Spring 2014
Industry Study

Final Report
Energy Industry

The Eisenhower School
National Defense University
Fort McNair, Washington, D.C. 20319-5062

ENERGY 2014

ABSTRACT: The Eisenhower School Energy Industry Seminar analyzed the domestic energy industry from the perspective of its relevance to national security. The seminar concluded that a healthy energy industry is critical to U.S. national security, and many of the energy challenges America faces at the national-level are also faced by the Department of Defense. The key to effective energy policies is the balancing of economic, environmental, and security concerns. The future energy security of the United States depends on the presence and functioning of global energy markets, as well achieving gains in energy efficiency, diversity, and resiliency. The time has come for the U.S. to implement energy related policies which will enable gains in all of these areas, and there is ample opportunity to use creative resourcing strategies to ensure the policies are both effective and economically viable.

Mr. Brian Anselman, Dept of State
Colonel Todd Bertulis, US Army
Mr. Louis Bono, Dept of State
Lieutenant Colonel Brian Bruggeman, US Marine Corps
Colonel Douglas Curry, US Air Force
Colonel Gary Gillon, US Army
Colonel Douglas Guttormsen, US Army
Ms. Christina Higgins, National Geospatial Intelligence Agency
Brigadier General Majed Karame, Lebanon Air Force
Ms. Beverly McAlister, Dept of Army
Ms. Mira Piplani, Dept of State
Commander Ernest Spence, US Navy
Lieutenant Colonel Ryan Suttlemyre, US Air Force
Colonel Stacy Townsend, US Army
Colonel Daniel Wolf, US Air Force
Colonel Kairgeldy Yesseneyev, Kazakhstan Navy

Colonel Richard Addo, US Army, Faculty Lead
Mr. David Amaral, Dept of Energy, Faculty
Captain Michael DeVine, US Navy, Faculty
Dr. Paul Sullivan, Faculty

LOCATIONS VISITED

Domestic:
Auto Grid (Redwood Shores, CA)
Chevron (San Ramon, CA)
Congressional Research Service (Washington, DC)
Conowingo Hydroelectric Station (Conowingo, PA)
Cove Point LNG Facility (Lusby, MD)
U.S. Department of Energy (Washington, DC)
  - Energy Information Administration
  - Office of Energy Efficiency and Renewable Energy

Dickerson Generating Station (Dickerson, MD)
Green Building Council (Washington, DC)
Japan Embassy (Washington, DC)
Loveridge Coal Mine (Morgantown, WV)
Maryland Energy Administration (Annapolis, MD)
Montgomery County Resource Recovery Facility (Dickerson, MD)
PJM (Valley Forge, PA)
Power Standards Laboratory (Alameda, CA)
Robinson Run Coal Mine (Mannington, WV)
Shell Refinery (Martinez, CA)
South Dakota School of Mines and Technology (Rapid City, SD)
Stanford University (Stanford, CA)
Strata Energy In-situ Uranium Mine (Crook County, WY)
Three Mile Island Nuclear Power Station (Middletown, PA)
University of California, Berkeley (Berkeley, CA)
WYODAK Coal Mine and Coal Power Plant (Gillette, WY)

International:
Hamaoka Nuclear Power Plant (Shizouka, Japan)
Hitachi-GE Power (Tokyo, Japan)
Isogo Coal Power Station (Yokohama City, Japan)
Japanese International Cooperation Association (Tokyo, Japan)
Kashiwa-no-ha Smart City (Chiba, Japan)
Ministry of Economy, Trade, and Industry (Tokyo, Japan)
Mitsubishi Corporation (Tokyo, Japan)
New Energy Development Organization (Kawasaki, Japan)
US Embassy (Tokyo, Japan)

Introduction

The energy industry is critical to the national security of the United States. Without secure, sustainable, and affordable access to energy, any nation will struggle to prosper. Energy security, in the context of this paper, means the nation's supplies and infrastructure are protected from disruption. Energy sustainability implies the sources of energy used by the country can be maintained for the foreseeable future, and their use does not pose an undue burden on the environment or other resources. Energy affordability means supplies of energy can be purchased at will, at prices set by open and competitive markets. The energy industry thus plays a vital role in ensuring sufficient access to energy for the nation, and the industry is joined in this responsibility by government. The role of the government with respect to energy is to establish and maintain a policy framework that enables industry participants to provide a secure, sustainable, and affordable supply of energy to consumers through free markets, while mitigating risk to the environment.

The purpose of this paper is to provide energy-related policy recommendations that will contribute to U.S. national security through 2050. This study was completed under the supervision of faculty members from The Eisenhower School for National Security and Resource Strategy at the National Defense University by a diverse group of U.S. armed forces officers, Department of Defense and Department of State civilians, and armed forces officers from Lebanon and Kazakhstan.

This paper first introduces the energy industry and provides an overview of U.S. energy interests as they relate to the National Security Strategy and the Department of Defense. It then examines trends in the energy industry, considers the preferred environment for the U.S. energy industry to the year 2050, and provides policy recommendations to realize the desired strategic environment. The paper concludes by discussing the resourcing, which will be necessary to implement the policy recommendations.

The U.S. Energy Industry and National Interests

Energy Industry Defined

The energy industry is complex, multi-faceted, and in many respects, global in nature. There are numerous industry participants, ranging from those involved in: electricity generation, transmission, and distribution; to hydrocarbon exploration, extraction, transportation, processing, and delivery; and research and development of new energy products and technologies and those involved in the oversight and regulation of the industry. While volumes could be written to completely describe the roles played by the various industry participants, due to space limitations only the industry sectors most relevant to the content of this paper (electricity, nuclear power, renewable energy, oil and gas, coal, and regulatory and policy making bodies) are covered.

Electricity: Three main components – generation, transmission, and distribution – comprise the nation's electrical system and provide approximately 40 percent of the nation's power to the residential, commercial, industrial, and transportation sectors (the other 60 percent is energy consumed by the nation in a form other than electricity).[1] Fossil fuels such as coal, natural gas, and to a lesser extent, oil, fuel more than 66 percent of all U.S. electricity generation facilities, while nuclear power generates approximately 20 percent of domestic electricity supply.[2] Renewable energy sources such as wind, hydro, solar, and biomass account for 12 percent of the country's electricity generation capacity.[3]

Nuclear Power: As of August 2013, the United States had 100 licensed commercial nuclear power reactors operating at 62 sites in 31 states and had the most nuclear powered electricity generation capacity of all 31 countries that generate commercial nuclear power.[4] There are currently 28 active license requests for new reactors and four reactors under construction in the United States; two of which represent the first reactors to receive construction approval in over 30 years.[5] The Energy Information Administration predicts the industry will add approximately 19.1 gigawatts of new generation capacity from 2012 to 2040, with 11.0 gigawatts of capacity coming from new reactors and 8.0 gigawatts coming from upgrading existing plants.[6] Despite these additions, there is expected to be a slight decrease in overall generation capacity during this period as older reactors are decommissioned. Nuclear power, despite it prolific use, is not without incident and controversy. The most recent significant nuclear incident in the United States was the 1979 partial core melt in the number two reactor at the Three Mile Island power station.[7] This incident resulted in the release of radioactive gas from the plant.[8] In 2011, the Fukushima Daiichi nuclear power plant in Japan suffered major damage from an earthquake and tsunami that resulted in several cores melting down and reactor explosions.[9] This incident resulted in significant levels of highly radioactive releases.[10] The Three Mile Island incident, while significant at the time, has faded into memory for many Americans. The incident in Japan, however, has resulted in several countries reevaluating their commitment to the use of nuclear power as an energy source. The American response to the Fukushima disaster has been less negative; one opinion poll shows the percentage of Americans who favor the use of nuclear energy dropped from 74 to 65 percent in the wake of the incident, but that indicator has subsequently recovered to reflect 69 percent of Americans again favoring nuclear power.[11] While the long-term consequences of a major incident like Fukushima are not yet known, it appears the American people are willing to accept the risks associated with nuclear power to enjoy the benefits it provides.

Renewables: Of the 12 percent of total U.S. electricity generation from renewable resources, hydroelectric accounts for 56 percent, wind for 28 percent, biomass for 12 percent, geothermal for 3 percent, and solar for 2 percent.[12] Other sources, such as wave and tidal energy, are being developed and deployed, but currently contribute less than one percent to the nation's electricity supply. Despite their relatively small contribution to the total electricity supply, "every year for the past decade, non-hydro renewables have increased both their net electrical output, as well as their percentage share of the nation's electricity mix." [13] Renewable sources are generally considered to be safer than nuclear and cleaner than fossil fuels, because they do not directly contribute to greenhouse gas (GHG) emissions; however, they are not without negative consequences. Damming a river to install a hydroelectric plant, for example, requires vast amounts of up-stream terrain, and often results in both up and down-steam ecological damage and change. Solar panel and wind farm installations are often opposed for their disruption of natural aesthetics, and wind turbines have raised the ire of environmentalists for the danger they pose to bird populations. The issue of intermittent production by many types of renewable power complicates their integration into the electricity grid. Despite the challenges, the hope of producing clean, renewably sourced electricity for the country, combined with financial incentives, continues to propel an expanding renewables sector.

Oil and Gas: At the turn of the century, America's oil and natural gas sectors were in a state of decline as domestic production faltered despite surging demand. However, beginning around 2007, the rising price of both oil and natural gas made the technological innovation of combining horizontal drilling and hydraulic fracturing to extract oil and gas from shale formations economically viable. This innovation has proven to be a game changer in the energy industry not only for the United States, but also for the world as the potential for substantially increased U.S. oil and natural gas production has fundamentally altered the global energy outlook. As a result of the so-called "Shale Gas Revolution," natural gas production in the United States has jumped 27 percent since 2000, while domestic natural gas proven reserves have grown 80 percent.[14] U.S. domestic oil production increased 15 percent in 2013 alone and is now at a 25 year high.[15] The United States remains the top oil consuming nation in the world, consuming about 18.5 million barrels of oil per day – which is about 80% more than the second highest consumer, China.[16] To meet its demand for oil, the U.S. imports approximately 40 percent of the oil it consumes from foreign countries.[17]

<u>Coal:</u> Coal is the largest fuel source for electricity generation in the United States, though its share has dropped from 50 percent in 2007 to 37 percent in 2012.[18] Moreover, coal is expected to be surpassed by natural gas as the primary fuel for electricity production by 2040.[19] The decline in coal's use is attributable to strong price competition from natural gas, the expansion of renewables use, and efforts to reduce GHG emissions. Despite reductions in domestic coal demand, U.S. coal production has declined only 14 percent since 2007 because of strong export demand, which has increased over 300 percent and kept prices relatively stable.[20] Domestic demand may decline further in 2015 when Mercury and Air Toxics Standards (MATS) come into effect.[21] The most recent MATS compliance study estimates that at least 16 percent of 2012 coal-fired capacity will be retired by 2015 due to the high cost of compliance.[22]

<u>Regulation and Policy:</u> The regulatory and policy environment in the United States is complex and partisan, at times inconsistent if not incoherent, and generally offers little strategic direction. It consists of a patchwork of lawmaking and governing bodies across multiple levels of government – there are 13 agencies and 26 congressional committees and subcommittees that oversee energy and environmental affairs on the federal level alone.[23] Additionally, 84 federal district courts retain the authority to influence the energy industry.[24] Energy, water, and the environment are national and local-level issues, and each of the 50 state governors and legislatures are intensely focused on "hometown" issues while wielding influence over permits, access, and infrastructure. Finally, there are industrial trade associations, environmental groups, and other stakeholders who seek to exert influence on the regulation and policy landscape.

U.S. National Interests Related to the Energy Industry

To be effective, energy policies must balance three primary considerations: security, the economy, and the environment. Balancing the use of these levers, policy makers can enable a future where energy is secure, sustainable, and affordable, but the task is daunting. President Obama summed up the challenge in a 2010 speech:

> The United States of America cannot afford to bet our long-term prosperity, our long- term security on a resource that will eventually run out, and even before it runs out [it] will get more expensive to extract from the ground. We can't afford it when the costs to our economy, our country, and our planet are so high. Not when [future generations] need us to get this right. It's time to do what we can to secure our energy future.[25]

Global energy markets and the manner in which energy and energy resources are produced have profound implications for U.S. national security and the security of our allies and partners. As the 2010 National Security Strategy (NSS) makes clear, "dependence on fossil fuels constrains our options," therefore the United States must ensure energy resource security.[26] According to the NSS, the United States has underinvested in new and efficient energy sources and technologies, which are essential to "competitiveness, long-term prosperity, and strength."[27] Recovering from this underinvestment will require a transformation of the ways energy is used; a diversification of supplies, investments in innovation, and expansion of clean energy technologies.[28] Finally, on the environmental side, the NSS notes "the danger from climate change is real, urgent, and severe."[29] As global climate patterns change, increased human suffering from drought and famine and new conflict over refugees and resources - notably food and water - should be expected.[30]

Although the goals of national security, economic prosperity, and environmental sustainability do not all always align, they need not force policy makers into "either/or" decision dilemmas. For instance, the Department of Defense (DoD), which is by far the largest consumer of energy in the United States, plays a critical role in the U.S. energy industry – consumer, security provider, technology developer, and investor, to name a few.[31] Recognizing these roles, DoD recently released a department-wide energy policy intended to "enhance military capability, improve energy security, and mitigate costs" associated with energy.[32] In addition, while the policy specifically identifies national security and economic goals, the DoD recognizes the importance of environmental sustainability as well.[33]

Energy Industry Trends

Foremost amongst the trends which will continue to impact the energy industry through 2050 are (1) growth in global demand for energy, (2) growth in the use of hydrocarbon fuels in a diverse energy portfolio, (3) uncertainty of renewable energy's role as a significant provider of energy, (4) competition for water, (5) role of natural gas as the fuel of choice, (6) need for securing energy supplies, (7) commitment to investment in energy technology and research and development, and (8) resistance to implementing national-level energy policies. Understanding these trends is necessary to assessing the future environment for the industry, and to developing and implementing national strategies.

Growth in the Global Demand for Energy

By the year 2050, global demand for energy will increase by at least 60 percent (*see* figure 1), driven primarily by demand in Asia (*see* figure 2), which will be most pronounced in China and India. Indeed, China's energy consumption surpassed that of the United States in 2010 and is expected to increase another 225 percent by 2040, while India's demand will more than double during the same period.[34]

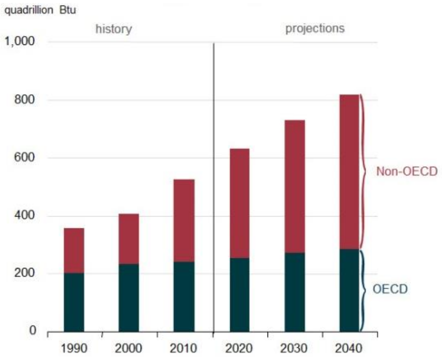

Figure 1. World Energy Consumption, 1990-2040.
Source: U.S. EIA, International Energy Outlook 2013.

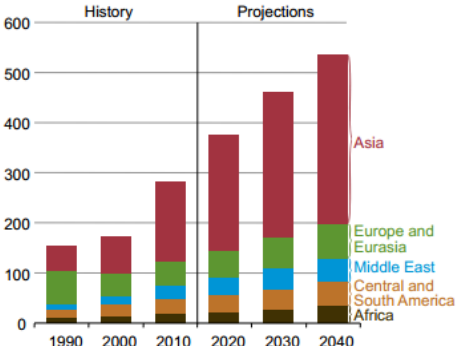

Figure 2. Non-OECD Energy Consumption by Region (quadrillion Btu), 1990-2040.
Source: U.S. EIA, International Energy Outlook 2013.

<u>Growth in the Use of Hydrocarbon Fuels in a Diverse Energy Portfolio</u>

The United States and the world will continue to rely on hydrocarbons for the foreseeable future. Despite significant growth in the use of renewable energy sources throughout the world, carbon-intensive fuels will still be used to provide almost 80 percent of the globally demanded energy through 2040.[35] Amongst carbon-based fuel sources, only coal is expected to show any slowing growth (*see* figure 3). Given the growing reliance on hydrocarbons, it is likely that global GHG emissions will significantly increase going forward absent advancements in, and proliferation of, carbon sequestration technologies or cost effective and efficient renewables (*see* figure 4). As with the trend in energy consumption growth, the bulk of the growth in GHG emissions will come from non-OECD nations (*see* figure 5).

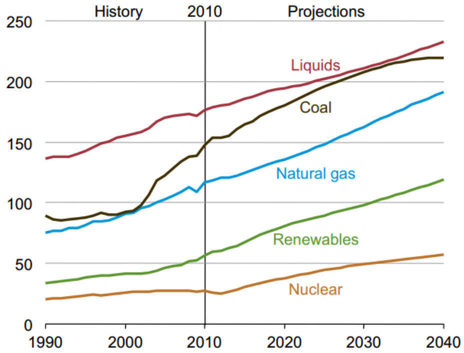

Figure 3. World Energy Consumption by fuel type, 1990-2040 (quadrillion Btu).
Source: U.S. EIA, International Energy Outlook 2013.

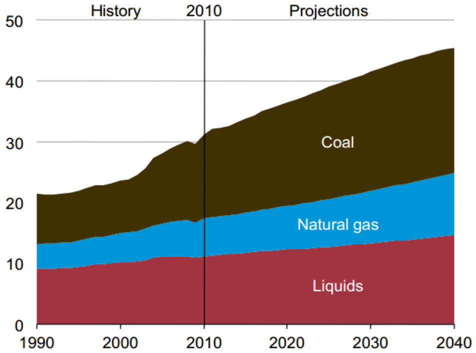

Figure 4. World Energy-related CO2 Emissions, 1990-2040 (billion metric tons).
Source: U.S. EIA, International Energy Outlook 2013.

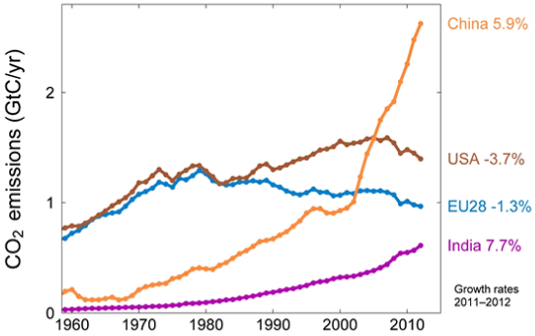

Figure 5. The World’s Four Largest GHG Emitting Regions.
Source: Globalcarbonproject.org, Global Carbon Budget 2013

Uncertainty of Renewable Energy's Role as a Significant Provider of Energy

In contrast with the growth of hydrocarbon use, the prospects for renewable energy in both developed and developing countries remain unclear, especially in the near-term. Renewables are advantageous because they are indigenous, they have a low carbon footprint, and they have relatively low energy production costs. Unfortunately, renewable energy sources are capital intensive, which often drive their total costs (initial investment plus operations and maintenance costs) to exceed the costs of hydrocarbon based sources of energy. In fact, a 2012 study by the OECD Nuclear Energy Agency showed the grid-level systems cost of installing solar and wind projects was 40 to 160 times higher than that for coal and gas powered electricity plants.[36] Additionally, a gas powered plant has a grid-level systems installation cost of $0.54 per megawatt-hour of generating capacity, while a solar plant has a systems installation cost of almost $83 per megawatt-hour of generating capacity.[37] Given this reality, a commitment to realizing the benefits of renewable energy (reduced GHG emissions, increased energy diversity, and reduced dependence on energy suppliers) at the expense of paying higher costs is required.

In addition to the cost-competitive disadvantage suffered by renewables, countries with large-scale electricity grids have trouble integrating renewables because of the intermittency of their production (solar, wind, and hydro) and the inability to store electricity for use during periods of peak demand. Further, those countries which have made a concerted effort to use renewable sources on a broad scale are finding they did not entirely understand the challenges they would face. In an attempt to offset the high cost of installation and incentivize their use, many governments adopted tax credits, feed-in tariffs and/or assured priority for electricity produced by renewables. These subsidies have undermined the ability of base load generators - nuclear plants in particular - to compete with the wind and solar producers. The first such nationwide, large-scale energy transition to renewables – the Energiewende in Germany – has been anything but smooth. In fact, the German Minister of Economics and Energy recently said, "I think we need to start over."[38] Absent a technological breakthrough that makes renewables cost competitive or the development of significant storage technology, it is difficult to imagine countries abandoning hydrocarbons or nuclear investments in favor of renewables at a pace faster than shown in figure 3.

Competition for Water

The combined effects of population growth and climate change are leading to water stress in many regions around the world. This in turn intensifies competition for the resource between the three largest uses: personal consumption (drinking, cleaning, and household use), agriculture, and electricity generation. This nexus of water, food, and energy, will continue to be the world's most basic resource allocation dilemma for the foreseeable future. In the United States, industrial water use, of which the energy industry is a subset, accounts for 43 percent of all withdrawals. This is just over three times the amount used for municipal purposes but is equal to the amount used for agriculture. In less developed countries, agriculture use accounts for 69 percent, industrial use for 19 percent, and municipal use for 12 percent.[39] That said, in both developed and developing countries, competition for water resources will intensify, especially in Asia where population growth is most acute.

As competition for water resources increases worldwide, recent developments in the energy industry have the potential to further aggravate these tensions. The production of oil and gas from shale formations by hydraulic fracturing ("fracking") is water intensive. Drilling and fracking a single well in the United States consumes in excess of five million gallons of water, and because of the nature of oil and gas production from shale, most wells require multiple fracking treatments during their lifetime.[40] While the demand for fracking water has not placed noticeable stress on the freshwater ecosystems in the United States because oil and gas rich shale tends to be near areas rich in water resources, other regions of the world may not be so lucky. Of particular concern is China, which ranks number one in the world for technically recoverable shale gas resources and number three for shale oil resources.[41] Approximately three-quarters of China is at medium-to-high water risk, and the lowest risk areas are primarily agricultural.[42] Given that most of China's known shale resources also are found in the agricultural areas, the competition for water is likely to be especially intense. The potential for instability and conflict extends beyond Asia, though, as the arid regions of the Middle East and North Africa are likely to aggressively compete for both water and energy resources.[43] In Saudi Arabia, for example, domestic consumption of oil has almost doubled since 2000 to three million barrels per day, which is 29 percent of their total daily production.[44] The increase in demand is due in large part to the energy demanded by water desalination plants.

Role of Natural Gas as the Fuel of Choice

The ongoing natural gas revolution in the United States has radically changed the nation's energy outlook. Between 2000 and 2012, dry natural gas production from shale increased 3100 percent and now accounts for 40 percent of all U.S. dry gas production.[45] This dramatic rise in shale gas extraction triggered a 58 percent decline in natural gas imports by the United States between 2005 and 2012.[46] Consequently, imported gas accounted for only 6 percent of U.S. consumption by 2012.[47] Moreover, the dramatic increase in American production capacity has resulted in the United States becoming the world's leading producer of natural gas, surpassing Russia in 2009.[48] Today, natural gas is a vital commodity in the United States, utilized in the electricity, industrial, residential, commercial, and transportations sectors. In 2013, America produced 93% of the gas it consumed.

In the future, the role of natural gas as the energy source of choice in the United States is expected to grow as its relative abundance, low price, and the mounting concerns over GHG emissions converge to redefine how America uses energy. Most pronounced will be the increased utilization of natural gas in the electric power and industrial sectors. As shown in figure 6, the United States has been transitioning from coal to gas powered generation for the past 25 years. Generating electricity from natural gas emits approximately 50 percent less carbon dioxide per kilowatt-hour than coal. Further, the cost to build a coal-fired power plant increased 19 percent from 2010 to 2012, whereas the cost to build a natural gas fired power plant decreased 10 percent during the same time period.[49] Thus, the transition from coal to gas likely will accelerate. As a result, the largest increase in natural gas consumption is expected to be in electricity generation as additional coal-fired electric plants are forced into retirement.[50] Low natural gas prices are also predicted to spur increased consumption in natural gas-intensive industries like primarily bulk chemical and fabricated metals producers, and machinery and transportation equipment manufacturers.[51] The final growth area in the United States for natural gas is the transportation sector. Since 1997, consumption of natural gas for transport increased almost 400 percent.[52] As infrastructure expands across the country, the viability of natural gas as an alternative to diesel fuel for use in the trucking and railroad sectors will continue to increase.

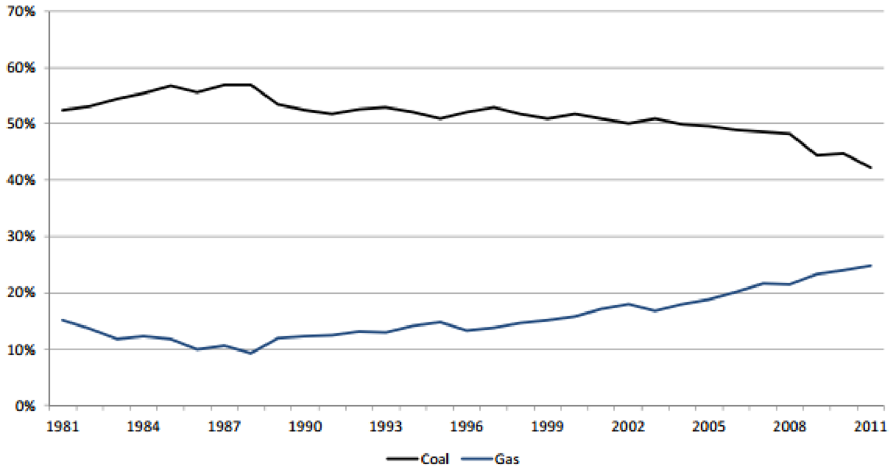

Figure 6. U.S. Coal and Gas Shares in Power Generation.
Source: IEA, Gas to Coal Competition in the U.S. Power Sector.

Securing Energy Supplies

Primarily enabled by the proliferation of cheap and readily accessible shale gas and the increased use of renewable sources to generate electricity, the United States is becoming increasingly more energy secure from the perspective of static consumers (power producers, industrial facilities, etc.), as evidenced by the U.S. becoming a net exporter of natural gas by 2017. Unfortunately, despite an increase in domestic oil production and import of Canadian supplies, the security of energy supplies for transportation use will remain a challenge. As previously noted, the U.S. consumes about 18.5 million barrels of oil per day – two-thirds of which is used for transportation – and 40 percent of the total consumption is currently imported.

Increasing Pressure on R&D Investments

Given the current national debt and years of projected future deficits due to growing entitlement and debt servicing costs, national energy R&D investments will likely come under increasing pressure. This phenomenon has already occurred during sequestration in 2013, when all types of federal R&D were indiscriminately cut by about 7 percent.[53] Additionally, some projections have government R&D spending staying flat for the next decade or longer.[54]

Resistance to Implementing National-level Energy Policies

Given the continuing Congressional gridlock and lack of a coordinated national energy strategy or policy, it is almost assured the United States will continue to face a legislative and regulatory environment in which sufficient support for comprehensive initiatives will be improbable, if not impossible, to obtain absent an energy crisis.[55] Recent attempts at formulating a national energy policy have been counterproductive, like the 2005 ethanol mandate, or widely criticized as excluding concerned parties as was the 2001 attempt by the Bush Administration National Energy Policy Development Group.[56] Additionally, the current presidential administration communicates energy objectives in the President's Energy Agenda, which calls for improvement in domestic oil exploration, fuel efficiency standards, and the development of renewables and domestic natural gas; however, the agenda does not attempt to initiate coordinated action by concerned agencies, and does not address the complex issues related to infrastructure modernization for the transportation and distribution of critical energy sources.[57]

Energy Alternative Futures and Preferred Environment

While the deterministic nature of the previously discussed trends is driving the U.S. in certain directions, U.S. decision makers also must consider how policy influences the development of different futures with respect to energy. These different futures may be thought of as a "solution space" because policy could move the U.S. toward an energy future that is more secure or less secure, more sustainable or less sustainable, and more affordable or less affordable, and combinations thereof.

Determining appropriate policy in this solution space is challenging because of the many decisions that will be made involve tradeoffs between oftentimes competing ends. For example, coal is an affordable energy source and domestic supplies are secure, but its use is unsustainable due to the GHGs released when burned. On the other hand, renewables are a secure and sustainable source of energy, but current technologies make them unaffordable on a large scale. Similar tradeoffs exist for every energy source, and conceived out policy must consider and account for these tradeoffs. Unfortunately, the development and implementation of these choices are incredibly complex and difficult. For example, opinions vary across the ideological spectrum on the need for policies like a national carbon tax or "cap and trade" system, how they would be implemented, and what effects, intended and unintended, they would have.

As if the policy making landscape were not complicated enough, policymakers must also take into account that the U.S. energy industry is not a "closed system." Given the scope of U.S. energy consumption and production, any policies instituted in the United States will have global effects. Added to this, these global effects may cause other countries to institute new policies in response to U.S. policies or their own strategic interests, which in turn, may have impacts in the United States. Consider two examples. First, the recent U.S. action to postpone a decision on the Keystone XL pipeline may cause a change in Canadian policy on when, where, and how it would like to export oil from its oil sands resources in Alberta, which may affect supply deliveries to U.S. refineries. Second, Saudi Arabia may change its oil production decisions based on its own strategic interest. As the second largest producer in the world, these decisions will impact the global market and the United States.

Finally, policy must also consider both positive and negative game-changing events. On the positive side, technological breakthroughs such as a large-scale, deployable energy storage breakthrough to solve renewable intermittency issues, effective carbon capture and sequestration technology, or a truly sustainable zero-carbon transportation bio-fuel would dramatically reshape the energy industry. On the negative side, another nuclear incident that releases radiation or large-scale groundwater contamination from fracking waste would also dramatically impact the direction in which the U.S. energy industry is heading.

With these considerations in mind, three conclusions are clear. First, the preferred future environment is one in which our energy sources are more secure, more sustainable, and more affordable. Second, policy will dramatically affect the energy future, and may require tradeoffs between competing interests. Third, game changing events may dramatically reshape the future of energy in the United States in both positive and negative ways.

Policy Levers and Recommendations

Given the preferred future environment, it is necessary to consider mechanisms policy makers can use to manage the overall energy trajectory. Such levers of influence include the following five elements: 1) efficiency; 2) energy markets; 3) diversity; 4) resilience; and, 5) R&D. Each of these elements will be discussed in turn, first by covering the policy levers, and then by giving specific policy recommendations. While, for the purposes of this paper, each policy recommendation is stated in one of these five policy sections, in reality, many of the recommendations will provide benefits across the other policy elements as well.

Of note, there are generally two approaches to implementing policy, either through mandates or incentives. When possible, the use of incentives is the preferred approach, as users often receive offsetting benefits to support the policy initiative.

Efficiency

Policy elements: Energy efficiency is arguably the United States' most powerful lever as it has enormous potential to reduce energy consumption, thereby positively affecting security, sustainability, and affordability. Added to this, it is the "cheapest" energy available, and as such, should be the cornerstone of any energy policy.

Greater energy efficiency reduces the demand for energy supplies, directly enhancing energy security and sustainability. The United States already has realized many benefits from energy efficiency in both static and transportation energy. Due to previous efficiency measures, the U.S. now uses only 55 percent as much energy for every dollar of GDP as it did in 1980.[58] Moreover, consider that 1970s automobiles averaged about 13.5 miles per gallon, but now average around 30 miles per gallon.[59]

Achieving further gains in energy efficiency in the U.S. will require improved public awareness of energy consumption, as well as the use of technology. Achieving revolutionary gains in energy efficiency will require the use of integrative design for all types of energy consuming devices – cars, buildings, and even industrial complexes. When design for such devices is begun with an integrative approach focused on energy efficiency, designers are able to combine multiple technologies in ways that achieve far greater efficiency than without complete integration.[60]

Analysis of energy consumption by sector in the United States (*see* figure 7) shows that the industrial and commercial sectors will undergo the greatest growth, while the residential and transportation demand will hold relatively steady. That said, there are significant opportunities for gains in efficiency in each sector; these opportunities will be discussed in turn.

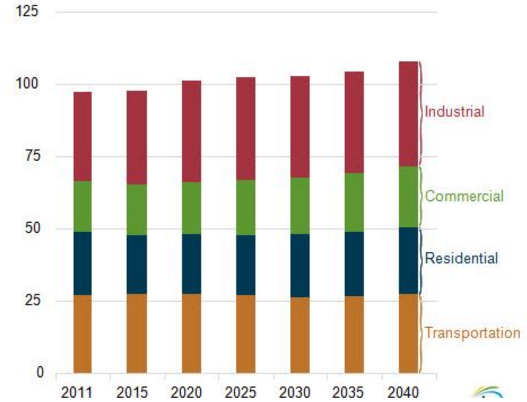

Figure 7. U.S. Energy Use by Sector (quadrillion Btu).
Source: U.S. EIA, Annual Energy Outlook 2014, U.S. Energy Demand

The transportation section offers the highest potential for efficiency gains. The transportation sector contributes about 28 percent of total GHG emissions and, as shown in figure 7, accounts for approximately the same percentage of energy use in the United States.[61] In 2011, the United States consumed approximately 19.5 million barrels of oil per day, of which approximately 14 million barrels per day were devoted to the transportation sector.[62] To support its daily oil consumption, the United States imported 8.9 million barrels per day.[63] Given the transportation sector is the single largest consumer for petroleum liquids, this creates a significant energy security vulnerability for the United States.

Achieving gains in transportation energy efficiency and fuel economy in vehicles can have a significant impact on improving U.S. energy security and sustainability. Unfortunately, realizing such gains will not be easy. Most of the aforementioned improvements in vehicle fuel economy occurred prior to 1985, with only a modest increase in average fuel mileage from 27.5 to 30 miles per gallon since.[64] The current fleet of vehicles on American roads is notoriously inefficient in converting fuel to vehicle movement. Approximately 85 percent of fuel energy consumed is lost in the conversion; astonishingly, only about 0.5 percent of the energy content in automotive fuel serves to move the driver and passengers.[65] Further, medium and heavy duty trucks make up only 5 percent of vehicles on the road, yet they account for 25 percent of the transportation sector's total fuel usage.[66] The enormity of the transportation sector and its potential gains in energy efficiency make it a priority target for efficiency initiatives. Of note, the Department of Energy estimates a 50% reduction in fuel consumption by light, medium, and heavy duty vehicles would reduce oil consumption by 3 million barrels per day.[67]

Residential and commercial buildings consume approximately 40 percent of the energy in the United States, as shown in figure 7, and that demand is expected to exceed 50 percent by 2050 with most of the growth coming from the commercial sector. Experts contend that energy use in buildings could be reduced 38 percent by 2050 by making relatively easy changes, and by using new and emerging technologies.[68] Unfortunately, this will be a formidable task given there are over 120 million buildings in the United States, each with its own unique retrofit requirements. However, technologies that can substantially improve energy efficiencies on a broad basis exist. While these technologies offer efficiency improvements individually, design integration enables a multiplier effect as most of the technologies can be integrated to achieve maximum benefit. To date, the potential energy efficiency gains for most buildings have not been realized due to the slow penetration of energy efficient technologies into the market place, the upfront capital costs and effort required to retrofit existing structures, and a lack of public awareness.

The industrial sector is the largest energy consuming sector in the United States (*see* figure 7) and has been shown to save more energy per program dollar spent than any other sector.[69] Across the sector, the bulk of energy consumed is used to provide heating or to drive machines. Unfortunately, nearly 40 percent of the energy used is eventually lost in the form of unrecovered heat.[70] Simply insulating pipes, ductwork, and wire bundles can help achieve sizeable efficiency gains by minimizing losses. Also, replacing motors and boilers with more efficient models also produces notable gains in efficiency. Moreover, capturing and reusing waste heat is a particularly useful technique to improve energy efficiency in the industrial sector. Combined heat and power (CHP), also known as cogeneration, captures waste energy and uses it to provide heating or cooling. In this method, instead of buying electricity from a utility and burning fuel to produce heat, an industrial facility uses cogeneration to provide both needs. In addition to increasing energy efficiency and reducing GHGs, CHP cogeneration also augments the local electrical grid because facilities can sell surplus energy to utility providers.[71] Increasing current domestic CHP capacity by 50 percent would lead to a reduction of one quadrillion BTUs of energy consumption (almost 1% of U.S. domestic use) and a decrease of 150 million metric tons of carbon dioxide emissions annually (about 2% of U.S. emissions).[72] Nevertheless, some utilities and local regulatory authorities impose barriers to CHP installations, while many industrial site managers are not familiar with the technology or its potential gains.[73]

Policy recommendations: Barring radical innovation in the transportation sector, the primary means to achieve efficiency goals is to first mandate aggressive efficiency gains for vehicles, then allow manufacturers to achieve the gains by making vehicles lighter and by equipping them with less powerful engines. Lighter vehicles are essential to any approach to improving fuel economy. According to the Rocky Mountain Institute, “A lightweight architecture reduces tractive load – the energy required to propel the vehicle by reducing losses from rolling resistance and allowing a smaller, lighter power train to deliver the same performance with less fuel.”[74] Analysts believe that a 10 percent reduction in weight can lead to a four to eight percent improvement in fuel economy.[75] Light-weighting vehicles and developing technology to reduce rolling resistance could make cars 50 percent more fuel efficient without any other advances in technology or engine performance.[76] Electric vehicles also stand to benefit from the use of lightweight materials because weight reductions would permit the use of smaller and lighter batteries.[77] Unfortunately, despite dramatic improvements in vehicle energy efficiency that are promised by lightening vehicles and using advanced internal combustion engines, the U.S. transportation sector would still maintain an enormous appetite for oil. Advanced electric and hybrid vehicles should complement the efficiency gains made by light-weighting and are likely the next generation of technology that will help autos achieve fuel ratings in excess of 100 miles per gallon. The DOE estimates transitioning to electric vehicles across the United States would decrease oil dependence by 80 percent and GHG emissions by 60 percent.[78]

As electric vehicles become more prevalent, care must be taken to ensure their performance is not outpaced by gains in gas and diesel vehicles. Electric vehicles (EVs) are a terrific alternative to petroleum fueled vehicles. Care must be taken, however, in establishing performance standards for electric vehicles. Reduction of the amount of energy consumed by EVs must be mandated to ensure they are not permitted to become less efficient than the gasoline and diesel powered vehicles they are meant to replace. Significantly stricter vehicle efficiency standards will reduce the reliance on oil as a transportation fuel while promoting the use of electricity, but the changeover from diesel to natural gas for rail and long-haul trucking use will require government policy to facilitate widespread adoption of the new fuel. To this end, policy must mandate at least 50 percent conversion from diesel to natural gas by 2050. In addition to a transition to natural gas, the U.S. also must remove mandates for corn-based ethanol, which has proven to be an unsustainable bio-fuel, raising the cost of corn and reducing corn’s availability in food markets. Of note, if current corn-based ethanol mandates remain, America’s entire corn crop could be devoted to fuel by 2022.[79]

In addition to personal vehicle efficiencies, the United States should also look to mass transit and collaborative consumption to provide transportation energy efficiencies. Mass transit already has proven to be successful in many metropolitan areas, saving 4.2 billion gallons of gasoline.[80] Additionally, “a single commuter switching his or her commute to public transportation can reduce a household’s carbon emissions by 10%, or up to 30% if he or she eliminates a second car. When compared to other household actions that limit CO2, taking public transportation can be 10 times greater in reducing this harmful greenhouse gas.[81] Given the United States has seen miles driven per capita decrease every year since 2004, it appears Americans are becoming more receptive to mass transit and collaborative consumption concepts, which is often referred to as the “sharing economy.”[82] With this in mind, the U.S. should promote car sharing, bike sharing, and carpooling as a means of both reducing congestion—in which, vehicles burn extra fuel and create emissions—and, making transportation energy more sustainable.

In terms of static energy, commercial and residential building codes must be mandated to require the use of energy efficiency technology in design and construction of new structures to reduce energy consumption over the life of the building. Additionally, renovations and major remodeling projects should be encouraged through tax incentives to upgrade old structures to meet modern efficiency standards.

In the industrial sector, national-level policy is necessary to stop utilities from impeding the installation of on-site CHP systems by industry. Reducing regulatory barriers and increasing public awareness would be important steps toward proliferating CHP technology in the industrial sector and realizing substantial efficiency gains. Of note, government incentives for industry to encourage the use of CHP technology are not necessary because these businesses are inherently focused on growing profits and reducing overall costs, to which CHP contributes. Rather, industry only needs increased awareness of the benefits of CHP and removal of regulatory barriers to installation.

Energy Markets

Policy elements: A focus on market-based operations is another powerful lever to enhance energy security and affordability. Energy sources are global commodities, though some energy markets are currently regional in their operation (electricity and natural gas, for example). In the future, it is likely that all energy markets will be global, although the electricity market likely will remain constrained to continental boundaries because of the physical limitations of transmitting electricity great distances (one possible exception to this limitation may be the trade of electricity between the European, Asian, and African continents where they come together geographically). It is important to note that energy security "refers to the uninterrupted availability of energy sources at affordable (or fair market) prices."[83] Consequently, energy security demands well-functioning global energy markets to connect sellers and buyers. In addition, functioning, transparent markets maximize competition and thus, affordability.

Oil will continue to be traded at spot prices for the foreseeable future, as the ability of the Organization of the Petroleum Exporting Countries (OPEC) to control the oil market has been limited by non-member suppliers. In contrast to the two oil shocks of the 1970s, OPEC no longer controls the world's spare production capacity, and therefore, has lost the ability to control prices by being "last to market." Also, starting in 2003, global demand for oil surged and the world's spare oil production capacity fell to very low levels. In fact, in some cases, demand exceeded total production capacity.[84] Since 2003, world oil prices have risen by nearly 400 percent while spare production capacity has remained uncomfortably low.[85] That said, high prices have stimulated new production. For example, oil prices over $90 a barrel have enabled the sustainment of unconventional oil production (e.g. fracking in North America and Canadian tar sands). As OPEC has lost its ability to control oil prices, consumers willing to purchase oil may do so, and global production capacity likely will continue to increase in response to strong demand and high prices – all indicators of functioning global markets.

Unlike oil, prices for natural gas vary significantly around the world and are often established by inefficient or less than transparent conditions. Natural gas prices are influenced by factors such as availability of and proximity to supply, infrastructure capacity, the price of oil or oil products, and severity of demand. They are also subject to socio-political factors such as subsidization, sanctions, and attempts by supplier and transit states to leverage power and influence over importing states. The United States has some of the lowest natural gas prices and some of the largest reserves in the world. It also has a vested interest in stabilizing global prices and ensuring liberal and transparent market conditions as its allies pay some of the world's highest prices in large part to preserve security of supply. Efforts are underway in both Europe and Asia to liberalize their respective markets, and the anticipated addition of new supplies coming online from North America, Australia, and eastern Africa, will catalyze this process by increasing market supply.

Like gas, the market for electricity is continental, and it too may undergo transformation. Current cross-border trade in electricity represents only a small portion of the total electricity produced – about 4.2 percent in 2013 for OECD nations.[86] Because of the difficulty in transmitting electricity efficiently over large distances, the trade in electricity is inherently local. In the North American market in 2013, only 1.5 percent of the total electricity produced was traded across national borders. In the European market, 10.7 percent was traded internationally, and in Asia, no electricity was traded internationally.[87] In the coming thirty five years, significant gains in electricity transmission efficiency are expected at the same time global demand for electricity is expected to double.[88] Because most of the growth in electricity demand will come from developing nations, and power generating stations require significant capital investments to install and considerable expertise to operate, developing nations will be enthusiastic customers for electricity exporting countries. The oceans likely will remain significant barriers to electricity export, but transmission between southern Europe and North Africa and from Southwest Asia to East Africa may well be possible. As these electricity markets develop, they will likely be similar in form and function to the Regional Transmission Organizations (RTOs) in North America or the Regional Wholesale Electricity Markets (RWEMs) in the European Union, but they will likely face new challenges, such as electricity theft, which is rampant in many underdeveloped and developing nations.

For all energy sources, the U.S. benefits from fully functioning, transparent markets that treat resources predominantly as global commodities with prices determined by supply and demand. Although markets cannot guarantee security of supply, they provide the best capability for the U.S. and its allies to acquire the energy they need at competitive prices.

Policy recommendations: There are a variety of options for U.S. policy makers to strengthen markets, but the biggest impacts would result from removing restrictions on the export of crude oil and natural gas. While this would not be a panacea, it would increase supply in energy markets, creating downward pressure on oil and gas prices. Additionally, it would provide increased domestic production that could be leveraged by the United States via the Defense Production Act during crises that could otherwise drain the Strategic Petroleum Reserve.[89] Further, U.S. oil and gas supplies being made available on world markets would provide allies in Asia and Europe a dependable stream of resources at market prices.

Export of crude oil also improves the strategic leverage of the United States in the geopolitical arena. While the U.S. government cannot necessarily determine who will receive the oil produced in the United States, the entry of U.S. crude oil into the international market mitigates the effects of global market disruptions and fluctuations (e.g. recent disruptions caused by unrest in Libya and threats to close the Strait of Hormuz by Iran). U.S. crude also could undermine the ability of petro states, like Russia, to use natural resources as a weapon. Moreover, because China is the world’s leading petroleum importer with increasing demand, U.S. exports would begin to give the United States a growing degree of leverage in its dealings with this regional competitor.

U.S. exports also would hamper the ability of OPEC and GECF--the oil and gas cartels--to achieve market dominance by cutting production. Indeed, following the row over Crimea, Russia now appears intent to strike a gas deal with China which could threaten the flow of gas to Europe. U.S. exports would provide European consumers with a hedge in the event Russia diverts volumes away from Europe.[90] Accordingly, the United States should expedite approval of LNG exports to non-free trade allies, like it recently did with India and Japan.[91]

In addition to increasing gas and oil exports, the United States should work with other economies to increase global supplies. The United States is currently working with the governments of China, India, Jordan, and Poland to assist in their development of unconventional natural gas resources.

The United States should expand this program to other potential gas exporters, such as Argentina and Mozambique, and promote business-to-business cooperation to expedite production in large demand-growth states like China and India.[92] The United States should also partner with Australia to promote liquidity and transparency in gas markets, and leverage its relationship with Qatar to do the same.[93] In addition to making markets more competitive, these actions also might help accelerate global movement away from coal to gas, thereby helping curb the growth of GHG emissions.

Refined oil products will remain critical to U.S. interests well into the future – especially for the Department of Defense. Unfortunately, U.S. refining capacity remains constrained by the supply of crude oil which can be delivered to refineries. The United States needs to invest in secure delivery mechanisms for crude oil. Relying on tanker ship deliveries to feed refining operations creates unnecessary vulnerabilities for the nation. Projects like the Keystone XL pipeline provide significant energy security for the U.S. at negligible impact to the environment, and produce significant economic value in the form of jobs and industrial production. Denying approval of the Keystone XL project for political reasons degrades national security and is not sound energy policy. Further, the lack of pipeline infrastructure results in gas and oil shipments being made via rail, which is significantly more risky than using pipeline networks. Continued delivery by rail risks accidents like the July 2013 explosion of a train carrying oil that killed 47 people in Quebec, Canada.[94] Approval for projects such as the Keystone XL pipeline should be granted immediately.

Energy Diversity

Policy elements: Energy diversification is a simple, but exceedingly important concept. While it may be politically, economically and/or environmentally expedient to utilize a single energy resource, over reliance on one or limited resources renders countries vulnerable to supply shocks and disruptions. That said, energy diversity prioritizes security and accepts that costs for energy may be higher than they otherwise might be to increase security.

Japan and the European Union learned the lesson of insufficient diversity the hard way. The March 2011 incident at Fukushima Daiichi exposed the Japan's overreliance on the nuclear power industry. As Japan shut down all of its nuclear plants in the wake of the accident, it had to abandon GHG emission goals when it reactivated mothballed coal and oil-fired power plants to meet electricity needs. Additionally, Japan was forced to pay high prices for LNG imports, which has caused an unfavorable shift in their trade balance and disruption of economic reform efforts in the three years since the accident. Similarly, in January 2009, several European states were literally left in the cold when Russia cut off natural gas supplies through Ukraine. Russia again exploited this European energy vulnerability in the Crimean and Ukraine crises of 2014. Closer to home, natural gas was, at times, unavailable in the northeast United States for power generation as supplies were prioritized for home heating during an uncharacteristically cold winter season. Luckily, excess power generation, predominantly from coal-fired plants, prevented power disruptions during the cold snap.

It is important to note that each fuel source has strengths and weaknesses for electricity generation. For example, nuclear power provides excellent base load generation with zero carbon emissions and high resistance to fuel disruption, but it is not flexible to electrical grid demand changes. Coal-fired generation provides responsive generation at low cost but has high GHG emissions. Renewable generation provides zero emission generation, but it is expensive and intermittent.

These examples illustrate the need for a diversified portfolio of energy sources. The 2013 production rates of various energy sources for electricity production are given in the top line of table 1. Over the past ten years, coal use for energy production in the United States has declined from 50 percent, oil has declined from 3 percent, natural gas has increased from 18 percent, and renewables have increased from 2 percent, while nuclear and hydro use have remained relatively constant.[95]

On the second line of table 1, the recommended targets for 2050 are based on an overall commitment for the United States to substantially reduce GHGs while not compromising energy security. To this end, coal only makes up 15 percent of the fuel used for electricity production and oil is eliminated as a feedstock for electricity; natural gas and nuclear expand to each supply approximately 30 percent of production demand. In 2050, hydro power reduces slightly to 5 percent of capacity as aging plants are taken offline without replacement, whereas other renewables expand significantly to account for as much as 20 percent of electricity production. With this energy mix, the United States will not be over reliant on any one energy source and could adjust production from one fuel source to another in the event of disruptions.

The largest long-term vulnerability with a recommended mix shown in table 1 would be the loss of nuclear capacity, because the electricity produced by nuclear plants provides base load supply. This vulnerability is mitigated because the peak-to-average electricity demand ratio in the United States is approximately 1.8, meaning peak demand exceeds average demand by 80 percent.[96] Because electricity producers maintain capacity to meet peak demand plus a reserve margin, there is sufficient spare capacity in the system to meet demand in the short term with the temporary loss of a significant base load provider. This loss would come at the expense of increased fuel and operating costs by the other providers, and with reduced reserve capacity to meet the demands imposed by extreme temperatures, but the system could meet most demands in such a case.

Table 1. U.S. Energy Production by Sector

	Coal	Oil	Natural Gas	Nuclear	Hydro	Renewable	Other
2013 (EIA data)[97]	39.1%	0.6%	27.4%	19.4%	6.6%	6.2%	0.2%
2050 (recommended)	5-15%	0%	30-40%	25-35%	5%	20-30%	nil

With respect to transportation fuels, motor gasoline accounts for 65 percent of fuel consumed, diesel approximately 21 percent of fuel consumed, jet fuel for 11 percent, and the remainder is made up of liquid petroleum gases and lubricants.[98] By 2050, diesel and gasoline will combine to account for only 50 percent of transportation fuels consumed, while natural gas and electricity will make up the other 50 percent. In this shift, natural gas will assume a major role powering railroad, long-haul over-the-road transportation, and short-distance fleet vehicles. Additionally, electric vehicles also will achieve significant penetration into the personal auto sector.

Policy recommendations: In terms of energy diversity for electricity production, the United States must commit to reducing coal's contribution to generation to no more than 15 percent of total production, while increasing nuclear power's contribution to 25-35 percent. This will substantially reduce overall GHG emissions from coal, but also minimize the use of natural gas fired plants for base load production.

One key aspect of a transition away from hydrocarbons to other fuel sources is to ensure the market reflects the true cost and actual impact of burning carbon-based fuels and emitting GHGs. Instituting a carbon tax or a "cap and trade" system is the only way to do this. If not done, it will be impossible to enable markets to send price signals that will make nuclear power and renewable sources economically viable. That said, these actions must be instituted carefully to ensure energy-intensive industries in the U.S. remain competitive and that costs are not overwhelming to consumers. This should be done while trying to rally international support for GHG emission ceilings, which will put U.S. companies on an equal footing with those of other countries. Of note, it likely will be very difficult to muster international cooperation, especially from developing countries with fast growing GHG emissions. On the consumer side, new efficiency initiatives like smart grid, demand response, and increased self-sufficiency via home-based renewables could help offset the increased costs for individual consumers.

Specific targets for renewable energy use in electricity production should not be made; instead, current emission reduction goals must be met by 2040, and violators must be subject to significant fines for non-compliance. This will allow the electricity market to find the most efficient means to meet the goals at the price consumers are willing to pay. Subsidizing renewable energy production skews market dynamics and damages the economic viability of other power producers. Diversity in supply is critical, and increasing reliance on renewables with subsidies can unbalance the nation’s energy portfolio.

Resiliency

Policy elements: Resiliency in the energy industry refers to the ability of the various sectors to respond to system breakdowns, disruptions, and attacks, while minimizing the impacts of the disturbance. Resiliency requires robust system designs with built-in redundancy to ensure local interruptions do not cascade into nation-wide system outages. Like diversity, resiliency sacrifices some affordability for a more secure and sustainable energy system.

Consequently, building resiliency requires investment in infrastructure and security. The U.S. electrical grid includes nearly a half million miles of lines, 5,800 power plants, and more than 140 million end-use customers.[99] The grid infrastructure is aging, and its ability to deliver uninterrupted service to businesses and homes is continually being stressed by periods of peak consumption. Although portions of the transmission grid are approaching 100 years in service, most of the system was designed to last only 40 to 50 years.[100]

In addition to age-related issues, the grid is increasingly vulnerable to attack and damage in both the physical and cyber realms. Of note, the sophisticated April 2013 attack on the Metcalf substation in San Jose, California highlighted physical vulnerabilities that must be corrected.[101] Adding physical barriers which preclude easy access to critical infrastructure not only prevents intentional malicious acts, it also helps guard against the effects of natural disasters.[102] Such security measures must be applied not only to the grid, but also to the critical infrastructure necessary for transportation, storage, and refining of petroleum products. Cyber security improvements will also increase resiliency. As all aspects of the energy industry become more integrated through the cyber domain, the requirement to secure energy related networks grows. In fact, the National Research Council has identified protecting energy infrastructure as one of the 14 most important technical initiatives across all infrastructure.[103] Malicious actors in the future will surely attempt to exploit any system vulnerabilities; therefore, cyber security is as important to building and maintaining resiliency as physical security.

Policy recommendations: The U.S. electrical grid is at significant risk from physical and cyber-attack and requires modernization of much of its infrastructure. Policy should require utilities and transmission operators to invest in and harden the grid. Automobile manufacturers provide an excellent analogue as national policy requires automobile manufacturers to invest in improving vehicle efficiency--individual consumers are not able to make such investments, so the responsibility to achieve gains must fall on producers.

Additionally, the United States should mandate full implementation of a national smart grid by 2050 for efficiency and resiliency gains. This smart grid uses digital technology to enable two-way communication between utilities and consumers, and sensing along transmission lines.[104] In terms of efficiency, the smart grid would move electricity with reduced transmission losses and allow for more effective demand response, thereby reducing costs for producers and consumers. In terms of resiliency, the smart grid would allow for quicker fault detection and isolation--whether caused by cyber or physical attack, or natural disaster--and quicker restoration of power following disturbances. Policy also should direct DOE to plan and conduct rigorous exercises that test the resilience of the grid against forces capable of crippling electricity distribution. These exercises should expand beyond the U.S. into Canada and Mexico to ensure vulnerabilities are not introduced from outside the nation's borders.

Further, the smart grid also would more effectively integrate small power producers and microgrids to further increase resiliency. Allowing easier integration of small producers to connect to the grid – to include home and business-based renewables, for example – and to sell excess electricity to the grid will encourage self-sufficiency. Local and small-scale self-sufficiency also contributes to resiliency as distributed generation reduces the overall impact of grid related service interruptions. Finally, the smart grid would also allow for the use of innovative storage ideas, to include using electric car batteries to serve as energy storage for home use in times of electricity service interruption.

Finally, non-electrical infrastructure, to include refineries and pipelines, also must be better secured. Past natural disasters, like Hurricane Katrina, have revealed the low excess production capacity maintained by U.S. refineries.[105] Recent increases in domestic oil production have sparked renewed investment in U.S. refining capacity, but more must be done.[106] As relatively small margins of production versus demand remain, the loss of refinery or pipeline infrastructure could cause price spikes for refined petroleum products. To build resiliency against these spikes, policy must demand continued investment in the physical security of this infrastructure.

R&D

Policy elements: Research and development to stimulate technological advances has great promise to positively affect energy security, sustainability, and affordability. Unfortunately, breakthroughs from R&D efforts are impossible to predict, both in importance and when they will occur, so R&D spending often becomes an easy target for reduction when discretionary funding constraints are imposed.

On the positive side, the U.S. Federal Government has created an extensive public-private energy R&D partnership between the Department of Energy, academia, industry, private investors, and national laboratories. This network has been responsible for developing meaningful future energy technology through experimental and applied research across the energy industry. Since 2010, funding for overall energy R&D as a percentage of the total federal R&D budget increased from 13 percent to 19.3 percent, for a total of $12 billion spent in 2013.[107] Within this vast energy research and development system, the Advanced Research Projects Agency-Energy (ARPA-E) "supports research of potentially high commercial impact that the private sector deems too risky for investment."[108] It provides the ideal environment, and the only environment in some cases, for very early-stage innovation to take place. However, ARPA-E accounts for only about 2% of the Department of Energy R&D budget, or just under $345 million for 2014.[109]

Policy recommendations: Despite increasing pressure from a growing national debt and sustained deficit spending, the United States must stay committed to investing in energy R&D, especially in the "high risk, high reward" space of new technology development.[110] As but one example, in the transportation sector, the commercial viability of electric vehicles, advanced lightweight materials, and advanced combustible engines will not be realized without further research, technological breakthroughs, and the emergence of mass-production techniques for these high technology products. These barriers also exist for many other potentially promising technologies like: small, modular nuclear reactor designs and the potential to make use of new nuclear fuels, like thorium; hydrogen fuel cells to power vehicles and homes; nuclear fusion to produce electricity; algae to produce bio-fuels; hyper-efficient batteries; wave or tidal energy for electricity production; and non-water based hydraulic fracturing technologies, just to name a few.

DoD Specifics

As the U.S. government's largest energy consumer, the Department of Defense can be seen as an analogue of the United States with respect to energy consumption. As such, policies that work for the DoD may translate well to the national level. While in times of crises the DoD will do what is needed to accomplish the mission, it is also investing in a long-term energy strategy with the same policy ends as the nation. Through the Operational Energy Strategy (OES), the DoD is working "to transform the way the Department consumes energy in military operations."[111] The strategy acknowledges that the armed forces' growing demand for energy limits operational possibilities, imposes high costs on the taxpayer, and exposes forces to increased risks to life and mission. The OES ultimately seeks to ensure the energy needs of U.S. forces are met through the implementation of three goals. The first goal is to reduce the military's demand for energy calling for "more fight, less fuel."[112] The second goal is to create depth amongst the sources of supply for military operations seeking "more options, less risk."[113] The third goal seeks to infuse energy security into the design and development of the future force building "more capability, less cost."[114] For example, many similar concepts are being integrated into the DoD as previously recommended in this paper: energy use consideration in the design and acquisition of military systems (integrative design); microgrids using renewable sources for forward operating bases; testing of bio-fuels in military vehicles; and, production of electricity using on-base sources (renewables and CHP) in the U.S., just to name a few.[115]

Policy Resourcing

Many of the policies described in this paper require resources for implementation. Given the fiscal challenges the U.S. is facing, these energy policies must be implemented in a "budget neutral" fashion. Thus, the following discussion follows the same structure as the policy elements and recommendations, and highlights areas of revenue collection and expenditure. Of note, the U.S. may consider an "Energy Trust Fund," similar to the existing Highway Trust Fund for escrowing revenues, paying costs, and creating a sustainable source of funding for future energy investments.

Efficiency: Some of the policies requiring gains in energy efficiency will cost the U.S. government, but the preponderance will fall on manufacturers and consumers. That said, gains in efficiency will provide incentives for consumers as they lower their energy costs. Unfortunately, the time required to recoup the investment of inefficient technology often dissuades many. As noted before, for new buildings and vehicles, efficiency initiatives would be mandated. For existing structures and vehicles, incentives which encourage consumers to make the initial investment, such as tax credits and technology adoption subsidies may be appropriate. After a grandfathering period, non-compliance fees for older vehicles and buildings which do not meet modern efficiency standards can help offset the cost of subsidies and serve as a motivator to speed adoption of the energy efficient technology by consumers. Of note, the industrial sector will benefit significantly from reduced energy costs by adopting CHP technology. Allowing accelerated depreciation of such investments will likely provide the necessary incentive for industry to move forward while minimizing the overall cost to government.

Markets: The recommended policies regarding markets would provide revenue to pay for many of the other policy recommendations. Exports of domestic oil and gas resources will provide increased and new revenue streams from tax receipts and extraction royalties. Approval of pipeline projects requires little in the way of fiscal resources, as those companies involved in the projects are responsible for construction and right-of-way costs.

Diversity: The recommended policies regarding markets will affect both government revenues and expenditures. On the revenue side, a carbon tax or cap and trade system would provide the government revenues to fund other energy projects, while reducing GHG emissions.[116] Additionally, higher electricity costs would be passed on to consumers to pay for more diverse electricity generation. This is important as failing to ensure energy consumers bear the fully burdened cost of energy will undermine many of the other policy initiatives proposed, especially those intended to increase energy efficiency. On the expenditures side, the government can help the transition to renewable sources and emission reducing producers by allowing accelerated depreciation of capital investments.

Resiliency: Investment in national energy infrastructure is a cost that must be borne by market participants. Power producers, utilities, transmission companies, and consumers all benefit from a reliable and resilient grid. The government can facilitate the infrastructure investment by providing low cost or government backed loans to fund construction and modernization, but ultimately the cost of delivering electricity over a secure grid must be borne by the producers and passed on to the consumers.

R&D: The greatest area for government spending contribution is in the funding of innovation, research, and development of new energy technology. Smart policy supports cutting-edge research and development across academic, industry, and government agencies. Organizations such as ARPA-E and the national laboratories must continue to facilitate the development of new energy technology via government grants and loan guarantees.

Conclusion

The energy industry touches all aspects of American life. It powers the economy, enables freedom of movement, and connects the nations of the world. The United States cannot have lasting national security without achieving energy security, and must do so in a sustainable and affordable way. To achieve these ends, the United States must take full advantage of efficiency measures, which are the “cheapest” energy available and can affect security, sustainability, and affordability. While the world’s demand for energy is rising, achieving energy security is still possible, and leveraging economic forces is an efficient way to achieve this security. Consumers must know and bear the cost of the energy they consume, and must contribute to mitigating the environmental damage that is caused by energy production. Functioning global energy markets are necessary to ensure all have access to energy resources at market prices. Additionally, a balanced and diverse national energy portfolio is required to ensure supply disruptions or infrastructure damage does not cause lasting, nation-wide harm. Further, a resilient energy industry is necessary, because threats to creating and maintaining energy security will continue to emerge. Finally, continued research and development into energy technology has the potential to positively affect our energy future, and must be continued. In the end, implementing and resourcing the policies recommended by this paper will contribute to creating a secure energy future for the United States.

NOTES

1. U.S. Energy Information Administration, *April 2014 Monthly Energy Review*, DOE/EIA-0035, April 2014, 23.

2. U.S. Energy Information Administration, “Electricity Data Browser, Net Generation by Energy Source: Total-All Sectors,” http://www.eia.gov/electricity/data/browser/#/topic/0?agg=2,0,1&fuel=vvg&geo=g&sec=g&linechart=ELEC.GEN.ALL-US-99.M~ELEC.GEN.COW-US-99.M~ELEC.GEN.NG-US-99.M~ELEC.GEN.NUC-US-99.M~ELEC.GEN.HYC-US-99.M&columnchart=ELEC.GEN.ALL-US-99.M~ELEC.GEN.COW-US-99.M~ELEC.GEN.NG-US-99.M~ELEC.GEN.NUC-US-99.M~ELEC.GEN.HYC-US-99.M&map=ELEC.GEN.ALL-US-99.M&freq=M&ctype=linechart&ltype=pin&pin=&rse=0&maptype=0, (accessed April 29, 2014).

3. Ibid.

4. Information Digest, "Section 3: Nuclear Reactors," 2013–2014 (NUREG-1350) 25: 3, http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1350/v25/sr1350v25-sec-3.pdf, (accessed April 29, 2014), 5-6; and U.S. Energy Information Administration, "What is the Status of the U.S. Nuclear Industry?" http://www.eia.gov/energy_in_brief/article/nuclear_industry.cfm, (accessed April 29, 2014).

5. Information Digest, "Section 3: Nuclear Reactors," 2013–2014 (NUREG-1350) 25: 3, 5-6. http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1350/v25/sr1350v25-sec-3.pdf, (accessed April 29, 2014), 38 and 50-52.

6. U.S. Energy Information Administration, "AEO 2014 Early Release Overview," http://www.eia.gov/forecasts/aeo/er/pdf/0383er(2014).pdf, (accessed April 29, 2014), 14.

7. World Nuclear Association, “Three Mile Island Accident,” January 2012, http://www.world-nuclear.org/info/Safety-and-Security/Safety-of-Plants/Three-Mile-Island-accident/, (accessed May 5, 2014).

8. Ibid.

9. World Nuclear Association, “Fukushima Accident,” April 22, 2014, http://www.world-nuclear.org/info/Safety-and-Security/Safety-of-Plants/Fukushima-Accident/, (accessed May 5, 2014).

10. Ibid.

11. Nuclear Energy Institute, *Perspective on Public Opinion October*, 2013, http://www.emagcloud.com/et/POPO_2013/index.html#/2/, (accessed May 5, 2014), 3.

---

12. Buy Clean Energy, “Why Clean Energy,” http://buycleanenergy.org/why, (accessed April 29, 2014).

13. Kenneth Bossong, “Renewable Energy Provides 14% of US Electrical Generation during First Half of 2013,” Renewable Energy World.com, August 27, 2013, http://www.renewableenergyworld.com/rea/news/article/2013/08/renewable-energy-tops-14-of-us-electrical-generation-during-first-half-of-2013, (accessed April 29, 2014).

14. U.S. Energy Information Administration, “U.S. Natural Gas Marketed Production,” http://www.eia.gov/dnav/ng/hist/n9050us2a.htm, (accessed April 29, 2014); and U.S. Energy Information Administration, *U.S. Crude Oil and Natural Gas Proved Reserves, 2012,* (Washington, DC: U.S. Department of Energy, April 2014), 12.

15. U.S. Energy Information Administration, “U.S. Field Production of Crude Oil,” http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=MCRFPUS1&f=A, (accessed April 29, 2014).

16. U.S. Energy Information Administration, “Top World Oil Consumers, 2012 [sidebar],” http://www.eia.gov/countries/index.cfm?topL=con, (accessed May 6, 2014).

17. U.S. Energy Information Administration, “How dependent is the United States on foreign oil?” http://www.eia.gov/tools/faqs/faq.cfm?id=32&t=6, (accessed May 6, 2014).

18. U.S. Energy Information Administration, “AEO 2014 Early Release Overview, Electricity Generation,” http://www.eia.gov/forecasts/aeo/er/early_elecgen.cfm?src=Coal-b5, (accessed April 29, 2014).

19. Ibid.

20. U.S. Energy Information Administration, “Quarterly Coal Report,” March 28, 2014, http://www.eia.gov/coal/production/quarterly/?src=Coal-b2, (accessed April 29, 2014).

21. U.S. Environmental Protection Agency, “Mercury and Air Toxics Standards (MATS), Basic Information,” http://www.epa.gov/airquality/powerplanttoxics/basic.html, (accessed April 29, 2014).

22. U.S. Energy Information Administration, “Coal-fired Power Plant Operators Consider Emissions Compliance Strategies,” March 28, 2014, http://www.eia.gov/todayinenergy/detail.cfm?id=15611, (accessed April 29, 2014).

23. Offshore Technology Conference 2010 Show Newspaper, “Straight talk from an insider,” May 4, 2010, 3.

24. Ibid, 3.

---

25. Barrack Obama, “Remarks by the President on America’s Energy Security,” March 30, 2011, http://www.whitehouse.gov/the-press-office/2011/03/30/remarks-president-americas-energy-security, (accessed April 20, 2014).

26. *2010 National Security Strategy*, May 2010, http://www.whitehouse.gov/sites/default/files/rss_viewer/national_security_strategy.pdf, (accessed April 20, 2014), 8.

27. Ibid, 9.

28. Ibid, 10.

29. Ibid, 47.

30. Ibid, 47.

31. American Council on Renewable Energy, *U.S. Department of Defense & Renewable Energy: An Industry Helping the Military Meet Its Strategic Energy Objectives*, January 2012, http://www.acore.org/wp-content/uploads/2012/01/DoD-Renewable-Energy-Primer.pdf, (accessed April 20, 2014), 1.

32. Department of Defense Directive 4180.01, “DoD Energy Policy,” April 16, 2014, http://www.dtic.mil/whs/directives/corres/pdf/418001_2014.pdf, (accessed April 20, 2014).

[33] *See* Department of Defense, *Quadrennial Defense Review 2014*. *See also* Center Naval Analyses Military Advisory Board, *National Security and the Accelerating Risks of Climate Change* (May 2014) (hereinafter “CNA”).

34. U.S. Energy Information Administration, “International Energy Outlook 2013,” DOE/EIA-0484, 2013, http://www.eia.gov/forecasts/ieo/pdf/0484(2013).pdf, 10.

35. Ibid, 2.

36. OECD Nuclear Energy Agency, “Nuclear Energy and Renewables, System Effects in Low-Carbon Electricity Systems, Executive Summary” 2012, http://www.oecd-nea.org/ndd/reports/2012/system-effects-exec-sum.pdf, 7-8.

37. Ibid, 8.

38. Luke Currin, “Writing Off Germany’s Energiewende as a Failure is Unwise,” The Energy Collective, March, 17, 2014, http://theenergycollective.com/lucurrin/353761/writing-germanys-energiewende-failure-unwise, (accessed April 29, 2014).

39. Aquastat, Food and Agriculture Organization of the United Nations, "Water Uses,” http://www.fao.org/nr/water/aquastat/water_use/index.stm, (accessed April 23, 2014).

---

40. Chesapeake Energy, “*Water Use in Marcellus Deep Shale Gas Exploration*,” May 2012, 1.

41. U.S. Energy Information Administration, “Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States,” June 2013, http://www.eia.gov/analysis/studies/worldshalegas/, tables 5 and 6.

42. World Resources Institute, Aqueduct, http://www.wri.org/our-work/project/aqueduct/aqueduct-atlas, (accessed May 5, 2014).

43. International Energy Agency. *World Energy Outlook 2012*, (Paris, France: International Energy Agency, 2012), 504.

44. U.S. Energy Information Administration, “Saudi Arabia,” http://www.eia.gov/countries/cab.cfm?fips=SA, (accessed May 6, 2014).

45. U.S. Energy Information Administration, *Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States* (Washington, DC: U.S. Department of Energy, June 2013), 13.

46. U.S. Energy Information Administration, “Today in Energy, U.S. Boosts Natural Gas Output and Use Since 2005, while OECD Europe Scales Back,” January 14, 2014, http://www.eia.gov/todayinenergy/detail.cfm?id=14591, (accessed April 29, 2014).

47. U.S. Energy Information Administration, *Natural Gas Monthly*, December 2013, (Washington, DC: U.S. Department of Energy, December 2013), 9.

48. Michael Ratner and others, *U.S. Natural Gas Exports: New Opportunities, Uncertain Outcomes* (Washington, DC: Congressional Research Service, September 17, 2013), 22.

49. U.S. Energy Information Administration, *Updated Capital Cost Estimates for Utility Scale Electricity Generating Plants*, (Washington, DC: U.S. Department of Energy, April 2013), 2-3.

50. U.S. Energy Information Administration, *Annual Energy Outlook 2014 Early Release Overview* (Washington, DC: U.S. Department of Energy, December 16, 2013), 11.
51. Ibid, 6.

52. U.S. Energy Information Administration, “U.S. Natural Gas Vehicle Fuel Consumption,” http://www.eia.gov/dnav/ng/hist/n3025us2m.htm, (accessed April 25, 2014).

53. Brad Plumer, “Coming R&D Crash,” The Washington Post Wonkblog, February 26, 2013, http://www.washingtonpost.com/blogs/wonkblog/wp/2013/02/26/the-coming-rd-crash/, (accessed May 13, 2014).

---

54. Kevin Bullis, “Energy Funding Outlook Looks Bleak as Obama Begins Second Term,” MIT Technology Review, February 1, 2013, http://www.technologyreview.com/news/510326/energy-funding-outlook-looks-bleak-as-obama-begins-second-term/, (accessed May 13, 2014).

55. Consider, for example, the most recent failure (May 2014) of the Senate to pass a relatively simple energy efficiency bill with strong bipartisan support. The bill was designed to reduce residential energy consumption, utility bills, and carbon footprints by making it easier for homeowners to purchase smart water heaters, and cheaper for manufactures to build efficient cooling and heating systems. According to the spokesman for the ranking Republican on the Senate’s Energy Committee, “it’s embarrassing that even an energy-efficiency bill can’t get past the floor.” Coral Davenport, “Amid Pipeline and Climate Debate, Energy-Efficiency Bill is Derailed,” The New York Times (May 12, 2014) http://www.nytimes.com/2014/05/13/us/politics/bill-to-encourage-energy-efficiency-fails-in-senate.html?_r=0

56. Robert McNally, "Energy Markets, Policy, and Geopolitics," (lecture, The Eisenhower School, National Defense University, Washington, DC, April 23, 2014, cited with permission of Mr. McNally); and U.S. General Accounting Office, *Energy Task Force: Process Used to Develop the National Energy Policy*, GAO-03-894 (Washington, DC: U.S. Government Accounting Office, August 2003), 4.

57. The White House, “The Obama Energy Agenda: Gas Prices," http://www.whitehouse.gov/energy/gasprices, (accessed April 23, 2014).

58. U.S. Energy Information Administration, “International Energy Statistics – Energy Intensity,” http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=92&pid=46&aid=2&cid=regions&syid=1980&eyid=2011&unit=BTUPUSDM, (accessed April 25, 2014; Energy Intensity using Market Exchange Rates versus BTU per Year in 2005 U.S. Dollars data extracted from the interactive data generator).

59. Daniel Yergin, *The Quest: Energy, Security and the Remaking of the Modern World*, (New York: The Pentagon Press, 2011), 614.

60. Amory Lovins, *Reinventing Fire: Bold Business Solutions for the New Energy Era*, (White River Junction: Chelsea Green Publishing, 2011), 95.

61. U.S. Environmental Protection Agency, “Sources of Greenhouse Gas Emissions,” http://www.epa.gov/climatechange/ghgemissions/sources/transportation.html, (accessed April 28, 2014).

62. U.S. Energy Information Administration, *Annual Energy Outlook, 2013*, (Washington, DC: U.S. Department of Energy, April 2013), 80.

---

63. U.S. Energy Information Administration, "Petroleum & Other Liquids, U.S. Imports by Country of Origin," http://www.eia.gov/dnav/pet/pet_move_impcus_a2_nus_epc0_im0_mbblpd_a.htm, (accessed April 28, 2014).

64. The White House, *Driving Efficiency: Cutting Costs for Families at the pump and Slashing Dependence on Oil*, http://www.whitehouse.gov/sites/default/files/fuel_economy_report.pdf, 3.

65. Rocky Mountain Institute, *Eliminating Oil for Transportation by 2050,* www.rmi.org/transportation, (accessed May 13, 2014).

66. U.S. Department of Energy, *Advanced Combustion Engine R&D: Goals, Strategies and Top Accomplishments*, DOE/GO-102009-2762, March 2009, 1; and The White House, *Driving Efficiency: Cutting Costs for Families at the Pumps and Slashing Dependence on Oil*, http://www.whitehouse.gov/sites/default/files/fuel_economy_report.pdf, 2-3.

67. U.S. Department of Energy, "Vehicle Technologies Office: Moving America Forward with Clean Vehicles," http://energy.gov/eere/vehicles/vehicle-technologies-office-moving-america-forward-clean-vehicles, (accessed May 13, 2014).

68. Amory Lovins, *Reinventing Fire: Bold Business Solutions for the New Energy Era*, (White River Junction: Chelsea Green Publishing, 2011), 79-80.

69. A. Goldberg, R. Taylor, and B. Hedman, *Industrial Energy Efficiency: Designing Effective State Programs for the Industrial Sector*, State and Local Energy Efficiency Action Network, March 18, 2014, ES-1.

70. Amory Lovins, *Reinventing Fire: Bold Business Solutions for the New Energy Era*, (White River Junction: Chelsea Green Publishing, 2011, 131.

71. Ibid, 136-137; and U.S. Department of Energy and U.S. Environmental Protection Agency, *Combined Heat and Power: A Clean Solution*, August 2012, 3.

72. U.S. Department of Energy, U.S. Environmental Protection Agency, *Combined Heat and Power: A Clean Solution*, August 2012, 3.

73. Amory Lovins, *Reinventing Fire: Bold Business Solutions for the New Energy Era*, (White River Junction: Chelsea Green Publishing, 2011, 138.

74. Rocky Mountain Institute, *Autocomposites Workshop Report, Kickstarting the Widespread Adoption of Automotive Carbon Fiber Composites*, January 2013, 4.

75. U.S. Department of Energy, *Materials Technologies: Goals, Strategies, and Top Accomplishments*, August 2010, 1; and Christopher Knittel, *Automobiles on Steroids: Product*

Attribute Trade Off and Technological Progress in the Automobile Sector, American Economic Review, December 2011, 3369.

76. Rocky Mountain Institute, *Eliminating Oil for Transportation by 2050*, www.rmi.org/transportation, (accessed May 13, 2014).

77. Rocky Mountain Institute, *Autocomposites Workshop Report, Kickstarting the Widespread Adoption of Automotive Carbon Fiber Composites*, January 2013, 4.

78. U.S. Department of Energy, "Vehicle Technologies Office: Plug-in Electric Vehicles and Batteries," http://energy.gov/eere/vehicles/vehicle-technologies-office-plug-electric-vehicles-and-batteries, (accessed May 13, 2014).

79. National Center for Policy Analysis, "Corn-based Ehtanol Production Should Cease," January 24, 2013, http://www.ncpa.org/sub/dpd/index.php?Article_ID=22773, (accessed May 13, 2014).

80. American Public Transportation Association, "Public Transportation Benefits," http://www.apta.com/mediacenter/ptbenefits/pages/default.aspx, (accessed May 13, 2014).

81. Ibid.

82. U.S. Policy Interest Research Group, "Millennials Lead Change in Transportation Trends; Government Should Reassess Transportation Policies," May 4, 2013, http://www.uspirg.org/news/usp/new-report-reduction-driving-likely-continue, (accessed May 13, 2014).

83. International Energy Agency, "Topic: Energy Security," http://www.iea.org/topics/energysecurity/, (accessed April 27, 2014).

84. U.S. Energy Information Administration, "Energy & Financial Markets, What Drives Crude Oil Prices?" http://www.eia.gov/finance/markets/supply-opec.cfm, (accessed April 27, 2014).

85. U.S. Energy Information Administration, "Short-Term Energy and Summer Fuels Outlook, Real Prices Viewer," http://www.eia.gov/forecasts/steo/realprices/ (accessed May 13, 2014); and Ibid.

86. International Energy Agency, "Monthly Electricity Statistics," January 2014, http://www.iea.org/stats/surveys/mes.pdf, 5.

87. Ibid, 2-4.

88. U.S. Energy Information Administration, "International Energy Outlook 2013," DOE/EIA-0484, 2013, http://www.eia.gov/forecasts/ieo/pdf/0484(2013).pdf, 12.

---

89. Kenneth Medlock III, “Are Global Natural Gas Markets in a Period of Transition? The Magic 8-Ball Says . . .” Forbes, Feb. 27, 2014, http://www.forbes.com/sites/thebakersinstitute/2014/02/27/are-global-natural-gas-markets-in-a-period-of-transition-the-magic-8-ball-says/.

90. Michael Wara, “America’s Natural Gas Lever,” The New York Times, March 7, 2014, http://www.nytimes.com/2014/03/08/opinion/americas-natural-gas-lever.html?_r=0.

91. Black & Veatch, “DOE Issues Second LNG Export Permit,” June 202, http://bv.com/energy-strategies-report/june-2013-issue/doe-issues-second-lng-export-permit, (accessed May 13, 2014).

92. The Unconventional Gas Technical Engagement Program is managed by the Department of State. *See* http://www.state.gov/s/ciea/ugtep/index.htm.

93. According to industry sources, 65% of the future production from Australia’s massive Gorgon project has already been allocated to long-term contracts that are indexed to the price of oil.

94. Lynn Doan, Joe Carroll, and Jim Snyder, “Rail Disasters Prompt U.S. Crackdown on Risky Oil Shipments,” Bloomberg Businessweek, February, 26, 2014, http://www.businessweek.com/news/2014-02-25/oil-by-rail-accidents-prompt-u-dot-s-dot-to-require-more-tests-of-crude, (accessed May 13, 2014).

95. US. Energy Information Administration, “Net Generation by Energy Source: Total (All Sectors), 2004-February 2014,” http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_1_1, (accessed April 29, 2014).

96. U.S. Energy Information Administration, “Today in Energy, Peak-to-Average Electricity Demand Ratio Rising in New England and Many Other U.S. Regions,” February 18, 2014, http://www.eia.gov/todayinenergy/detail.cfm?id=15051#tabs_SpotPriceSlider-8, (accessed April 29, 2014).

97. U.S. Energy Information Administration, “Net Generation by Energy Source: Total (All Sectors), 2004-February 2014,” http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_1_1, (accessed April 29, 2014).

98. U.S. Energy Information Administration, “April 2014 Monthly Energy Review, Table 3.7C Petroleum Consumption: Transportation and Electric Power Sectors,” http://www.eia.gov/totalenergy/data/annual/index.cfm#petroleum, (accessed April 29, 2014).

99. Executive Office of the President, *Economic Benefits of Increasing Electric Grid*

Resilience to Weather Outage, August 2013, http://energy.gov/sites/prod/files/2013/08/f2/Grid%20Resiliency%20Report_FINAL.pdf, (accessed February 27, 2014).

100. United States Government Accountability Office, Report to Congressional Requesters, *Climate Change*, *Energy Infrastructure Risks and Adaptation Efforts*, GAO-14-74, January 2014, http://www.gao.gov/assets/670/660558.pdf, (accessed March 3, 2014).

101. On April 16, 2013, small arms fire at the Metcalf substation knocked out 17 transformers in less than 20 minutes. It took workers nearly a month to bring the station back into service. The attack was well planned, with the perpetrators also severing fiber optic communication cables to delay substation system self-diagnostic reporting of malfunctions. For more information, see here: http://online.wsj.com/news/articles/SB10001424052702304851104579359141941621778.

102. Consider, for example, the devastating impact of the 2011 tsunami in Japan and Hurricanes Katrina and Sandy on energy infrastructure. According to the recently released National Climate Assessment, extreme weather events will pose an increasing threat to U.S. energy infrastructure, particularly infrastructure located on or near the coastlines. J. Dell, S. Tierney, G. Franco, R. G. Newell, R. Richels, J. Weyant, and T. J. Wilbanks, 2014: Ch. 4: Energy Supply and Use. *Climate Change Impacts in the United States: The Third National Climate Assessment*, 115-16. *See also* CNA, 4.

103. U.S. Department of Energy, “Energy Delivery Systems Cybersecurity,” http://energy.gov/oe/services/technology-development/energy-delivery-systems-cybersecurity, (accessed May 13, 2014).

104. U.S. Department of Energy, “What is the Smart Grid?” Smartgrid.gov, https://www.smartgrid.gov/the_smart_grid, (accessed May 13, 2014).

105. Richard Karp and Esther Pan, “Katrina and Oil Prices,” Council on Foreign Relations, September 7, 2005, http://www.cfr.org/world/katrina-oil-prices/p8834, (accessed May 13, 2014).

106. Clifford Krauss, “Domestic Crude Oil Drives a Cautious Refining Revival,” The New York Times, March 3, 2014, http://www.nytimes.com/2014/03/04/business/energy-environment/oil-boom-is-driving-a-revival-in-refining.html?_r=0.

107. Office of Science and Technology Policy, "2013 R&D Budgets," The White House, http://www.whitehouse.gov/administration/eop/ostp/rdbudgets/2013, (accessed May 6, 2014).

108. Statement of the Honorable Steven Chu before the Committee on Energy and Natural Resources, U.S. Senate, 111th Congress, second session, January 21, 2010, 56.

---

109. Advanced Research Projects Agency-Energy, "ARPA-E FY2014 Budget Request." Department of Energy, http://arpa-e.energy.gov/?q=arpa-e-site-page/arpa-e-budget, (accessed March 21, 2014).

110. In addition to enhancing energy security, such investments will also (and are necessary to) reduce GHG emissions. *See* H. D. Jacoby, A. C. Janetos, R. Birdsey, J. Buizer, K. Calvin, F. de la Chesnaye, D. Schimel, I. Sue Wing, R. Detchon, J. Edmonds, L. Russell, and J. West, 2014: Ch. 27: Mitigation. *Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., p. 657.

111. Operational energy is defined as the “energy required for training, moving, and sustaining military forces and weapons platforms for military operations; U.S. Department of Defense, *Energy for the Warfighter: Operational Energy Strategy*, May 2011, 1.

112. Ibid, 1.

113. Ibid, 1.

114. Ibid, 1.

115. According to the Center for Naval Analyses, “it makes sense to continue investing in alternative and renewable energy sources. By reducing our dependence on a single fuel source, such as fossil fuels, these efforts make our bases more operationally resilient and our fighting forces more effective.” CNA, p. 24.

116. H.D. Jacoby et al., p. 653.

BIBLIOGRAPHY

Advanced Research Projects Agency-Energy, "ARPA-E FY2014 Budget Request." Department of Energy, http://arpa-e.energy.gov/?q=arpa-e-site-page/arpa-e-budget.

American Council on Renewable Energy, *U.S. Department of Defense & Renewable Energy: An Industry Helping the Military Meet Its Strategic Energy Objectives*, January 2012, http://www.acore.org/wp-content/uploads/2012/01/DoD-Renewable-Energy-Primer.pdf.

American Public Transportation Association, “Public Transportation Benefits,” http://www.apta.com/mediacenter/ptbenefits/pages/default.aspx.

Aquastat, Food and Agriculture Organization of the United Nations, "Water Uses,” http://www.fao.org/nr/water/aquastat/water_use/index.stm.

Black & Veatch, “DOE Issues Second LNG Export Permit,” June 202, http://bv.com/energy-strategies-report/june-2013-issue/doe-issues-second-lng-export-permit.

Bossong, Kenneth, “Renewable Energy Provides 14% of US Electrical Generation during First Half of 2013,” Renewable Energy World.com, August 27, 2013, http://www.renewableenergyworld.com/rea/news/article/2013/08/renewable-energy-tops-14-of-us-electrical-generation-during-first-half-of-2013.

Bullic, Kevin, “Energy Funding Outlook Looks Bleak as Obama Begins Second Term,” MIT Technology Review, February 1, 2013, http://www.technologyreview.com/news/510326/energy-funding-outlook-looks-bleak-as-obama-begins-second-term/.

Buy Clean Energy, “Why Clean Energy,” http://buycleanenergy.org/why.

Chesapeake Energy, “*Water Use in Marcellus Deep Shale Gas Exploration*,” May 2012.

Currin, Luke, “Writing Off Germany’s Energiewende as a Failure is Unwise,” The Energy Collective, March, 17, 2014, http://theenergycollective.com/lucurrin/353761/writing-germanys-energiewende-failure-unwise.

Doan, Lynn, Carroll, Joe, and Snyder, Jim, “Rail Disasters Prompt U.S. Crackdown on Risky Oil Shipments,” Bloomberg Businessweek, February, 26, 2014, http://www.businessweek.com/news/2014-02-25/oil-by-rail-accidents-prompt-u-dot-s-dot-to-require-more-tests-of-crude.

Executive Office of the President, *Economic Benefits of Increasing Electric Grid Resilience to Weather Outage*, August 2013, http://energy.gov/sites/prod/files/2013/08/f2/Grid%20Resiliency%20Report_FINAL.pdf.

Global Carbon Project, Global Carbon Budget 2013, http://www.globalcarbonproject.org/carbonbudget/.

Goldberg, A., Taylor, R., and Hedman, B., *Industrial Energy Efficiency: Designing Effective State Programs for the Industrial Sector*, State and Local Energy Efficiency Action Network, March 18, 2014.

Information Digest, "Section 3: Nuclear Reactors," 2013–2014 (NUREG-1350) 25: 3, http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1350/v25/sr1350v25-sec-3.pdf.

International Energy Agency, "Gas to Coal Competition in the U.S. Power Sector," http://www.iea.org/publications/insights/insightpublications/CoalvsGas_FINAL_WEB.pdf

International Energy Agency, "Monthly Electricity Statistics," January 2014, http://www.iea.org/stats/surveys/mes.pdf.

International Energy Agency, "Topic: Energy Security," http://www.iea.org/topics/energysecurity/.

International Energy Agency. *World Energy Outlook 2012*, (Paris, France: International Energy Agency, 2012).

Karp, Richard and Pan, Esther, "Katrina and Oil Prices," Council on Foreign Relations, September 7, 2005, http://www.cfr.org/world/katrina-oil-prices/p8834.

Knittel, Christopher, *Automobiles on Steroids: Product Attribute Trade Off and Technological Progress in the Automobile Sector*, American Economic Review, December 2011.

Krauss, Clifford, "Domestic Crude Oil Drives a Cautious Refining Revival," The New York Times, March 3, 2014, http://www.nytimes.com/2014/03/04/business/energy-environment/oil-boom-is-driving-a-revival-in-refining.html?_r=0.

Lovins, Amory, *Reinventing Fire: Bold Business Solutions for the New Energy Era*, (White River Junction: Chelsea Green Publishing, 2011).

McNally, Robert, "Energy Markets, Policy, and Geopolitics," (lecture, The Eisenhower School, National Defense University, Washington, DC, April 23, 2014).

Medlock III, Kenneth, "Are Global Natural Gas Markets in a Period of Transition? The Magic 8-Ball Says . . ." Forbes, Feb. 27, 2014, http://www.forbes.com/sites/thebakersinstitute/2014/02/27/are-global-natural-gas-markets-in-a-period-of-transition-the-magic-8-ball-says/.

National Center for Policy Analysis, "Corn-based Ehtanol Production Should Cease," January 24, 2013, http://www.ncpa.org/sub/dpd/index.php?Article_ID=22773.

Nuclear Energy Institute, *Perspective on Public Opinion October*, 2013, http://www.emagcloud.com/et/POPO_2013/index.html#/2/.

Obama, Barrack, “Remarks by the President on America’s Energy Security,” March 30, 2011, http://www.whitehouse.gov/the-press-office/2011/03/30/remarks-president-americas-energy-security.

OECD Nuclear Energy Agency, “Nuclear Energy and Renewables, System Effects in Low-Carbon Electricity Systems, Executive Summary” 2012, http://www.oecd-nea.org/ndd/reports/2012/system-effects-exec-sum.pdf.

Office of Science and Technology Policy, "2013 R&D Budgets," The White House, http://www.whitehouse.gov/administration/eop/ostp/rdbudgets/2013.

Offshore Technology Conference 2010 Show Newspaper, “Straight talk from an insider,” May 4, 2010.

Plumer, Brad, “Coming R&D Crash,” The Washington Post Wonkblog, February 26, 2013, http://www.washingtonpost.com/blogs/wonkblog/wp/2013/02/26/the-coming-rd-crash/.

Ratner, Michael and others, *U.S. Natural Gas Exports: New Opportunities, Uncertain Outcomes* (Washington, DC: Congressional Research Service, September 17, 2013).

Rocky Mountain Institute, *Autocomposites Workshop Report, Kickstarting the Widespread Adoption of Automotive Carbon Fiber Composites*, January 2013.

Rocky Mountain Institute, *Eliminating Oil for Transportation by 2050,* www.rmi.org/transportation.

Statement of the Honorable Steven Chu before the Committee on Energy and Natural Resources, U.S. Senate, 111th Congress, second session, January 21, 2010.

The White House, *Driving Efficiency: Cutting Costs for Families at the pump and Slashing Dependence on Oil*, http://www.whitehouse.gov/sites/default/files/fuel_economy_report.pdf.

The White House, “The Obama Energy Agenda: Gas Prices," http://www.whitehouse.gov/energy/gasprices.

U.S. Department of Defense Directive 4180.01, “DoD Energy Policy,” April 16, 2014, http://www.dtic.mil/whs/directives/corres/pdf/418001_2014.pdf.

U.S. Department of Defense, *Energy for the Warfighter: Operational Energy Strategy*, May 2011.

U.S. Department of Energy, *Advanced Combustion Engine R&D: Goals, Strategies and Top Accomplishments*, DOE/GO-102009-2762, March 2009.

U.S. Department of Energy, "Energy Delivery Systems Cybersecurity," http://energy.gov/oe/services/technology-development/energy-delivery-systems-cybersecurity.

U.S. Department of Energy, *Materials Technologies: Goals, Strategies, and Top Accomplishments*, August 2010.

U.S. Department of Energy, "Vehicle Technologies Office: Moving America Forward with Clean Vehicles," http://energy.gov/eere/vehicles/vehicle-technologies-office-moving-america-forward-clean-vehicles.

U.S. Department of Energy, "Vehicle Technologies Office: Plug-in Electric Vehicles and Batteries," http://energy.gov/eere/vehicles/vehicle-technologies-office-plug-electric-vehicles-and-batteries.

U.S. Department of Energy, "What is the Smart Grid?" Smartgrid.gov, https://www.smartgrid.gov/the_smart_grid.

U.S. Department of Energy and U.S. Environmental Protection Agency, *Combined Heat and Power: A Clean Solution*, August 2012.

U.S. Energy Information Administration, *Annual Energy Outlook, 2013*, (Washington, DC: U.S. Department of Energy, April 2013).

U.S. Energy Information Administration, *Annual Energy Outlook 2014 Early Release Overview* (Washington, DC: U.S. Department of Energy, December 16, 2013).

U.S. Energy Information Administration, "AEO 2014 Early Release Overview, Electricity Generation," http://www.eia.gov/forecasts/aeo/er/early_elecgen.cfm?src=Coal-b5.

U.S. Energy Information Administration, *April 2014 Monthly Energy Review*, DOE/EIA-0035, April 2014.

U.S. Energy Information Administration, "Coal-fired Power Plant Operators Consider Emissions Compliance Strategies," March 28, 2014, http://www.eia.gov/todayinenergy/detail.cfm?id=15611.

U.S. Energy Information Administration, "Electricity Data Browser, Net Generation by Energy Source: Total-All Sectors," http://www.eia.gov/electricity/data/browser/#/topic/0?agg=2,0,1&fuel=vvg&geo=g&sec=g&linechart=ELEC.GEN.ALL-US-99.M~ELEC.GEN.COW-US-99.M~ELEC.GEN.NG-

---

US-99.M~ELEC.GEN.NUC-US-99.M~ELEC.GEN.HYC-US-99.M&columnchart=ELEC.GEN.ALL-US-99.M~ELEC.GEN.COW-US-99.M~ELEC.GEN.NG-US-99.M~ELEC.GEN.NUC-US-99.M~ELEC.GEN.HYC-US-99.M&map=ELEC.GEN.ALL-US-99.M&freq=M&ctype=linechart&ltype=pin&pin=&rse=0&maptype=0.

U.S. Energy Information Administration, “Energy & Financial Markets, What Drives Crude Oil Prices?” http://www.eia.gov/finance/markets/supply-opec.cfm.

U.S. Energy Information Administration, “How dependent is the United States on foreign oil?” http://www.eia.gov/tools/faqs/faq.cfm?id=32&t=6.

U.S. Energy Information Administration, “International Energy Outlook 2013,” DOE/EIA-0484, 2013, http://www.eia.gov/forecasts/ieo/pdf/0484(2013).pdf.

U.S. Energy Information Administration, “International Energy Statistics – Energy Intensity,” http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=92&pid=46&aid=2&cid=regions&syid=1980&eyid=2011&unit=BTUPUSDM.

U.S. Energy Information Administration, *Natural Gas Monthly*, December 2013, (Washington, DC: U.S. Department of Energy, December 2013).

U.S. Energy Information Administration, “Net Generation by Energy Source: Total (All Sectors), 2004-February 2014,” http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_1_1.

U.S. Energy Information Administration, “Petroleum & Other Liquids, U.S. Imports by Country of Origin,” http://www.eia.gov/dnav/pet/pet_move_impcus_a2_nus_epc0_im0_mbblpd_a.htm.

U.S. Energy Information Administration, “Quarterly Coal Report,” March 28, 2014, http://www.eia.gov/coal/production/quarterly/?src=Coal-b2.

U.S. Energy Information Administration, “Saudi Arabia,” http://www.eia.gov/countries/cab.cfm?fips=SA.

U.S. Energy Information Administration, *Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States* (Washington, DC: U.S. Department of Energy, June 2013).

U.S. Energy Information Administration, “Short-Term Energy and Summer Fuels Outlook, Real Prices Viewer,” http://www.eia.gov/forecasts/steo/realprices/.

U.S. Energy Information Administration, “Today in Energy, Peak-to-Average Electricity Demand

Ratio Rising in New England and Many Other U.S. Regions," February 18, 2014, http://www.eia.gov/todayinenergy/detail.cfm?id=15051#tabs_SpotPriceSlider-8.

U.S. Energy Information Administration, "Today in Energy, U.S. Boosts Natural Gas Output and Use Since 2005, while OECD Europe Scales Back," January 14, 2014, http://www.eia.gov/todayinenergy/detail.cfm?id=14591.

U.S. Energy Information Administration, "Top World Oil Consumers, 2012 [sidebar]," http://www.eia.gov/countries/index.cfm?topL=con.

U.S. Energy Information Administration, *Updated Capital Cost Estimates for Utility Scale Electricity Generating Plants*, (Washington, DC: U.S. Department of Energy, April 2013).

U.S. Energy Information Administration, *U.S. Crude Oil and Natural Gas Proved Reserves, 2012*, (Washington, DC: U.S. Department of Energy, April 2014).

U.S. Energy Information Administration, "U.S. Field Production of Crude Oil," http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=MCRFPUS1&f=A.

U.S. Energy Information Administration, "U.S. Natural Gas Marketed Production," http://www.eia.gov/dnav/ng/hist/n9050us2a.htm.

U.S. Energy Information Administration, "U.S. Natural Gas Vehicle Fuel Consumption," http://www.eia.gov/dnav/ng/hist/n3025us2m.htm.

U.S. Energy Information Administration, "What is the Status of the U.S. Nuclear Industry?" http://www.eia.gov/energy_in_brief/article/nuclear_industry.cfm.

U.S. Environmental Protection Agency, "Mercury and Air Toxics Standards (MATS), Basic Information," http://www.epa.gov/airquality/powerplanttoxics/basic.html.

U.S. Environmental Protection Agency, "Sources of Greenhouse Gas Emissions," http://www.epa.gov/climatechange/ghgemissions/sources/transportation.html.

U.S. General Accounting Office, *Energy Task Force: Process Used to Develop the National Energy Policy*, GAO-03-894 (Washington, DC: U.S. Government Accounting Office, August 2003).

U.S. Government Accountability Office, Report to Congressional Requesters, *Climate Change, Energy Infrastructure Risks and Adaptation Efforts*, GAO-14-74, January 2014, http://www.gao.gov/assets/670/660558.pdf.

U.S. Policy Interest Research Group, "Millennials Lead Change in Transportation Trends; Government Should Reassess Transportation Policies," May 4, 2013, http://www.uspirg.org/news/usp/new-report-reduction-driving-likely-continue.

Wara, Michael, "America's Natural Gas Lever," The New York Times, March 7, 2014, http://www.nytimes.com/2014/03/08/opinion/americas-natural-gas-lever.html?_r=0.

World Nuclear Association, "Fukushima Accident," April 22, 2014, http://www.world-nuclear.org/info/Safety-and-Security/Safety-of-Plants/Fukushima-Accident/.

World Nuclear Association, "Three Mile Island Accident," January 2012, http://www.world-nuclear.org/info/Safety-and-Security/Safety-of-Plants/Three-Mile-Island-accident/.

World Resources Institute, Aqueduct, http://www.wri.org/our-work/project/aqueduct/aqueduct-atlas.

Yergin, Daniel, *The Quest: Energy, Security and the Remaking of the Modern World,* (New York: The Pentagon Press, 2011).

2010 National Security Strategy, May 2010, http://www.whitehouse.gov/sites/default/files/rss_viewer/national_security_strategy.pdf.