efforts in energy efficiency and non-carbon energy will remain high due to depleting interest in the House's request. Nuclear energy budget has increased \$121 million from 2018, \$69 million above the request, totalling at \$1,326. However, funding of Fusion Energy Sciences decreased by \$192 million (36.1%), including a \$75 million decrease in contribution to ITER. Although increases are staggering to benefit non-carbon energy R&D, these rates still fall far behind average R&D within other public divisions of funding.

The private sector plays a dominant role in commercializing new technologies, however there are gaps in the innovation process because of diminished incentives. The government relied on the private sector in the 1980s to find more success investing in energy resources, however, without a push from the government, the private sector found no significance in investing in a market without competition and little reward. The federal government is attempting to spend more on energy efficiency and non-carbons, yet the private sector is spending more in oil, gas, networks and utilities sectors, and developing new production technologies (Fig 14.3). Fossil energy expenditures represent above half the cumulative private sector investment represented, while nuclear holds barely any reserve and other sources hold less.²⁹

Major drivers of energy R&D are: valuable patents, growing demand and technical viability. The declining interest in sponsored technological development and marketable products is unsurprisingly cutting into innovation potential in private energy industries. Trends in patenting developments in the industry reveal a strong correlation between capital and the rate of innovation in the fossil fuel sector, regardless of federal funding decreasing overall. However, a strong correlation exists between public investments, innovation, competition and market success (See fig. 14.4).

²⁹ FY 2019 R&D Appropriations Dashboard, 2019.

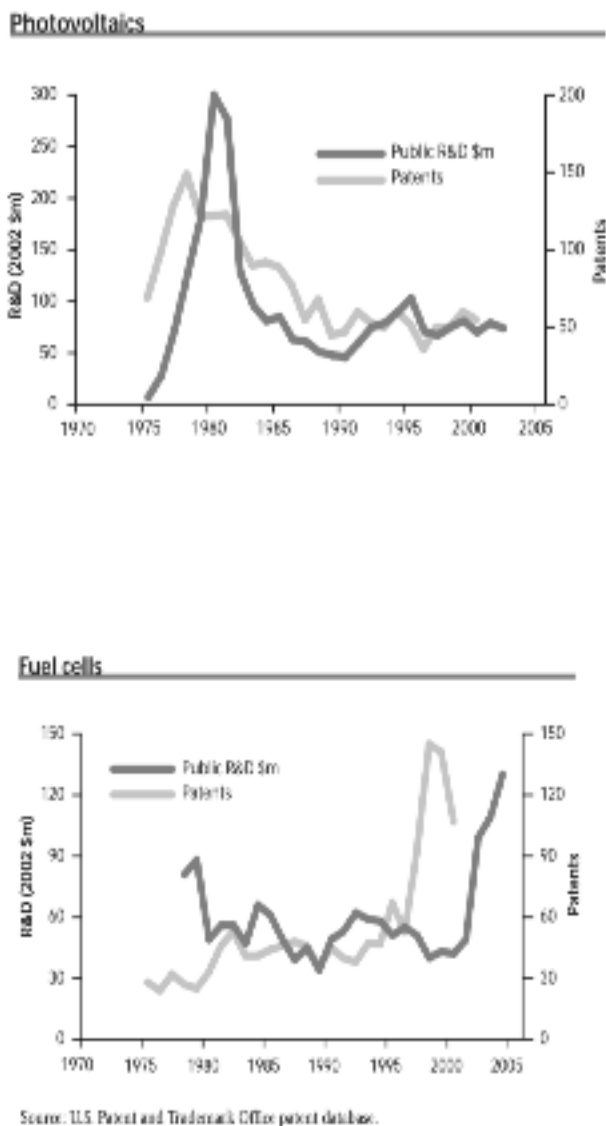


Fig 14.4 Comparison of trends in federal support and patents granted for two energy technologies.

Source: Kammen, Daniel and Gregory Nemet. "Reversing the Incredible Shrinking Energy R&D Budget," *Real Numbers*. Pp. 84-88. *Issues of Science and Technology*, 2005. Accessed January 25, 2019.

Changing Priorities

In 2018, caps on government spending increased significantly to boost funding for applied R&D programs. This trend has continued into 2019. While Trump's budget request is significantly lower than the budget enacted in 2018, the House and Senate both leveled out the

decision with increased funding. Slight increases are comparable to the prior fiscal year and show little growth. There is incredible economic opportunity in the \$6 trillion global energy market as energy demand is projected to grow extensively in the next several decades. This opportunity could improve the US economy in profound ways, however, the US's competency and leadership in the growing market is lacking in the rapidly evolving technological sector. The U.S., as a pioneer, experienced great economic growth from the technological boom of the 20th century and the current administration will benefit similarly if energy priorities are reconfigured.

Global competitors in Europe and Asia are investing heavily in development to build their economies. South Korea's science and technology sectors have grown faster and stronger than any other country in the past 30 years. Japan has been increasingly investing in non-carbon energy resources, advancing in energy innovation in solar power, hydrogen research and maintains the largest nuclear energy R&D budget. European nations such as Germany, Finland, Sweden and Denmark reinvest greater percentages of GDP into energy R&D compared to the US, diminishing US presence in key global markets. At current rates of development and funding, China will exceed the US in total R&D funding by 2022. The US contains large technology and energy companies with necessary skills to contribute to innovation and growth, however these skills need to be appropriately nurtured and invested in, to further the energy R&D industry.

Japan had the largest share of public energy R&D in its total R&D budget in 2017 of just over 12%. The US has the largest public R&D among the International Energy Agency (IEA) countries, but energy R&D makes up as little as 2% of it. Other IEA member countries show relatively large shares of energy efficiency and non-carbon investments. The US low-carbon energy R&D budgets grew by 11% in 2017 from the previous year, amounting to an additional \$700 million USD. However, Canada's low-carbon energy R&D budgets grew by 55% amounting to \$240 million USD, the second-highest increase among IEA countries in 2017. It is important for the US to remain a global influencer to represent our national priorities as well as lead the global market of innovative technologies.

Our national spending declares the priorities of the US. Funding for R&D is largely concentrated among a few departments, such as in FY2017, eight federal agencies received 96.3% of funding, with Department of Defense holding 29.3% and Department of Health and Human Services with 27.3%, holding two-thirds of all federal R&D funding. Currently in the pharmaceutical industry, drug companies are investing ten times as much R&D as energy companies. The total private sector energy R&D is less than the R&D budget of individual biotech companies such as Amgen and Genentech. The pharmaceutical industry maintains a strong foundation of a mix of private and public sources with budget allocations, research grants, publicly-owned research institutions and funding of higher education institutions. The US in 2014 reported \$56.6 billion USD from businesses while the government R&D expenditures were \$33.5 billion USD. The US military is another example of priority federal spending on R&D. Since the 1960s, defense R&D has continuously made up over half of the total R&D provided by US support. Trump has increased the defense budget to \$686 billion in FY 2019: The Fig. 14.1

captures the non-defense spending recorded, while defense holds similar total of all non-defense R&D in total.

The lack of attention to long-term energy investment in the US has affected response to climate change concerns and economic consequences of distributions in energy. Energy resource use will continue to implement health effects and livelihood in the future of the US. Climate change and pollution will eventually take a toll on the health industry as recovery is needed if energy non-carbon sources are not created. The impact of pharmaceutical lobbying in congress and direct campaign contributions to legislators through Political Action Committees (PAC)³⁰ has taken funding away from energy R&D. Prioritize need to be set straight in order to allow energy R&D to develop and become economically successful.

There is gap in the provision of incentives to innovative startup companies seeking to bring clean energy hardware to the market. This is a critical stage for energy innovation as private energy R&D has a large impact on commercializing technology. Government intervention is necessary in order to drive private and public energy R&D to create advanced discoveries. The government needs to introduce large incentives for start-ups as well as large corporations to tolerate risks with their research development. Without correction, it will be rare for new investments and technologies to take a leap of faith in a dying marketing.

The energy research budget should be increased to allow improvements in energy efficiency and innovation in the private and public sector. Governments can create patents and record existing funding to address key research gaps and focus on commercial potential. Pharmaceutical and software industries typically invest 5-15% of revenues to R&D investments, while the energy industry leaves R&D investment below the average of 2.6% of all US industries. The IEA will continue to lead the way with its efforts to compile and disseminate reliable energy R&D statistics and the US should take advantage of those resources. The economic stimulation of improving private and public sector energy strategy would transform markets by expanding capitalization opportunities and improve emerging non-carbon energy technologies. The economic outcome would stimulate the market by creating jobs, and building a more sustainable non-carbon to economic growth.

Conclusion

The oil crisis allowed for the US to recognize that non-carbon energy source development is possible with increased public and private funding. The US needs to increase public energy R&D funding to improve the energy market with innovation of private industries. Since the 1970s, private sector investment has diminished due to cheap oil as a focus of capital interest. The government created the opportunity for the private sector to grow and accomplish more successful innovations, however, the withdrawal of federal funding was reciprocated in the private sector. The private sector focused on fossil fuel funding after concluding that oil prices would remain cheap. The oil industry was cheap and profitable so, economically, it was

³⁰ Political Action Committee (PAC) is an organization that pools campaign contributions from industries and donates funds to campaigns for or against candidates or legislation. See *Historical Trends in Federal R&D* 2019)

more profitable for the private industries to reevaluate their funding. The government trusted that their decline in investment would allow focus on private industries investment success and encourage free market. Ultimately, the market diminished due to less investment to development in alternative energy resources due to cheap oil. Oil companies were able to prosper with profound amounts of oil and increased investment so oil industries also drew the attention of government investment. The US together spends less investment as a percentage of GDP in federal and private sectors together compared to other developed countries. It is important for the US to stay in the energy resource development market in order for the US to have influence on the global market and process of innovation.

This summary of trends in federal funding for energy R&D highlights several major conclusions:

- Federal sector declined non-carbon energy investment during the 1980s due to theory that private sector is more successful independently in the free market.
- Private sector investment in non-carbon technologies has diminished due to cheap oil.
- Federal support through a combination of policies and incentives is necessary to stimulate private sector energy investment.
- The US spends less in investment, as a percentage of GDP, in both federal and private sectors compared to other developed countries.

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Fifteen

Policy Instruments for Energy Change: Review

Challenges and Outlooks for Change

Jenne Lawrence

Introduction

Since World War II, the United States has enacted a wide range of energy policies whose success has been varied. These policies have tended to be more reactive and proactive, responding to real or perceived crises and circumstances impacting the nation's energy security. Now, however, the country faces a new context for its energy policy decisions, one defined by the seemingly opposite influences of climate change on the one hand, with its demand for reducing emissions, and, on the other hand, a vast expansion in oil and gas production. Given this new context, it is valuable to review some of the most notable energy policies of the past at both the federal and state level. A main goal of this study is to determine their relative successes and failures and thus applicability to the present and future. Such evaluation can only help guide informed policy recommendations for future administrations.

The 1970s: A Decade of Change

US energy policies have typically responded to significant changes and challenges. The 1970s was a period of tremendous change, due primarily to oil crises. The series of events that unfolded at this time would shatter America's deceptions surrounding our energy reality indefinitely, propelling it into action. It was here that the United States realized its need to redefine its relationship with fossil fuels, reduce its dependence on foreign nations, and search for alternative sources of energy (solar, wind, nuclear, etc.). Subsequent decades and administrations would be driven by two concerns: energy security and, eventually, climate change. With these ideas in mind, the country would develop national and statewide initiatives to ensure our access to reliable energy sources and mitigate the destructive effects of greenhouse gas emissions.

On October 16, 1973, the Arab members of the Organization of the Petroleum Exporting Countries (OPEC) made the dreaded announcement that they would be raising the price of oil by 70 cents per barrel, in addition to placing an embargo on exported oil to the United States. Moreover, they planned on reducing their overall production of oil by 5% from September's levels, and continuing to slash their output in 5% increments until the organization's political and economic aims were met. This was in large part a response to the United States' choice to become involved in the Yom Kippur War, where they supported Israel with substantial military aid (IER).

At the time, net imports of petroleum accounted for 35% of US petroleum consumption, a generous amount. The embargo, in addition to reduced production, resulted in an unstable market that made prices soar. Within the span of a few months, the cost of oil increased from \$3/barrel to \$12/barrel by January 1974 (IER). The primary concern that this event revealed was a major deficiency in our ability to control our energy supply, namely our imports. In an attempt to gain back some of this control and prevent the price of gasoline from skyrocketing for American motorists, former President Richard Nixon intervened in the economy by introducing price controls on oil and gas (IER). Psychologically, a set price for oil was reassuring when the market was so unpredictable, and costs were high. However, people soon realized how disastrous the repercussions would be. A large concern for the US was that it was a significant importer of oil and gas. In practice, because of domestic price controls, while the price for consumers remained low, importing refiners had to still pay the world price, which was high (Murphy). They could not afford to keep up with the growing demand for transport of fuel. Hence, a shortage ensued. Additionally, there was a spike in the black-market sale of oil. Use of petroleum being large in other sectors besides transportation, the global rise in oil prices had a negative impact on the U.S. economy as a whole.

The damage was exacerbated by the existing energy policy of price controls on fuels, especially gasoline. By keeping prices artificially low, below their market value, the policy had produced three major results that significantly increased the impact of the oil crisis. It decreased peoples' incentive to conserve, suppressed any motive for improving fuel economy by vehicle manufacturers, and it weakened any incentive for developing or marketing alternative sources of energy (Graetz, 34). As the policy did not change even after the crisis, adding to a second oil crisis in 1978, related to the Iranian Revolution, a confused situation of mixed signals regarding energy use came to exist. "Congress endeavored to keep oil and gas prices low to benefit energy consumers, while presidents and environmental organizations exhorted citizens to use less" (Graetz, 34). Overall, price controls were a poorly conceived government intervention in the economy that had detrimental effects on the American people. Although the rationale behind their involvement seemed sound at first, supported by existing economic ideas, it proved wrong and damaging. The key lesson that large-scale subsidizing of energy consumption makes a nation more vulnerable to crises and works against energy security was not quickly learned. Only with a major change in economic thinking, introduced by the Reagan Administration in 1981, were price controls eliminated. Future administrations were wise to learn from this.

The Reagan Administration: 1981-1989

Ronald Reagan had a very different approach to addressing our energy needs. Contrary to previous administrations, which emphasized government-based solutions, Reagan was a strong advocate for the free-market and private enterprise. He believed that the market would ultimately determine the nation's energy mix and sort out challenges, driving innovation progress. Among other things, this meant "...decontrolling of oil and gas, opening up public lands for exploration and reducing burdensome environmental standards" (Katz, 137). Notably he provided tax benefits for those tied to the fossil fuel industry, while severely cutting funding for renewable energy. In fact, efforts to incentivize conservation fell from \$799 million in

1980 to \$189 million in 1984. He continued this trend with attempts to do away with the Department of Energy, though he ultimately failed. He did however manage to diminish their responsibilities, staffs and budgets. He also significantly reduced spending on synfuels (Katz, 143). Unavoidably, his philosophy was met by several opponents, namely the environmental community and conservationists as well as liberal democrats. This shift in thinking would have a lasting impact for decades to come, as investment in energy R&D would remain low well into the 21st century, slowing down the advancement of renewable energy.

Securing Our Energy Supply

Following the initial shock of the early 1970s, government policy turned much of its attention towards securing our energy supply. The mantra of subsequent administrations became “Safeguarding America’s energy”, “Independence from foreign oil”, and, “Achieving energy self-reliance”. Notable policies that came into effect at this time include the 1975 Energy Policy and Conservation Act and the 1977 Department of Energy Organization Act. Continuing in line with this trend was the establishment of the Trans-Alaskan oil pipeline in 1975.

The Energy Policy and Conservation Act: 1975

The Energy Policy and Conservation Act of 1975 (EPCA) sought to “increase domestic energy supplies and availability; to restrain energy demand; [and] to prepare for energy emergencies”, among other things (94th United States Congress). One of its most noteworthy resolutions was the establishment of the Strategic Petroleum Reserve (SPR), a 727 million-barrel-capacity complex of four underground storage caverns, located along the Texas and Louisiana Gulf Coasts. It is the largest emergency supply in the world and acts as a buffer in case of future disruptions to our energy supply (CNN, 2019). There are three reasons to withdraw oil from the reserve, including (1) a large-scale drawdown due to a severe energy disruption, over 30 million barrels; (2) a limited drawdown, up to 30 million barrels; and (3) a drawdown for test sale or exchange, up to 5 million barrels (Lantero, 2015). Among its many advantages, the SPR protects the economy by mitigating price increases and allows diplomatic flexibility, enhancing foreign policy. In practice this means that “in a major energy disruption, the president will not be forced into an immediate choice between military intervention, foreign policy concessions, harsh demand restraint measures, or severe damage to the U.S. economy” (Beaubouef, 221). Remarkably, the policy takes a passive approach to manipulating the economy by allowing the market to do much of the work. In times of need, the government will withdraw a given amount from the reserve, then allow supply and demand to take over, resulting in an overall calming effect (Beaubouef, 220).

Over the course of its existence, the United States has only released deposits a handful of times, including during Operation Desert Storm in 1991, when it led a coalition of military personnel to intervene in Saddam Hussein’s occupation of Kuwait, thus initiating the Persian Gulf War. At the time, the government approved the release of 33.75 million barrels to alleviate the expected damage. Throughout of the conflict, world oil markets remained amazingly calm, arguably much thanks to the SPR. Energy secretary James Watkins remarked, “We have sent an important message to the American people that their \$20 billion investment in an emergency

supply of crude oil has produced a system that can respond rapidly and effectively to the threat of an energy disruption” (“History of SPR Releases”). The SPR has been criticized for a few reasons. Some say that it is no longer needed, as the oil market has changed considerably over the last several decades. Others say it doesn’t respond fast enough in crisis situations, taking two to three weeks to complete the process. And still others say it does not have the capacity to truly have an impact on world markets, being only able to provide 4.3 million barrels per day, when U.S. and world petroleum consumption levels are 19.96 and nearly 100 million barrels per day, respectively (Beaubouef, 230).

Though these statements are not false, they miss some important points. Yes, the market for oil has changed. The United States is producing more than ever before, technology has improved, and there are an increasing number of non-OPEC countries producing oil, allowing for more variety and flexibility. However, one must also consider economic expansion, low energy prices, and the transportation needs of a growing country that each contribute to a high demand for oil. Petroleum literally drives our country, and in the event that our access to it were to be compromised, the country would suffer greatly. As for the arguments that there is not enough oil to have a meaningful impact, and that the response time is too slow, these opinions are misguided. First, policymakers have never assumed that the country would completely run out of our crude oil supply. It would only need enough to supplement a loss. Second, the market for energy depends on much more than just numbers. Rather, it has everything to do with psychology. People are driven by “expectations, fears, hopes, and beliefs about the future availability of oil”. The mere announcement of a drawdown can have a much greater influence than the oil itself (Beaubouef, 237). The bottom line is that the Strategic Petroleum Reserve is a critical addition to our energy policy. It provides security in the face of uncertainty and keeps government intervention at arm’s length. The consequence of not having it could have detrimental effects on our economy and ultimately our ability to effectively conduct foreign policy.

The Department of Energy Organization Act: 1977

In 1977, under the Carter administration, the Department of Energy Organization Act was implemented. This act established the Department of Energy (DOE) as a cabinet-level organization and, notably, lead way to the Eastern Gas Shales Project (EGSP), which proved to have a substantial impact on our current natural gas boom. Between 1976 and 1992, the EGSP set out to explore the potential of the Western Appalachian Basin, where roughly 40 percent of its comprised 160,000 square miles is inhibited by Devonian shale gas deposits. Although the presence of these deposits has been known for over a century, since the late 1800s, it was not until very recently that ways of extracting it in lucrative quantities were discovered. Namely, a result of government R&D and investment in new drilling technologies (U.S. Dept. of the Interior).

Hydraulic fracturing is not a new process but was first developed in the 1940s. When it was initially conceived, gas companies would drill *vertically* into the Earth and pump highly pressurized water into the ground in order to remove the gas. While effective, it did not generate

nearly as much gas as it does at present. With the efforts of the EGSP, extraction was done by combining fracking with *horizontal* drilling, allowing companies to go even further, reaching the natural resource at an unprecedented depth. According to the Earth Institute at Columbia University, this method could “descend down to 10,000 feet, then curve to drill horizontally thousands of more feet...”, resulting in a productivity increase of 3-5 times the average of vertical drilling (Cho, 2014).

Despite the obvious advantage of solidifying our energy security, there are numerous issues with shale gas extraction. Namely, damage to local clean water supplies, the endangerment of infrastructure and communities, the possibility to chemical leaks, and declining air quality due to the release of harmful compounds. These concerns will need to be fully considered in our energy future. Today, the United States is able to realize the full potential of its natural gas reservoirs, much thanks to the government-funded research and development of the 1970s. The EIA’s 2018 Annual Energy Outlook projects a substantial rise in our production over the course of the next several decades and expects a 59% increase between 2017 and 2050. According to the report, the nation will grow from producing 73.6 billion cubic feet per day (Bcf/d) to 118 Bcf/d (U.S. Energy Information Administration).

The Trans-Alaskan Oil Pipeline: 1773

The Trans-Alaskan oil pipeline (TAPS) was constructed with energy security and independence in mind. It was approved by Congress on November 13, 1973, just under a month after OPEC announced its embargo against the United States, and production began in 1975. While the oil reserves were discovered years earlier, in 1968, it wasn’t the energy crisis that the project was able to be approved and move forward, despite objections from natives and conservationists. The pipeline connects the oil fields of Prudhoe Bay in northern Alaska to the harbor at Valdez, covering an expanse of 800 miles, and carries an average of 1.8 million barrels per day to the lower 48 states (Ray 2014). The impact of the pipeline is wide and varied. According to research conducted by the Heritage Foundation, a conservative think in Washington D.C., TAPS is a critical appendage of the United States economy, supplying thousands of American jobs, increasing revenue, and securing our energy supply. They reported in 2014 that the pipeline had transported nearly 17 billion barrels of oil over its 37-year lifetime, accounting for 20 percent of U.S. domestic energy production between 1980 and 2000. Currently, it carries an estimated 500,000 barrels every day, though that number has been in steady decline for the past several decades, as supply decreases. At its peak production, its output was 2.1 million barrels/day. Now, that number is closer to 10 percent. In terms of employment, 127,000 jobs in Alaska are related to the oil industry today, while 60,000 additional jobs have been created as a result of the “broad economic benefits” the pipeline has brought. Family incomes and state revenue have also experienced substantial growth (Griffith, 2014). This side of the debate tends to downplay the environmental effects and emphasize the economic and energy security aspects.

Conversely, there are those who recognize the dangers of the pipeline. Notably, the Exxon Valdez oil spill in March of 1989, which spilled between 260,000 and 750,000 barrels –

equivalent to 11 million gallons – of crude oil into Prince William Sound. It was the second largest oil-spill in the history of the United States, covering 1,300 miles of coastline and 11,000 square miles of ocean (Alaskan Center official). The spill had a detrimental impact on the wilderness, killing an estimated 250,000 sea birds, 3,000 otters, 300 seals, 250 bald eagles and 22 killer whales. There has also been additional economic loss, as many of the local towns in the surrounding area suffered. Certain projections have guessed the spill cost the economy \$2.8 billion, as salmon and herring, once an abundant source of revenue for fisherman, never fully recovered, ultimately causing bankruptcy for those dependent on their prosperity (“Exxon Valdez Oil Spill”). Moreover, between 1980 and 2010, there have been an additional 1,219 spills with varying magnitudes spread across three separate oil fields along the pipeline. (Robertson, 2013). There is currently discussion about the future of the pipeline and what may happen if the supply continues to run low. As the volume of oil decreases, the number of technical problems, including the buildup of ice and paraffin wax (found naturally in crude oil), increases. One of the proposed solutions is to open drilling in the Arctic National Wildlife Refuge (ANWR) and the neighboring National Petroleum Reserve-Alaska (NPR) located in northeastern Alaska. This would force new oil through the pipeline, thereby reducing blockages (Wight, 2017). However, this is much easier said than done. ANWR has a considerable history that cannot easily be overlooked.

Environmentalists and others alike are concerned about the definitive consequences of drilling in the country’s largest national wildlife refuge, which contains an expansive variety of plants and animals, including polar bears, caribou, wolves, eagles, and migratory birds (ANWR.org). In a recent national survey conducted by the Yale Program on Climate Change Communication, a large majority of American voters (70%), including democrats and republicans, opposed drilling in ANWR (Leiserowitz, et al., 2017). Nevertheless, the current administration continues to work towards drilling. As of now, the move is more a political statement than anything else, as the country has recently become a major exporter of oil. Obtaining the right to extract the resource will set a dangerous precedent for future energy endeavors and ultimately act as a “win” over the environmental community. TAPS came in response to an uncertain time in our energy past. It provided a domestic source of oil when the country feared dependence on foreign nations, ultimately creating a sense of stability. Still, there are environmental repercussions that it has failed to avoid and holds the potential to wreak further damage, in cases such as ANWR.

Much as the 1970s challenged the government and American people in many ways, it also opened up important dialogue on a central aspect of our economy, our national security, the environment, and our prosperity and welfare at large. We came to realize how precarious our energy reality could be and took steps to mitigate any potential future crises. We are now better prepared to deal with supply disturbances and understand what works and does not work. However, we have also learned how energy security may at times compromise our relationship with the environment. Policies of the 2000s would be driven by this dilemma and consider it to a whole new degree, turning attention towards climate change and the need to reduce greenhouse gas emissions, especially carbon.

The Energy Policy Act: 2005

The Energy Policy Act of 2005 “sets forth an energy research and development program covering: (1) energy efficiency; (2) renewable energy; (3) oil and gas; (4) coal; (5) Indian energy; (6) nuclear matters and security; (7) vehicles and motor fuels, including ethanol; (8) hydrogen; (9) electricity; (10) energy tax incentives; (11) hydropower and geothermal energy; and (12) climate change technology” (109th Congress). In short, it is a law that addresses our growing energy needs while considering the ramifications of greenhouse gases and climate change. It accomplishes this using several methods, such as offering tax benefits to those who increase their energy efficiency. One example is the Energy Efficient Commercial Buildings Tax Deduction, aimed at creating incentive for people to invest in more efficient building systems. Though this offer expired in 2013, it deducted \$.60/square foot for lighting, HVAC, and Envelope, or \$1.80/square foot for an entire building (archive.org). Tax credits are also awarded to individuals who invest in their own efficiency, whether it be through home improvements or switching towards hybrids or other forms of alternative transportation (Congress.gov).

Critics are wary of certain aspects of the bill, including its exemption of fluids used in hydraulic fracturing from protections under the Clean Air Act, Clean Water Act, and Safe Drinking Water Act. Additionally, it subsidizes the fossil fuel industry and lacks measures that promote conservation. Nevertheless, the plan is a demonstration of our increased awareness and urgency when it comes to climate change and makes the effort to explore ways of reducing our impact on the environment through incentive-based measures.

The Clean Power Plan: 2015

The Clean Power Plan, a cornerstone of the Obama Administration’s energy policy, was announced on August 3, 2015 in conjunction with the EPA. Its aim was to reduce carbon emissions produced from power plants in order to combat climate change by 32% from 2005 levels by 2030 (Office of the Press Secretary, 2015). Among other things, the Plan acknowledged the role that fossil fuels will inevitably play in our energy future but emphasized the need to produce them more cleanly and efficiently. This would ultimately be achieved by meeting unique energy goals, something each state would have considerable leeway over. However, it really discouraged the use of coal plants while supporting alternatives like natural gas, wind, and solar energy. Notably, it was the product of years of unprecedented outreach and public engagement (EPA, 2017).

Ultimately, it has failed to ever go into effect. Despite its ambitions, the policy was strongly challenged in court and at the executive level. Most recently, current President Donald Trump released an executive order in March 2017, instructing the suspension, revision, and rescinding of the Clean Power Plan, among other things. He is also a known advocate of coal and energy independence. His administration is not the only opponent to the Plan, however. Shortly after its release, more than two dozen states, alongside industry representatives and others, charged the EPA for going beyond what the law would allow (“What Is the Clean Power Plan and How Can Trump Repeal It?”). For example, the Plan would inevitably threaten those

who heavily depend on the coal industry, including Wyoming, the nation's leading coal-producing state (Davenport 2016). It would also come at a substantial upfront cost, costing the country an estimated \$33 billion by 2030 (EPA 2017). In 2016, the Supreme Court blocked it from moving forward. Evidently it requires some modifications before it is ready to be accepted by the American public. The Trump administration has recognized this to a degree, but their idea of a replacement is relatively modest in comparison to the original Clean Power Plan. Instead of widespread systemic change, the EPA's most recent proposal, under the direction of Andrew Wheeler, would regulate the emissions of individual coal plants, making uncertain improvements to overall emissions (Friedman and Plumer 2018).

The reality is that carbon-emitting coal and oil are the source of a significant portion of U.S. energy. Coal specifically is the cheapest and most abundant natural resource that the United States has. It provides the country with energy and job security, despite the effects it has on air quality, health, and the climate. Unfortunately, the transition to lower-emitting fuels (natural gas) and zero-emitting fuels (sun, wind, nuclear) outlined in the CPP proved to be much too drastic in the given period of time—at least for some. An updated version of the plan should implement similar goals as the first, but perhaps at a more gradual rate. Moreover, it must emphasize the improved efficiency of existing carbon-emitting plants. As the leading contributor of greenhouse gas emissions in the United States, carbon must be maintained at a level that mitigates the effects of climate change and provides a sustainable environment for future generations. The Obama administration's solution, while comprehensive, was too radical a change for many to accept. It also threatened anyone associated with the fossil fuel industry. As such, it is crucial that it provide a substantial transition period, while increasing focus on the improved efficiency of current carbon-producing generators.

Energy Efficiency Mandates

An important step towards achieving our national energy goals is the adoption of statewide energy efficiency policies. According to the EIA, as of 2017, there are 6 states with energy efficiency goals or pilot programs, 24 states + DC with energy efficiency resource standards (EERS), and 7 states that have adopted or extended policies since 2016. The intent of these policies has been to “lower the growth of electricity consumption by using electricity more efficiently” (EIA). Energy efficiency resource standards “establish specific, long-term targets for energy savings that utilities or non-utility program administrators must meet through customer energy efficiency programs”. They are implemented through legislation or regulation and can be applied to both gas and natural gas utilities. Though similar to renewable energy standards (RES) and renewable portfolio standards (RPS), EERS differs in a few ways. Whereas RES focuses on electric utilities generating a specified percentage of their electricity from renewables EERS hopes to gain energy savings from energy efficiency measures (ACEEE). Additionally, EERS usually increases over time (EIA). An example of an energy efficiency program is the Appliance and Equipment Standards Program. This program was initially established in conjunction with the Energy Policy and Conservation Act of 1975 and has been regularly updated since then. As reported by the Environmental and Energy Study Institute, more than 40 percent of the total energy consumed in the United States goes towards

building operations, much of which is the result of appliances and building-related equipment (Hampton). Under this program, the DOE is required to “periodically review standards and test procedures for more than 60 products, representing about 90% of home energy use, 60% of commercial building energy use, and 30% of industrial energy use” (Department of Energy).

The benefits are far and wide-reaching, saving billions at the national level. The Department of Energy expects these standards to produce utility bill savings of %1 trillion by 2020 and more than \$2 trillion by 2030 for consumers. Since 1990, home appliances have gained a significant amount of efficiency, with new clothes washers that use 70% less energy, dishwashers using more than 40% less energy, air conditioners using more than 50% less energy, and furnaces using roughly 10% less energy. Notably, this efficiency translates to about \$321 in savings each year for households, and \$59 annually for those who regularly update their appliances (DOE). All in all, fewer natural and financial resources are wasted when efficiency is improved. When states adopt EERS, they are investing into their own economies and environmental well-being.

Carbon Prices: Emissions Trading and Taxes

As was mentioned in previous sections, carbon remains a central contributor to climate change. Two ways that the United States may be able to mitigate its impact is with carbon pricing policies, like cap-and-trade and carbon taxes. Particularly in the electricity and transportation sectors, as together these make up 60% of greenhouse gas emissions in the country (Kaufman 7). Although different in some respects, they share several basic similarities that ultimately work towards reducing emissions. Under cap-and-trade, affected sources, such as power plants, are allotted a certain amount of pollution that they may emit. It is then up to them how they use that allowance, whether they want to allocate it towards compliance, trade it on the market, or save it for future compliance. Compliance may be met in a variety of ways, allowing a great deal of flexibility. For instance, a carbon-emitting producer may install pollution control technology, replace pollution controls with more advanced technologies, switch to fuels that emit less pollution, or shift production to lower emitting or more efficient units (EPA).

In 2013, California set out to create its own emissions trading program in a push to reduce their greenhouse gas emissions. Specifically, their goal was to lower their emissions by more than 16% between 2013 and 2020, and an additional 40% by 2030. Those affected by the initiative include large electric power plants, large industrial plants, and fuels distributors (“California Cap and Trade”). As of 2015, the state was on track to meet their initial target for 2020. However, they still have a long way to go before achieving their ultimate goal. It will require much more ambitious reductions, including the sale of additional permits and further investment in R&D that promotes less carbon-intensive technologies. (Hausfather, 2017 and Kaufman, 23). This method has proven to work at a national and regional level, the European Union being the largest emissions trading scheme in operation (“Emissions Trading”). California has also shown promise and could potentially provide a blueprint for other states to follow. Still, there are many who believe that emissions trading is not enough, and that it lacks the ability to transform the country’s energy consumption. For one, people don’t have much of an incentive to

reduce their emissions below the level allowed by the cap. Moreover, it appears that paying to pollute in many cases is actually cheaper than installing and updating all new equipment. During the Obama administration's first year, its proposed budget expected credits would trade for roughly \$14 per ton of greenhouse gas. Put in more tangible terms, that is equivalent to raising the price of gasoline about another dime per gallon, hardly enough to shock anyone (Victor).

Taxes, on the other hand, could be more effective at incentivizing individuals and companies to use less by directly establishing a price on CO₂ emissions. The challenge is overcoming public perception and political barriers. This was evident in Washington state's recent carbon tax proposal. Initiative 1631 called for \$1 billion annual fees by 2023, setting the price at \$15 per ton of carbon pollution. Part of the problem was that many of the largest polluters would have been exempt from the tax, while the greatest burden fell on Washington families (Rainey, 2018). Opponents have voiced that the 15-member panel, appointed by the governor, would have far too much power. They would be handling billions of dollars, with no specific plan in place for how that money would be spent (Burnton). Cap-and-trade and carbon fees are two viable options for reaching our emissions reductions goals. Both come with obvious benefits and drawbacks. Deciding which to use may be up to individual states to decide, though a national carbon policy would ultimately create the most significant impact in the long run. Introduced gradually over time, both have the potential to spur the development of low-carbon technologies, encouraging people to move towards other sources of energy.

Conclusion

Over the course of the last several decades, we have witnessed tremendous change across our energy landscape and realized the scope of our impact on the environment. As the world's largest economic and technological superpower, the United States has the capacity and therefore the obligation to deal with the threat to our climate, despite our close relationship to oil and gas. Obviously, there is much to consider in the development of future policy. Geopolitical and environmental factors, individual well-being, the economy, and so on. It is the intention of this research to help sort out some of these components and guide potential policy recommendations. Summarized below are a few of the key takeaways from this brief history of our energy policy.

- Energy security and climate change are the two most influential forces that determine energy policy.
- Carbon-emitting fuels are not going away in the near future.
- The key will be to improve the fossil-fuel industry by making it as efficient as possible.
- Government involvement in the economy is something that is necessary but should be limited to a degree.
- Throughout history, Americans have never been asked to pay the market price for oil. Our government has always brought it down to artificially low numbers, ultimately decreasing our incentive to use less or make substantial investment in other non-carbon-emitting fuels.
- Progress will be made through the collaboration of national and state-wide policies

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Sixteen

Public Awareness and Education *Government Support to Educate the Public* Yookyeong (Jenny) Do

Introduction

A well-informed public tends to demand policies that better serve their actual needs and reduce or eliminate those that are detrimental in significant ways. This has been shown repeatedly with environmental protection, for example, strong movement in favor of clean air and water laws during the 1960s and early 70s resulted in efficacious measures (the Clean Air Act and Clean Water Act) that have significantly improved the health of U.S. citizens. Today, children in school learn basic facts about pollution, and the environment. Some part of this has been aided by government information campaigns and funding for relevant research. Public perception is a crucial force, therefore, to drive policy making, energy efficiency and climate concerns. The current administration seeks to significantly weaken environmental protections to facilitate the reach of free market capitalism. As such, public perception can be a double-edged sword. When people are informed as to their better interest, they can have positive influence in the halls of policy decisions. In contrary, when people are not adequately informed, they can pose a negative impact on policy making. This paper will first discuss the importance of public awareness and education in energy, analyze the current trends and finish by examining ways to raise public awareness.

The Importance of Public Awareness and Education in Energy

Public understanding of energy realities remains woefully inadequate. Energy issues are inextricably linked to climate concerns such as clean air and water that are most immediately felt by the public. Yet, widespread misconceptions that have affected energy policy making in recent decades. One of the biggest public misconceptions lies in nuclear power. There have been no more than three major accidents, only one of which (Chernobyl) has any associated injuries or fatalities from radiation. After more than 30 years, the total number of nuclear related casualties is less than half the typical number for the oil and gas industry in a single year (Agresti 2018). Besides the minor risk of accidents, nuclear is a renewable, affordable and non-carbon energy source and far less harmful than the fossil fuels. Another example is the false notion, that the U.S. can phase out fossil fuels completely in about two decades, despite the country's overwhelming and socially penetrative dependence on oil and gas. At present, the US has over 1.1 million active oil and gas wells (Kelso). Replacing such an immense system of energy production and distribution will require many decades (Smil 72). Such misunderstandings have

an impediment to policies that favor energy resilience.³¹ Today, they act to hamper progress in mitigating climate change, a goal that impacts every major national priority. Conversely, properly raised awareness can implement effective policies for the public. For instance, Hawaii passed legislation setting a 100% renewable portfolio standard (RPS) by 2045, Vermont updated a bill creating a 75% RPS by 2032, and Nevada passed to increase the RPS to 50% by 2030 (Marcy). Those passed legislation would require significant increases in renewable electricity generation, aiming for mitigating environmental problems and developing local economy. Yet, the approval of updated RPS was mainly decided upon the public's vote, supporting renewable energy. Public opinion can have a direct influence on policy implementation.

The Current Trend of Public Awareness of Energy in the US

According to the Pew Research Center in 2016, most Americans in the research sample acknowledge the energy boom in the United States. About 72% of Americans were aware that the United States is producing more energy in 2016 than it did 20 years ago. Still, 27% of Americans considered that the US either used about the same amount of energy or less energy than before. Moreover, the majority of Americans favor increasing renewable energy far more than any other sources. This strongly suggests a concern with climate change and reducing emissions. Yet, a majority of 54% oppose supporting nuclear power, the source for 60% of US non-carbon electricity. Ironically, such opposition was higher than for offshore drilling of oil and gas and for fracking. In addition, 83% of Americans agreed that increasing use of renewable energy sources is a top priority for the country's energy policies. However, to ensure businessman and consumers relying on renewable energy sources, 54% of the US adults agreed that the government regulations are necessary. However, there are more people (49%) who claim that reduced environmental regulations can still effectively protect air and water quality than the people (47%) who say cannot. More than half of American adults say government regulations are necessary to increase renewable energy use, but simultaneously believing that reducing environmental regulations can still protect the atmosphere and water quality is a contradiction. In short, people fail to establish a connection between government regulation and environmental regulation. This also insinuates the need for raising awareness.

Regarding connections between renewable energy sources and air pollution, among a representative sample of 1,012 adults, about 68% of Americans believed that solar power is very effective at minimizing air pollution, and about 63% said wind power is instrumental in decreasing air pollution. Americans were less confident about whether other energy sources are influential in mitigating air pollution. For example, about 72% of US adults considered natural gas is very or somewhat effective in reducing air pollution. The huge error here is that people mistake natural gas. Natural gas indeed emits less carbon dioxide (CO₂) than coal does approximately by half, but its emission still contributes to global greenhouse gas emissions, which may not be low enough to keep within a demanding global carbon budget. Moreover, methane, which is a potent greenhouse gas, is also released through the natural gas supply

³¹Resilience as the capacity to tolerate disturbance and to continue to provide affordable energy services to consumers. A resilient energy system can rapidly recover from shocks and can deliver alternative energy service needs in changed external circumstances. See Chaudry et al. iv

chain. Methane is a much more potent greenhouse gas than CO₂, particularly over short time-scales and consequently, as methane emissions increase, the reduced end-use CO₂ emissions compared to other fossil fuels can be eroded. As a result, overall CO₂-equivalent methane emissions may be significant that any benefits associated with reduced end-use carbon intensity could be negated (Balcombe et al.).

For nuclear power, despite it is non-carbon source, surprisingly only about 28% of the Americans in the sample considered as very effective. The most strikes against nuclear power is placed on its safety issues such as fear of radiation of atomic waste and nuclear proliferation. This shows a profound misunderstanding. The ANS (American Nuclear Society) provided the truth against the myth about nuclear energy. As an example, for the representative misperception that Americans get most of their yearly radiation dose from nuclear power plants, ANS elucidated that in fact, only 0.005% of the average American's annual radiation dose comes from nuclear power; 100 times less than we get from coal. Moreover, regarding the myth that nuclear reactor might explode like an atomic bomb, ANS explained that the truth is it is impossible for a reactor to explode like a nuclear weapon because these weapons contain special materials in particular configurations, neither of which are present in a nuclear ("Top 10 Myths About Nuclear Energy"). Such misconception might have affected the public to perceive nuclear power as not a suitable energy source.

To sum up, most Americans recognized both solar and wind energy as effective at reducing air pollution. More than half of the public says that the use of coal (60%) and oil (53%) are at least not too useful at minimizing air pollution, but still some population consider coal (12%) and oil (17%) are very effective at reducing pollution. Americans were less convinced about whether natural gas and nuclear power are influential in minimizing air pollution. 72% of the population consider natural gas as at least somewhat effective despite of its contribution to CO₂ emission. Moreover, still 35% of US adults believe that nuclear power is not practical for air pollution reduction, although it does not produce direct CO₂ emissions. Such consequences might have come from misguided knowledge, and lack of energy understanding, which can create divisive opinions. Colliding opinions can further hamper policy-making and implementing because they hinder integrating the public's opinion. Yet to mitigate the public's divisive opinion, raising awareness is crucial to integrate public perception and guide environmental legislation.

Potential Areas for Raised Awareness

Accuracy of information is pivotal. As social media develops, information can proliferate easily through the web and media platforms, resulting in a quick global impact (Kumar and Sha). Social media is great platform to disseminate information and mobilize the public. The downside to social media is that misleading information can also spread to millions of people in a short time, making it essential to provide precise information with frequent updates. Moreover, solving the unfamiliarity and misinformation that the public perceives is also critical. As an example, people still fear utilizing nuclear power as an energy source due to its historical association with nuclear weapons and mass destruction. The disasters of Fukushima and the Gulf oil spill were not nearly as catastrophic as many people think (Muller xv). "Nobody died from radiation at

Three Mile Island or Fukushima, and fewer than 50 died from Chernobyl in the 30 years since the accident." Also, many scholars and scientist claim that nuclear power is the safest way to make reliable, sustainable electricity (Shellenberger). Nuclear power is safe, and waste storage is not a difficult problem, but unfounded fears remain in society (Muller xvi). When such misinformation is circulated amongst the public, people may effectively alter their perception and make counterproductive decisions.

Additionally, the level of public awareness in energy is relatively low compared to other areas like health, and environment. Today, children learn in school basic facts about pollution, the environment, and the need for protecting people from various forms of contamination in air, water, soil, and food. However, most institutions lack courses and programs on energy outside of engineering and physical sciences. Only 8 percent of 1638 institutions have systematic energy studies (Blockstein et al.). Such insufficient education state naturally weakened the public's understanding and awareness on energy. Yet, energy education is a pivotal tool not only to teach basic facts about energy, but also to practice smart energy decision making for their own families and in their homes ("About NEED"). Basic facts, in the context, refer to the flow of energy, including the process of how energy is produced, distributed, delivered, consumed, and wasted by the types of energy sources.

Raising awareness on energy saving and energy efficiency is critical because energy demand from every home will decrease, contributing to significant savings and reduction in carbon emissions. Besides conventional methods of using less energy, raising awareness on the new technologies that every households can invest to maximize energy efficiency is also important. For instance, providing estimated cost savings from increased energy productivity through the installation of certain objects such as insulation, solar panels, and cool roofs, will incentivize the people to invest more (Muller 123-129). About 5,500 schools in the United States saved huge amount of money on electricity and left them more money to spend on educational problems by installing solar panels, which significantly increased energy efficiency (Gilpin). Like such, realization of energy conservation and energy efficiency investments is crucial not only because it can reduce CO₂ emission that helps environmental issues, but also it can make significant contributions to cost savings as well as to the sustainable development (Kim 20). Increased awareness in these areas will give the public a good grip on energy realities, help people make informed decisions and support comprehensive energy policies.

How to Raise Public Awareness

To mobilize public support and carry out the work that is consultative and participatory, standard information and shared understanding through education is essential. It is important to note that raising awareness goes beyond basic instructions. It is to explain issues and provide knowledge so that people can make their own, informed decisions ("Public Awareness"). Active and cooperative participation from interested stakeholders such as energy experts, energy service provider, NGOs, media, and local business players are significant. They should collectively consider several factors from financial conditions including energy costs, financial support of a technological innovation to the R&D, advertising methods and education (Mondal).

Running awareness campaigns, providing training at the school level, spreading awareness via the media, encouraging public participation are also important.

A good example comes from the non-profit organization “Terra Pass,” which successfully raised the awareness for companies and individuals to understand and take responsibility for their climate impact. The organization provides online education tools to calculate carbon footprint and encourages individuals, businesses and institutions to create, and implement emission reduction project as well as to develop renewable energy solutions by purchasing carbon offsets. To date, Terrapass helped more than 1000 businesses, institutions, and individuals to take responsibility for their impact on the climate through renewable energy and greenhouse gas reduction projects that in aggregate have reduced equivalent to billions of tons of carbon dioxide (“The Terrapass Story”). As a result, providing education and incentivizing energy consumers to consider economic, social, and environmental aspects of their energy use is crucial to raise the awareness creation (Kim 20).

The role of government is crucial. The government can increase public awareness by managing and trying to influence social norms through advertising campaigns, information blitzes, or appeals from respected figures (Kinzig et al.). The 2002’s Keep Cool campaign of New York State Energy Research and Development Authority (NYSERDA) is a clear example of the state-level government increased awareness on smart energy use during the summer. It aimed for promoting energy conservation and energy efficiency by changing the resident’s energy consumption patterns. NYSERDA provided a range of residential programs such as energy assessment, lists of recommended installments from insulation to efficient lighting to a heating system, Energy Star® certified appliances. (“Home Energy Efficient Programs”). Consumers were encouraged to trade in their old room air conditioners (RACs) for new, energy-efficient, Energy Star(R) labeled RACs, and receive a \$35 bounty. As a result, more than 175,000 inefficient RACs were removed, and successfully yielded 63 megawatt of demand reduction (“New Yorkers Have the Power to Keep Cool”). The example explicitly demonstrates the successful collaboration of the federal and state government benefiting both the economy and the environment.

Advertisements were a big hit in the Keep Cool campaign. The campaign captured the public’s attention through consistent advertisement from retailers and manufacturers via brochures, posters, and even sales receipts (Hammer and Maxwell 2003). Today, the social media platforms have developed so much that people can easily acquire information regardless of their location. Therefore, utilization of social media can be a very effective tool to facilitate the process of raising the public’s awareness. In addition, the common feature of successful awareness creation is economic incentives. Financial incentives stimulated schools to install solar panels and the residents in New York to install new Energy Star appliances. Devin (qtd. in Gilpin 2017), a vice president of business development for Sun Tribe, states that “people are excited about environmental benefits, but what has moved the needle is the economics.”

Moreover, government's range of policy approaches also can serve to create or reinforce social norms by signaling to the public that this is an issue that others think is important. As an example, under laws and regulations, the government can discourage certain undesirable behaviors by levying a fine or encourage desirable behaviors through subsidies. (Kinzig et al. 2014).

A clear example is the movement in favor of clean air and water laws during the 1960s and early 70s, resulting in efficient government intervention (the Clean Air and Clean Water Acts), that significantly improved the health of U.S. citizens. Under the Clean Air Act, Environmental Protection Agency (EPA) has set and implemented emissions standards to control pollution from everything from passenger vehicles, heavy-duty trucks, and buses, construction, and farm equipment, even to lawn garden equipment. The result was very successful. The air quality was improved despite increased economic activity and more miles traveled on average per person ("History of Reducing Air Pollution"). Between 1970 and 2017, the aggregate emissions of the six-common pollutant dropped by 73 percent while the US economy continued to grow by 262% ("Our Nation's Air"). Similarly, under the Clean Water Act, EPA has implemented pollution control programs such as setting wastewater standards for the industries and businesses. The Act made it unlawful to discharge any pollutant from a point source into navigable waters unless a permit was obtained. As a result, the water quality in lakes, rivers, streams in the US has greatly improved since 1972 ("Summary of Clean Water Act"). To sum up, the public's high awareness of the environmental threats problem stimulated government's intervention and consequently, successfully made cleaner environment.

Conclusion

Public awareness is a fundamental step to make informed decisions. Yet, public awareness and education on energy is lagging compared to that on other sectors such as health and environment. Accuracy and addressing misleading information are important factors when raising awareness. Moreover, emphasizing on energy conservation and efficiency is significant to ensure a secure and affordable energy future. To successfully increase the awareness, small and big organizations can cooperate to implement different campaign movements, advertisement through media. Above all, strong government support and funding are crucial for a sustainable rise in awareness.

- Government intervention is pivotal to change people's behaviors by changing policies and influencing public behavior.
- Change citizen's perspectives and norms is vital to mobilize public support.
- Lack of education naturally contributed to the public's lack of understanding on energy.
- Misperceived perception can disturb government to make beneficial decision for the public.
- Social media and financial incentives are effective tools to facilitate the process of raising awareness.

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Seventeen

Policy Recommendations

Blueprints to Transform US Energy and Mitigate Effects of Climate Change

Liam Casey, Jenne Lawrence & Serena Baserman

Introduction

In the writing of this report intended for the next President of the United States, the authors committed to balancing several priorities including national security, public health and welfare, reduction of greenhouse gases in order to address global climate change, public awareness and a realistic view of the government in order to suggest policies that were feasible to implement. The policies below touch on all of these priorities, and are the product of careful research into the sectors and technologies they address.

Envision Future Technologies

Revamp Outdated Technologies

With the abundance of natural gas resources in the U.S. and efficiency of drilling for it, natural gas is guaranteed to be a part of the short-term future for U.S. energy. As such, we endorse the implement of laws that regulate local pollution from fracking. This is not one of the most difficult technical problem to address, and to companies that profit extensively from this practice, cleanup would not inhibit the possibility of profiting. Making strong efforts to both regulate pollution and demonstrate that the government is vested in protecting local areas will help garner public support of these energy policies.

Secondly, future national energy policies must include a strong investment in upgrading and reinforcing pipeline infrastructure. A DOE report found that since 2004, oil pipelines off the coast of New Orleans have been spilling oil into the Gulf Mexico daily, equating to between 300 to 700 barrels of oil a day. Not only do these weaknesses cause environmental damage, but they represent a prominent economic loss and threat to U.S. national energy security.

Invest in Breakthrough Technologies

Future presidents should expand R&D with long-term commitment and incentivize private investment. Investments and policies should focus on technologies with breakthrough potential, especially in decarbonizing. Focus on breakthrough technologies can strengthen cross-border relationships with LEDCs by assisting in development with cost effective and non-carbon technologies. Technologies with high potential include offshore wind, deep decarbonization, smart grids, advanced nuclear reactors and geothermal technology. There are several reasons why the United States has a large stake in energy innovation. The US has historically played a leading role in energy innovation and benefited immensely from it. Few countries have the financial capacity to innovate quickly while addressing climate change. The

US must continue to lead global energy innovation, support non-carbon energy infrastructure and strengthen the economy by partnering with other countries.

Embrace a Strong Nuclear Energy Program

Rather than continue the trend of closing nuclear facilities, we advise that future Presidents 1) upgrade old reactors, including 2) building new reactors with government support using standardized building requirements. This will help with important safety implementations, and enhance the U.S.'s ability to scale the production of nuclear plants domestically and assist in scaling efforts worldwide. 3) Commit to providing a platform to scientists focused on nuclear waste storage. The next president must also commit to promoting public awareness of the benefits of nuclear power, in order to minimize public opposition to the reliance on this non-carbon energy source.

Provide Federal Direction for Energy Markets

Implement a National Carbon Tax

For decades, economists across the ideological spectrum have been promoting a carbon tax as the most efficient way to quickly reducing greenhouse gas emissions. However, an effective implementation will account for several important factors. For one, a carbon tax must reconcile and address its inherently inequitable effects on a tax-paying population. Taxing emissions disproportionately affects lower income and rural citizens who respectively a) would lose a larger percentage of their income to the tax and b) are subjected to a greater reliance on carbon for transportation. In its most recent attempt to implement a carbon tax, the State of Washington felt the effects of a policy proposal that failed to sufficiently accommodate for and include rural voters (Mass). The U.S. has the opportunity to learn from Canada, and the tax rebates that accompany the country's new carbon tax provide citizens. These rebates are issued proportionally, and dispersed more widely to low income and rural communities. With the revenue from such a carbon tax, revenue should initially be spent on rebates to the most adversely consumers and short-term programs (for example, by using carpool technology discounts) to alleviate transportation costs. Later, revenue spending should gradually transition to directing more revenue from the carbon tax to research, development and infrastructure and less to tax rebates. This funding should be directed toward facilitating the transition from coal resources towards fracking pollution mitigation efforts and the economic optimization of the natural gas industry.

Another option for the implementation of this tax involves a varied implementation of the tax with states directing their own spending of tax revenue. This could allow some states to fund climate change adaptation and mitigation efforts, while others could offset the pressure of another tax on transportation. Another consideration relates to the imposition of a carbon tax on exported products: we recommend that production taxes on exports to countries that don't have carbon taxes are delayed in order to protect American competitiveness.

Raise the Federal Gasoline Tax

We advise legislation that raises the federal gasoline tax above 18 cents per gallon to 26 cents per gallon or higher (Blackmon). This will eventually help guide the country towards paying the market price of oil, and compensate for the negative externalities concealed by government subsidies, but allegedly will not adversely affect the of supply, demand, or societal equity of access (Blackmon). However, the implementation of this tax, and its timing in relation to a carbon tax, would require careful economic analysis of its effects to individual consumers. That said, this policy has support from multiple sides of the political spectrum, with some proponents advocating that it be even higher than the increase proposed above.

Facilitate Improvements in Market Efficiency

Lawmakers must implement incentives so that choices in the market encourage efficiency for consumers rather than inhibiting profit. This methodology applies to both markets for consumer goods and markets for utilities. The next president should regulate to require 1) continued efficiency labeling for appliances as a continuation of the energy star labeling program. 2) Require the emphasis of MPG standards at the point of sale in the auto industry. In a meta-analysis, with consumers reported a willingness to pay higher prices for more higher MPG standards suggesting that this could be an effective policy to guide consumer decision making (Friedman). 3) Standardize MPG that cars need to be held to through CAFE standards as described in Chapter Six, and make incremental increases to this standard periodically.

International Leadership and Trade Ties

The United States currently occupies an important role as a major energy producer and innovator in energy technologies. Given our resource and technological capabilities, this country has a clear opportunity to lead the world on a sustainable energy course. The United States can further its role as an energy leader is through the creation of new multilateral trade deals with provisions related to energy. A lack of trade agreements prevents the lowering of tariff and non-tariff barriers to energy trade and thereby inhibits the facilitation of strong diplomatic and economic relationships built on energy. For example, the United States is a major producer of natural gas. However, bureaucratic restrictions under the Natural Gas Act of 1938 makes it difficult to export to countries with whom we lack trade agreements. In addition, the withdrawal of the United States from the Trans Pacific Partnership (TPP) cost American renewable firms millions in lost profits and allowed China to take on a greater role exporting solar panels and wind turbines to neighboring Asian states. A lack of trade agreements makes it difficult for American energy companies to export their commodities overseas. This drives up prices and makes rival energy countries—such as the Russian Federation and Iran—a more viable supplier to these countries. The next president should ultimately mandate that all future trade deals negotiated by his or her administration lower energy trade barriers.

Modernize the U.S. Electrical Grid and Urban Development

US Grid

Currently, the US grid system has three main problems: changing sources of power generation, the physical integrity of the grid itself, and various cybersecurity threats. Each of these issues requires a different policy solution, but all three require an enhanced federal role.

With regard to the first problem, our grid system is designed to distribute power to homes via a centralized, steady source. Renewable power generation is highly unstable, and so the need for sophisticated smart grid technology becomes apparent. Smart grid technology basically allows for the two way communication between utilities and customers, working quickly to respond to changing energy demand and reroute energy supply accordingly. The American Recovery and Reinvestment Act of 2009 set aside \$4.5 billion to encourage 200 electric utilities to update grid systems. Congress has unfortunately not allocated any grant money to smart grid technology since 2009 (“Recovery Act: Smart Grid Investment”). Energy-policy specialists argue that if the federal government allocated \$338 billion to \$476 billion over 20 years to this technology, energy savings over said period would equal \$1.3 to \$2 trillion (McMahon). Furthermore, an aging US electrical grid will need to be improved to protect its resiliency and security. The current cost to replace all of the US electrical grid amounts to \$5 trillion (McMahon). Given this massive sum, a smarter option would be to prioritize updating parts of the grid that need the most work. For example, parts of the power transmission network could be upgraded to increase efficiencies and lower energy costs. Perhaps most importantly, a lack of strong cyber-security protocols regarding the US electrical grid undermines national security. Mitigation of cyber threats requires that Congress pass legislation mandating that local utility companies adopt stringent cybersecurity strategies to limit the influence of hostile actors.

Urban Design and Transportation

In addition to updating the grid system, the federal government must also must take a pre-emptive role with respect to urban planning. Many American cities are relatively new and were developed during the time of the automobile. Ease of transportation meant that cities could easily be spread out over long distances. Given that 28% of US carbon emissions come directly from transportation, policymakers should utilize smarter urban planning to reduce driving hours and car ownership (“Sources of Greenhouse Gas Emissions”). The first way government could accomplish this would be to implement private-public partnerships to improve public transportation options. In Los Angeles, for example, billionaire entrepreneur Elon Musk’s Boring Company plans on building hyperloop tunnels below the sprawling city as a means of cheap and fast public transportation. The Boring Company has struggled to raise capital for start-up costs, so the federal government could allocate grants and loans to encourage public transportation in American cities. Moreover, the federal government should mandate that future urban developments utilize space more efficiently and give people more choices for mobility. Locating residences, commerce, institutions, and workplaces near transit stations promotes mobility and reduces necessity for automobiles.

Expenditures and Funding Avenues for Policies

While we acknowledge that several of these recommendations require funding, be it in urban infrastructure or investment, we will point out that revenue from the market-correcting taxes we recommend (e.g. on carbon and the price of gasoline) can be used for these other recommended purposes. Secondly, funding for these efforts can and should come in part from cuts to national defense spending. This decision is justifiable in as far as these policies are

addressing national security through efforts to mitigate the intensity of climate change. Finally, these policies can manifest in the form of tasks assigned to pre-existing federal departments. For example, the DOE and EIA are already responsible for public information campaigns. As previously mentioned, we recommend that the State Department adopt enhanced programing with the goal of enhancing U.S. energy leadership, and promoting accessibility to affordable non-carbon technologies in rapidly industrializing countries.

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