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Industry Study

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Energy Industry

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ENERGY 2012

ABSTRACT: In 1973, President Nixon outlined the strategic importance of a comprehensive national energy plan to reduce demand growth through efficiency measures and encourage diversity by developing alternate fuel sources. After almost 40 years, the United States (U.S.) has not been able to enact a comprehensive energy strategy and fossil fuels still comprise over 80 percent of total American energy consumption. The expansion and industrialization of developing countries, notably China, is spurring increased demand for traditional energy sources and driving prices higher in the global market. This trend represents a strategic concern which must be addressed in order to ensure U.S. global leadership and to guarantee resilience against energy price shocks that could threaten global stability. This paper develops three possible policy options to pursue as a centerpiece to a comprehensive energy strategy. The first policy option suggests significantly increasing our nuclear energy footprint to serve as a bridge to energy supply diversity. The second policy option suggests reducing energy industry regulation to take economic advantage of the recent boom in proven hydrocarbon reserves and fund increased research and development (R&D) of alternate fuel sources to speed their adoption. The final policy option suggests the implementation of a carbon tax to send a price signal to the energy market which would incentivize alternate energy sources. Each of the policy options was weighed against its expected impact on promoting economic growth, increasing diversity of energy sources and improving resilience as a hedge against geopolitical instability. Group consensus was built around implementing a carbon tax as the better of the three options to increase the diversity of energy supply and enhance national security.

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PLACES VISITED

Domestic:

- BHP Billiton (Houston, TX)
- Congressional Research Service (Washington, DC)
- Conowingo Hydroelectric Power Plant (Darlington, MD)
- CONSOL Energy, Inc. Robinson Run Mine (Morgantown, WV)
- Covanta Waste Incinerator Electricity Generation Plant (Dickerson, MD)
- Embassy of Canada (Washington, DC)
- Embassy of Mongolia (Washington, DC)
- Exxon Mobil, Downstream Corporate Headquarters (Fairfax, VA)
- Montgomery Resource Recovery Facility, Division of Solid Waste (Rockville, MD)
- Federal Energy Regulatory Commission (Washington, DC)
- FedEx Field Stadium (Landover, MD)
- GenOn Dickerson Generating Station (Dickerson, MD)
- Halliburton (Houston, TX)
- Houston Fuel Oil Terminal (Houston, TX)
- Shell Deer Park Refinery (Houston, TX)
- Shell Exploration & Production (Houston, TX)
- Texas General Land Office (Austin, TX)
- Texas Railroad Commission (Austin, TX)
- Three Mile Island Nuclear Generating Station (Middletown, PA)
- University of Texas, Center for Electromechanics (Austin, TX)
- U.S. Congress (Washington, DC)
- U.S. Coast Guard Facility (Houston, TX)
- U.S. Department of Energy, Energy Information Administration (Washington, DC)
- U.S. Green Building Council (Washington, DC)

China:

- Beijing Normal University (Beijing)
- China Petroleum University (Beijing)
- Peking University (Beijing)
- ENN Renewable Energy (Beijing)
- GE Research Center (Shanghai)
- Shanghai Institute for Int'l Studies (Shanghai)
- SMARTGRID Expo (Shanghai)

Ulaanbaatar, Mongolia:

- Erdenes-Tavan Tolgoi
- GE Mongolia
- Liberty Partners
- Ministry of Mineral Resources and Energy
- Newcom Group
- UNDP Energy Conservation Centre
- United States Embassy

Actions to reduce the rate of growth in energy demands will also improve our ability to protect and improve the quality of our environment. While we must rely on conventional forms of fuel to meet our immediate energy needs, it is clear that the answer to our long-term needs lies in developing new forms of energy.[1]

-- President Richard Nixon, 1973

INTRODUCTION

The challenge to achieve energy security through diversity has been echoed by successive Presidents over the last 40 years, yet the United States still derives over 80 percent of its total energy from fossil fuels. Energy policy has been haphazard during this period, marred by the inability of stakeholders at all levels to agree on key priorities or the means necessary to achieve them. In an increasingly global energy market, economic strategy must be anchored with strong, coherent policy. In order to maintain global leadership, the United States needs a comprehensive energy policy focused on creating a more diverse energy supply. Good policy will sustain future economic growth and improve resilience against energy price shocks that threaten global stability. This can be achieved by accelerating innovation in renewable energy technologies, incentivizing energy efficiency and properly assessing the negative externalities associated with the use of fossil fuels. Recent technological breakthroughs in domestic natural gas extraction have boosted domestic energy supply and created a window of opportunity to move forward on a comprehensive energy strategy. This paper seeks to capitalize on this opportunity by offering three policy options to enhance energy diversity and security by 2050, and then recommends the best option to achieve the stated objective.

Energy strategy has a critical impact on global economic growth and is essential to sustaining industrial output and maintaining military capability. The United States cannot maintain a position of global leadership if it continues to make energy policy through crisis management. This ad hoc management style will not sustain continued domestic growth through 2050 due to the rapid growth of developing countries, notably China, that spur increased global competition for traditional energy resources. Increased competition in the global energy market magnifies the importance of energy exporters such as Iran and tends to stifle future growth as energy prices rise to balance risk and demand. A successful energy strategy will strengthen national security by ensuring the reliability of energy supply, minimizing shocks to energy prices in the global market, incentivizing energy efficiency and improving energy diversity.

Methodology and Purpose

Stakeholders in the energy industry comprise the full range of political viewpoints and working towards policy consensus requires agreement on strategic fundamentals. For the purposes of this paper, economics guided this study team's strategic analysis and assessment of the energy industry. Viewing energy through an economic lens de-emphasized political arguments and allows readers of all political views to evaluate policy options on widely accepted merits. Though the economic lens is not perfect, it comports well with field studies conducted in Mongolia and China where economic concerns clearly outweighed concerns regarding global climate change and to a lesser extent, air pollution.

The study team, while representing a limited cross section of the American public, still found achieving consensus extremely difficult. In the end, our willingness to compromise made consensus possible and our diversity of opinion made this a better product; possibly indicating

the way forward in a challenging political environment. Our final recommendation is a strategic priority, not a comprehensive solution. Each of the three options presented have elements that can complement the strategic priority and should be considered for implementation in parallel.

THE DOMESTIC ENERGY INDUSTRY

The energy industry can be defined as the entire lifecycle of producing energy and selling into end-use markets; also referred to as upstream and downstream components. Upstream functions include the exploration, recovery and production/generation of fuel sources (e.g. electricity generation, crude oil extraction, etc.). Downstream refers to the products consumed at the end-market. Elaborate transmission and distribution systems (oil/gas pipelines, electricity grids, etc.) transport energy or fuel directly to the consumer. The U.S. fuel market is segmented into fossil fuels and renewables. Fossil fuels (petroleum, natural gas and coal) are the predominant domestic energy sources and account for over 80 percent of total U.S. consumption. As depicted in Figure 1, approximately 16 percent of U.S. energy needs are served by renewable energy sources including nuclear, hydroelectric, wind turbine, biomass and solar.[2] Energy Information Administration (EIA) projections indicate a gradual increase in the use of renewable sources in U.S. energy consumption, particularly biofuels.

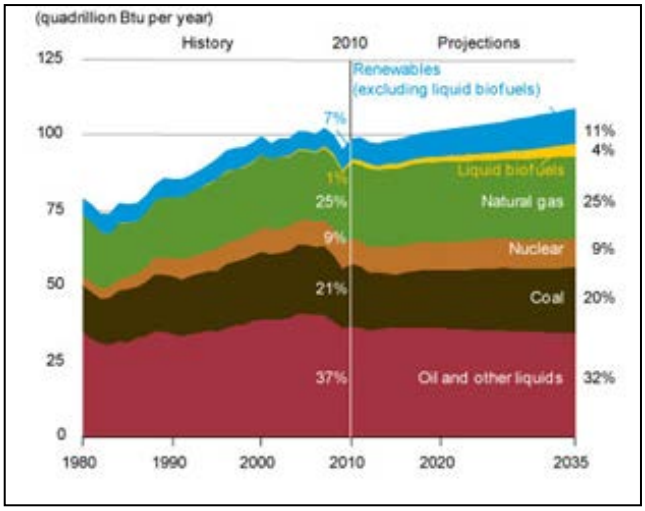


Figure 1: U.S. primary energy consumption by fuel, 1980-2035. [3]

The recent technology enhancement that combined horizontal drilling with hydraulic fracturing (fracking) has opened new fields for the extraction of oil, natural gas and natural gas liquids. Commercial extraction of hydrocarbons trapped in low permeability rock formations (tight resources) were not previously considered economically recoverable. Fracking has unlocked tremendous reserves and created a game changing boom in the U.S. energy industry. Since 2007, these breakthroughs contributed to an increase in domestic oil and natural gas production and decreased U.S. dependence on imports. Tight oil development in combination with the increased extraction of offshore resources in the Gulf of Mexico promise to increase domestic production of oil from close to 5 million barrels per day (mbpd) to 6.7 mbpd by 2020; production rates not seen since 1994.[4] In addition, the extraction of crude from the oil sands in Canada now provides a growing source of feedstock to U.S and the world markets.

The global market for energy has far reaching effects on domestic energy supply and economic growth. The rise of the Organization of Petroleum Exporting Countries (OPEC) in the 1970's demonstrated that the global market for oil can be manipulated very effectively by producers. Supply manipulation of the energy market and instability in the Middle East were decisive factors that drove President Nixon to outline his strategy for the development of alternate sources of energy. A global market for energy means that even as the U.S. approaches energy independence, prices are still subject to global shocks that occur regularly in the energy industry due to high instability in numerous energy producing countries. Federal oversight of

only the domestic energy industry does not suffice to guarantee stability; national security depends on an energy strategy that accounts for the global market.

Patterns of fuel use vary significantly by sector. The predominant energy segments are transportation, residential and commercial buildings, industrial applications and electricity generation. For example, oil provides 94 percent of the energy used for transportation, but only 1 percent of the energy for generating electricity.[5] Industrial applications and transportation consume the vast majority of energy. Government policies intended to modify energy usage will need to focus on alternatives that provide clean, reliable energy to service these sectors.

The U.S. energy industry is governed by federal, state and local laws and regulations. The policy recommendations contained within this paper focus primarily on federal laws and regulations with the objective of diversifying the sources of energy and ensuring energy security.

CURRENT ENERGY SITUATION

Numerous factors, such as the advent of hydraulic fracturing, have created a window of opportunity for the domestic energy industry and federal policy makers. Energy exports are growing while imports from less stable parts of the world are shrinking.[6] In 2011, and for the first time in 62 years, the U.S. was a net exporter of petroleum products.[7] At the same time, per capita energy consumption in the U.S. is approximately three times the world average[8] and the U.S. only holds 1.4 percent[9] of the world's proven oil reserves while consuming approximately 19 percent annually.[10] While imports still play an enormous role in the economy, domestic energy production is significantly increasing. A balance must be struck between access to resources, cost, and preservation of the environment. A brief overview of the current resource and regulatory situation follows to provide a baseline for analysis.

According to the EIA, the following conclusions describe the resources and demand for energy in the U.S. to 2035:[11]

- Projected growth of energy use slows and energy efficiency increases[12]
- Domestic crude oil production increases
- Net petroleum imports make up a smaller share of total liquids consumption[13]
- Natural gas production increases throughout the projection period.[14]

Legal and Regulatory Incentives

The federal government has incentivized energy production through tax preferences since 1916 but, until 2005, these incentives focused primarily on stimulating domestic production of oil and natural gas.[15] This focus began to change in 2005 when incentives became increasingly geared toward efficiency and the increased use of renewables. The Energy Policy Act of 2005 increased the focus on energy efficiency and the use of alternative vehicles.[16] The American Recovery and Reinvestment Act of 2009 expanded preferences for efficiency, renewable energy and alternative fuel vehicles.[17] By 2011, 78 percent of the budgetary cost of federal energy related tax provisions promoted energy efficiency and renewables.[18] In contrast to incentives for fossil fuel and nuclear energy, federal incentives for renewables have been temporary in nature - resulting in boom and bust investment cycles in the renewable energy sector.[19] In order to encourage the market to embrace supply diversity initiatives, consistent and substantial incentives must be enacted by the federal government.

The Nexus of Energy, the Environment and the Economy

Concerns over the environmental impacts of energy production and the security implications of global energy supplies have grown significantly since the 1970s. The increase in sustainable energy is viewed as an important component of national security, but there is little consensus on how to address the negative externalities of energy production and consumption. International efforts – notably the United Nations Framework Convention on Climate Change and the Kyoto Protocol have suffered from lack of political consensus – even among signatories (including the U.S.). Domestically, the federal government has been slow to act. However, the Supreme Court ruled in 2007 that the Environmental Protection Agency (EPA) has the authority to regulate CO_2 and other greenhouse gases (GHG), finding that they fit within the Clean Air Act's broad definition of air pollutants.[20] Subsequently, the EPA issued a standard for carbon emissions from power plants larger than 25 megawatts (MW).[21] Experts expect that most, if not all, natural gas fired plants will be able to meet this standard; however, new coal plants would need to reduce emissions to meet the target (ostensibly through the use of carbon capture and storage).[22] The new EPA standards make investment in new coal plants cost prohibitive.

Game Changer for U.S. Energy: Hydraulic Fracturing and Horizontal Drilling

Technological Advances and Capacity

As a result of an innovative combination of older technologies, natural gas that resides within shale deposits is now economically recoverable. Proven reserves are expected to approach 750 trillion cubic feet in the lower 48 states.[23] Greatly increased production has lowered domestic prices and natural gas is expected to dominate new electricity generation capacity as it is cheaper than coal fired generation and renewables such as wind and solar. Approximately 225,000 wells have been drilled since 1989, bringing the number of wells to 487,627 in 2010.[24] Additionally, the industry supported more than 600,000 jobs in 2010 and is expected to grow another 170,000 jobs by 2015, possibly reaching 1.3 million jobs by 2035.[25]

Shale oil plays are estimated at 24B barrels which will boost U.S. production significantly over the coming decades.[26] According to a report by the National Petroleum Council, tight oil resources are greater than previously thought and production may grow to between 2M and 3M barrels per day.[27] The Bakken oil field contains about 3.6B barrels of recoverable oil making it the largest U.S. field since Prudhoe Bay in Alaska. Production since 2005 has increased dramatically from 3,000 barrels per day to about 400,000 barrels per day.[28]

Environmental Tradeoffs and Considerations for the Expansion of Fracking Efforts

In addition to the economic benefits and a decrease in dependence on imports, many tradeoffs accompany modern shale extraction. Reported environmental and health issues have increased in proportion to the number of operational wells. Current issues include:

- Community safety due to increased seismic activity
- Impacts to the environment due to infrastructure footprint
- Consumption and contamination of fresh water supply
- Increased GHG emissions from extraction, transportation, and processing.[29]

Within the past five years, these issues have gained the attention of both state and federal governments. Although complaints from private citizens are on the rise, scientific data to

substantiate (or debunk) these complaints have been slow to materialize. The EPA has recently stepped in to provide oversight and research universities are beginning to find linkages to social impacts. For example, researchers at Columbia University concluded that a series of earthquakes occurring in Ohio in 2011 were caused by injection wells for fracking wastewater.[30]

Water issues have been the most frequent topic of debate and drive a significant portion of research. Approximately 2 to 4 million gallons of water per well are mixed with sand and chemicals then pumped into the well system during the fracturing process.[31] The volume of water required causes concern over the depletion of water resources, while chemical additives have caused concern over the contamination of ground water and the surrounding environment.

Ground water contamination is a risk due to several factors. Seepage or spillage can occur through poor bore casing construction, natural geological or manmade features via migration of gases, and poor storage methods. Anecdotal and scientific evidence of ground water contamination has been seen in Wyoming and Pennsylvania spurring the EPA to evaluate the situation and supply fresh water to affected residents in Pennsylvania.[32]

Current U.S. Policy Regarding Modern Oil and Gas Extraction

The variety of state and federal laws and regulations which apply to conventional oil and gas activities also apply to shale development. Federal regulation with regard to fracking is administered primarily through the EPA; however the Bureau of Land Management and Department of Agriculture are involved if development occurs on federal lands. Most federal laws grant "primacy" to the States to implement programs with limited federal oversight, allowing States to develop their own regulations.[33]

About 22M acres, or 57 percent, of currently leased federal lands have not been explored or developed. Additional federal incentives have recently been provided, such as shorter land lease terms, to encourage and incentivize more efficient oil and gas development.[34]

As a result of the opportunities and challenges arising from rapid shale resource development, both federal and state policies are challenged to keep pace with development. Recently, the President responded to growing safety and health concerns by ordering the Department of Energy (DOE) to generate a report on the safety of shale gas production. The report stated, "if action is not taken to reduce the environmental impact accompanying the very considerable expansion of shale gas production expected across the country – perhaps as many as 100,000 wells over the next several decades – there is a real risk of serious environmental consequences causing a loss of public confidence that could delay or stop this activity."[35]

Litigation is on the rise in Arkansas, Colorado, Louisiana, New York, and Pennsylvania regarding damage to property and health. Many states are now limiting drilling through legislation and regulation.[36] According to David Burnett, an associate research scientist with Texas A&M's Global Petroleum Research Institute, "Sometimes environmental considerations aren't the same as the public considerations, and many times the economic considerations don't fit. There could be better management practices used. We have to find a balance."[37]

SECURITY CHALLENGES FOR THE ENERGY INDUSTRY

While the U.S. energy landscape is experiencing a renaissance, the industry faces several domestic and worldwide challenges. The internet and communication technology have enabled the global market to immediately determine global energy prices based on real-time supply, demand and risk data. While pricing real time supply and demand data is beneficial to the

energy market, immediate pricing of perceived risks leads to some unnecessary price shocks as global leaders have insufficient time to effectively intervene. Global energy prices will also be increasingly affected by changing demographics and economic conditions around the globe; particularly within less developed countries. Increasing populations, growing economies and an emerging middle class in countries such as Brazil, China, India and several African Union territories have increased energy demands on a global scale. Demographic studies project further expanding populations and redistribution of wealth to the emerging middle class in these countries through 2050, thus increasing demand for energy in these economies.

Much political discourse centers on energy independence versus energy security. The terms are often used interchangeably, yet there is a distinct difference. Energy security is defined as having assured access to sufficient, affordable and stable energy supplies, while energy independence means energy needs are fulfilled exclusively by domestic sources. Daniel Yergin states, "Energy independence is a very appealing term, but it sets an impossible goal for the foreseeable future. What we need to do is diversify our energy sources just as investors diversify their portfolios to make them safer."[38] Yergin's approach is practical as economic benefits accrue from trade with stable partners, while pursuing energy independence has the potential to cause unnecessary economic and environmental harm.

According to the EIA, the U.S. is still dependent on foreign crude oil producers for approximately 49 percent of domestic needs.[39] While the foreign crude oil imports peaked in 2005, the U.S. will likely depend upon foreign sources of crude oil for the foreseeable future. Additionally, the vast majority of global oil shipping traverses seven critical chokepoints (the top four are the Straits of Hormuz, Malacca, Bab-el-Mandeb and the Suez Canal); most of which are in the Middle East and Asia where political tensions and potential armed conflict can cripple commercial shipping and distort global prices.[40] While the U.S. is not immune to global price shocks, the majority of U.S. oil imports do come from our neighbors; Canada and Mexico. The U.S. must improve energy diversity to increase resilience to global market irregularities and sustain a healthy national economy with consistent economic growth.

The energy industry relies on robust infrastructure to generate, distribute and trade energy. Maintaining, expanding and protecting this infrastructure is extremely capital intensive. Adding to this challenge, much of U.S. energy infrastructure is owned and operated by the private sector and, as in the case with electrical transmission, the infrastructure is aging and suffering from underinvestment. For example, the average age of a power transformer is 40 years, which is also the average lifespan of the equipment.[41] Since transformers have a long expected useful life, they are long lead items that are usually only manufactured when ordered.

Of fairly recent concern within political and business circles is the threat of cyber crime and terrorism. Networks of computers and sensors control the energy infrastructure components including the electrical generation facilities, oil and gas production facilities, transmission and distribution networks and pipelines. As the sophistication of automation increases, the threat of cyber attacks from adversaries and criminal elements has increased significantly. Adversaries have been probing U.S. critical infrastructure for potential vulnerabilities that can be exploited at will. In particular, according to U.S. intelligence officials, both Chinese and Russian organizations have been attempting to map critical U.S. infrastructure, such as the electrical grid and pipelines.[42] In fact, national security officials believe that "Cyberspies have penetrated the U.S. electrical grid and planted software programs that could be used to disrupt the system."[43]

U.S. energy infrastructure is vulnerable to potential terrorist attacks on multiple fronts. In recent years, electricity generation and oil and gas production firms have financed significant

investments in physical security, particularly at nuclear power plants. A major concern for the nuclear industry is the security of spent fuel rods. This radioactive material is generally stored onsite and it is a significant challenge to secure spent nuclear fuel (SNF) against theft by terrorist organizations without a centralized interim or long term storage facility.

Another low probability but highly consequential threat to the electric grid is from an electromagnetic pulse (EMP). An EMP can be generated from major solar storms, as seen in Quebec in 1989, or from an aerial nuclear blast, as first noted with the Starfish nuclear detonation in 1962.[44]

ENERGY OUTLOOK

Globalization created a level of economic interdependence not envisioned 50 years ago. The energy outlook for 2050 will contain developments unforeseen by today's policy makers. We do know that rapid economic development and population growth will have a tremendous impact on the global energy future. Rising demand for energy will strain the earth's finite supply of fossil fuel resources. According to the EIA, global energy consumption will grow 53 percent from 2008 to 2035 with the majority of consumption, 83 percent, occurring in non-Organization for Economic Cooperation and Development (OECD) countries.[45] China alone will account for more than 30 percent of the projected demand growth and will soon supplant the United States as the largest consumer of the world's energy resources.[46]

These trends indicate a global environment where fierce competition for energy resources will dominate geopolitical calculations and challenge national security interests if the U.S. cannot maintain a global leadership position. According to the International Energy Agency, an enormous investment of $38T in global energy supply infrastructure is required from 2011 to 2035 to keep pace with the increasing global energy demand.[47] U.S. leadership on energy diversity innovations is necessary not only to enhance national security, but also to improve global stability. For example, the surest way to ensure the continued peaceful rise of China is to ensure its access to adequate energy sources to fuel continued economic development. Field studies in China and Mongolia reinforce this conclusion as both national economies factor coal resources much more heavily in their economic planning than in the United States.

Increased use of fossil fuel energy in the coming decades will negatively impact global climate change efforts due to increased carbon emissions. Global emissions of carbon dioxide are continuing to rise,[48] with China and the U.S. leading the world as the two largest emitters.[49] Carbon dioxide and other GHG are at the center of the debate on anthropogenic climate change and are deemed responsible for shrinking polar ice caps, rising sea levels and damage to the ecological system. Anthropogenic climate change is yet another politically divisive issue in the U.S., but with over 80 percent of domestic energy consumption coming from fossil fuels, achieving a greater degree of energy diversity will enhance efforts to control climate change while at the same time improving national security – a true win/win policy.

Significant investments in energy research and development can pay tremendous dividends towards the development of alternate energy sources and should be sponsored by both the public and private sectors in order to be most effective. The 2009 American Recovery and Reinvestment Act appropriated $97B and mobilized roughly $100B more in private capital to invigorate energy related research and development.[50] In 2010, the federal government established energy innovation hubs that accelerate the path from laboratory innovation to technological development and strengthen American competitiveness, economic growth and

energy security.[51] However, these programs fall short of efforts by other competitors around the world. In 2010, China's state investment in renewable energy R&D was nearly $49B (more than a third of combined global investment) while U.S. federal investment was approximately $35B.[52]

A key step in closing the gap in R&D investment was the establishment of the Advanced Research Projects Agency-Energy (ARPA-E). Modeled after the Defense Advanced Research Projects Agency (DARPA), ARPA-E is intended to advance energy research and innovation. In fiscal year 2013, ARPA-E requested a 27 percent increase in funding for a total budget of $350M to advance projects leading to transformational energy technologies.[53] ARPA-E is currently managing 121 advanced science research projects to include electric power technology, batteries for electrical energy storage, efficiency through innovative thermo devices, electro fuels and innovative materials and processes for carbon capture technologies.

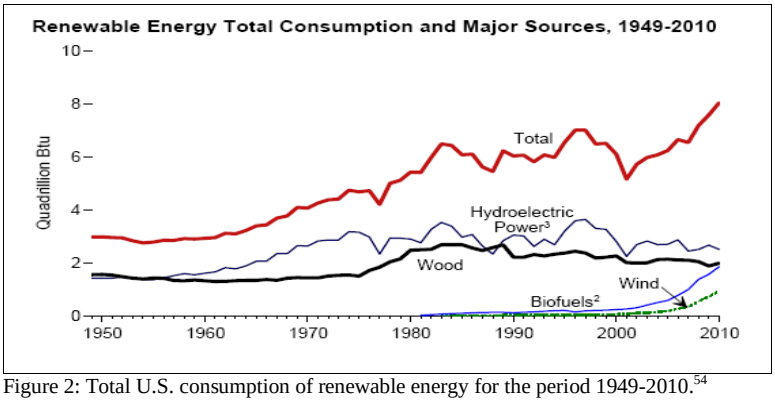


Figure 2: Total U.S. consumption of renewable energy for the period 1949-2010.[54]

Figure 2 reflects the boost in total U.S. consumption of renewables, especially during the last decade which is indicative of growing government and consumer demand for alternative energy sources. However, the federal government's investment in advancing renewable energy falls short compared to international counterparts. Once again, China is expected to spend $473.1B on renewable energy alone over the next five years.[55] For the United States to take and maintain the lead position as a renewable energy innovator, further financial investment in programs such as ARPA-E will be needed.

THE ROLE OF GOVERNMENT

The federal government must take a leading role in an issue as vital to national security as energy policy. Heated debates between many factions - political affiliation, public vs. private investment, economic vs. environmental - have caused a failure to reach a governing consensus and implement a comprehensive energy policy for over four decades. With a look toward 2050 and a goal of attaining energy diversity despite tough fiscal constraints and instability in oil-rich countries, the U.S. must commit to collaborating across factions, working collectively as a nation to achieve global leadership in the energy sector, marshal resources wisely, inform policy decisions and create a viable and sustainable future.

The political climate continues to pose difficulties in developing a comprehensive energy strategy. Over the course of the next several decades, the U.S. must make a concerted effort to learn from the mistakes of the past, adopt a policy that is an acceptable political compromise and take a fundamental step to securing the future of energy in the U.S. In addition to this critical responsibility, the federal government is responsible for several roles regarding the regulation of

the national energy industry. First and foremost, the government must serve as a catalyst to drive innovation and R&D into new technologies. Private industry has indicated that the capital investments required for new technology exceed the capabilities of individual companies and the government should augment R&D efforts to continue a rich history of spurring innovation.[56] The key to this effort is to not be prescriptive, but to provide broad guidance and investment guarantees. This will require funding R&D efforts across the entire energy industry to encourage diversity and allow markets to operate.[57]

Globally, the federal government must ensure the U.S. continues to lead rather than fall behind on energy innovation. With other countries already taking the initiative to implement carbon taxes and other incentives, the U.S. must re-prioritize taking a leading role in energy as part of its budgetary obligations and allocations – in the interest of energy security. The government should collaborate with other nations to create a sustainable energy future by incentivizing change, improving efficiency and creating a diverse, secure and stable energy landscape. Many states are leading diversity efforts with renewable portfolio and efficiency standards and the federal government should incentivize best practices and initiatives.

Lastly, it is critical that the federal government become the lead communicator and educator with regard to the energy industry. Government entities, particularly the DOE, as part of a close partnership with industry, must make an effort to better inform the public to mitigate concerns and provide increased understanding. The EIA is a non-partisan entity that provides factual information regarding the status of the energy industry, but an effort must be made to inform the general public, particularly at a time when many industry professionals are touting technologies that are changing the face of the industry, yet raise concerns over environmental safety (i.e., fracking).[58]

POLICY OPTION #1 – NUCLEAR POWER AS A BRIDGE TO ENERGY DIVERSITY[59]

> "…the United States pledges before you, and therefore before the world, its determination to help solve the atomic dilemma – to devote its entire heart and mind to finding a way by which the miraculous inventiveness of man shall not be dedicated to his death, but consecrated to his life."[60]
>
> -- President Dwight D. Eisenhower, 1953

Since the time of President Eisenhower's address to the United Nations General Assembly, nuclear power has been harnessed for the benefit of the world to produce a significant fraction of the energy - primarily electricity - that the U.S. and world utilizes. As of August 2011, 104 licensed nuclear reactors located at 65 sites in 31 states generated nearly 20 percent of the electricity consumed in the United States.[61] Nuclear power is a proven source of reliable energy but still must be carefully analyzed to determine how it can contribute most effectively to the U.S. energy future. To abandon this critical energy source would leave a large gap in U.S. electricity generation capacity, whereas an expansion of its usage will improve energy supply and security.

Nuclear power has a negligible carbon footprint compared to fossil fuels such as coal and natural gas that are used for baseload electrical power generation. An interdisciplinary MIT study titled "The Future of Nuclear Power" concludes: "… [T]he nuclear option should be retained, precisely because it is an important carbon-free source of power that can potentially make a significant contribution to future electric supply."[62]

The very low carbon footprint has become even more salient in recent years as scientists continue to unravel the impact of GHG on earth's global climate. Should that link continue to grow stronger and achieve consensus, nuclear power can provide one bridge to a future where clean, renewable energy sources can reliably meet the energy needs of the world. Whether combating global warming through lower GHG emissions in the near-term or buying time to find new energy resources for the long-run, nuclear power has a continued role to play in supplying the United States and the world with energy, and policies should be put in place to maximize the benefit from this critical energy source.

Spent Nuclear Fuel

One issue with nuclear power is spent nuclear fuel (SNF). The requirement to properly dispose of SNF has been a topic of concern for some time. "Reactors across the country have accumulated 72,000 tons of spent fuel. Some utilities have packed four times as many spent fuel rods into temporary holding pools than the structures were designed to contain."[63] To quantify the volume this represents, the 72,000 tons of spent fuel would, "roughly speaking…cover one football field to a depth of approximately 20 feet."[64]

One possible solution is to utilize a centralized interim storage facility until a long-term permanent storage solution can be agreed upon, sited, built and made operational. The Blue Ribbon Commission (BRC) on America's Nuclear Future performed a study to look at options for SNF storage. In this study, the BRC looked at the eight previous studies since 1985, with five of the eight being done since 2008.[65] Collectively, experts state:

> The construction of a facility and movement of [spent nuclear] fuel will not only be a positive step forward in the management of the problem, but there will be a great deal of learning about how to meet the challenges of managing spent fuel at a national level. Optimistically, those lessons may uncover different options and processes that will be beneficial in this process. But even the pessimist will recognize that if this turns out to be more difficult than expected and greater problems are encountered, it is better that these challenges be known.[66]

The technical benefits of a centralized interim storage plan are clear. The plan also provides many benefits in terms of costs. SNF can be removed from current and retired sites to eliminate government payments for not meeting the timeline for permanent storage, and by removing it from retired sites, costs for security to protect the SNF at retired locations can be saved. In addition, once SNF is removed, retired sites can then undergo final decommissioning.

Technological Innovations

New nuclear reactors are being considered in the U.S. and technology developed over the past 40 years can be brought into active use. These technology developments will further improve the safety margin and economics of nuclear reactors. The new generation designs, commonly referred to as GEN III+, incorporate design features that utilize natural forces such as gravity that "require no electricity or human action"[67] to ensure proper cooling of the fuel assembly in the event of an emergency that cuts power to the reactor.

In addition, reactors in the U.S. use a "once-through" fuel cycle. One option to extend the nuclear fuel supply would be to take the SNF and reprocess it to remove the remaining fissionable material. This fuel cycle technology is used in Europe and has the economic

advantage of utilizing a higher fraction of the uranium in the fuel rods which reduces overall uranium usage and SNF issues.

Black Swan Events

An additional aspect that must be considered with nuclear power is the consequence of a serious failure due to a highly unlikely event, sometimes referred to as a Black Swan event.[68] The question becomes, "How much risk can be accepted, and is the risk truly understood?" Michael Corradini, a member of the Nuclear Regulatory Commission (NRC) advisory committee on reactor safeguards was quoted by Adam Piore saying, "The question is what are you willing to design for – and does society understand that and accept that factor of safety?"[69] Risk is inherent with nuclear technology. The MIT report stated, "We do not believe there is a nuclear plant design that is totally risk free…Safe operation requires effective regulation, a management committed to safety, and a skilled workforce."[70] Thus, smart, thorough government oversight and regulation must continue to evolve and drive the industry to the lowest possible risk.

Policy Option

The SNF issue can be solved, new technology can make nuclear power safer and more cost competitive, spent fuel can be reprocessed to extend the fuel supply and lessons learned coupled with stringent siting requirements can minimize the possibility of a Black Swan Event. Thus, with a concerted effort, nuclear power can be expanded to provide a larger fraction of U.S. electricity generation. However, in order to make a substantial change, government will need to get actively engaged and modify the current policy on nuclear energy. The first order of business is to establish an interim centralized waste storage facility while the country finalizes a plan for long-term, permanent disposal. At the other end of the fuel cycle, the U.S. must also consider the option to move from a once through fuel cycle to a fuel cycle that allows remaining fissionable material to be recycled in an effort to extend available uranium resources.

The second step is to mandate an increase in the utilization of nuclear power. A mandate increasing U.S. nuclear-powered electricity generation from a current level of 20 percent to 40 percent over 15 years will ensure the U.S. is on a path to replace a significant fraction of fossil fuel consumption. With current natural gas and coal prices relatively inexpensive compared to renewable energy sources; it will be extremely difficult to sustain progress on energy supply diversity through renewable energy sources without a mandate.

To maintain the current level of nuclear power, while planning and beginning to execute the proposed expansion mandate, the NRC must continue to prudently support the extension of current operating licenses from 40 years to 60 years. In addition, studies need to be completed so plants that are in good condition and well-maintained can seek extensions out to 80 years. The capital investment of nuclear power plants becomes more attractive with longer utilization timeframes that allow longer revenue streams and additional time to amortize the investment.

To help with the development of new nuclear reactors, the government must expand its loan guarantee program. The U.S. must also work to streamline the siting and licensing process to minimize delays in building new nuclear plants. The NRC should also mandate the utilization of current sites for new reactors. The government must also be willing to increase the size and capabilities of the NRC to ensure the safe operation of the nuclear fleet in the United States. The stringent management of the industry will be necessary to minimize the possibility of a nuclear accident; however, it must be clear that no matter what actions are taken there will always be the remote possibility of an incident.

Finally, the U.S. must lead the world and establish first-class standardization for the oversight and operation of nuclear power plants. It is only through the completion of these tasks that the U.S. can confidently expand the use of nuclear power as a clean energy source and provide time to work on alternative sources of energy and make them available on a large scale.

Conclusion

Nuclear power must play a more prominent role in the electricity generation portfolio of the United States. The nuclear waste issue can be solved; new technology can make nuclear energy safer and more efficient, while robust regulation can keep it safe and reliable. The use of nuclear energy can provide a reliable, carbon-free source of energy to mitigate climate effects while decreasing the use of fossil fuels and allowing more time for the U.S. to gracefully transition from a fossil fuel economy to an economy driven by energy from clean, renewable sources of energy such as wind and solar which continue to be developed.

POLICY OPTION #2 – ECONOMY FIRST[71]

"The stone age didn't end because we ran out of stones."
-- Former Saudi oil minister Sheik Ahmed Zaki Yamani

This policy option rests on two relatively simple premises. First, the world is on a technological path leading to a green energy future: not *because* it is green, but because it is *better*. Consumers will adopt new energy sources when those sources are better and cheaper than what they replace. It just so happens that better and cheaper energy will also be greener energy. Second, the security of the U.S. must be at the forefront when considering energy policy. Admiral Mullen, former Chairman of the Joint Chiefs of Staff, stated that debt is "the single, biggest threat to our national security."[72] Policies that increase debt are detrimental to national security. At the same time, policies that continue our reliance on foreign oil, or increase susceptibility to global price shocks also decrease national security. This option tackles debt and security simultaneously.

During WWII, the U.S. faced the strategic problem of having two large enemies on opposite sides of the world. Unable to address both simultaneously, the U.S. prioritized. Japan's attack was the impetus for U.S. entry into WWII, but the government chose a "Europe First" strategy; engaging and defeating Nazi Germany first while simultaneously preparing for the more difficult Imperial Japan. Roosevelt recognized that a gut reaction to the attack on Pearl Harbor was poor strategy and would have overextended U.S. forces and led to possible defeat.

The U.S. faces a similar situation today with two significant problems. The first is the economy. Not since the Great Depression has a recession cut so deep and a recovery been so tepid.[73] Federal spending as a percentage of gross domestic product (GDP) is at record levels, outpacing historical revenues by 7 percent[74] and the national debt now exceeds 100 percent of national GDP for the first time since WWII.[75] Aggravating these figures, the Congressional Budget Office reports that mandatory spending on social programs is consuming an ever-increasing portion of the budget.[76] Structural debt, increased spending and a faltering economy are significant contributors to Admiral Mullen's concern. The second problem relates to the negative externalities of carbon-based fossil fuels such as acidification of the oceans or their possible contribution to climate change. Based primarily on climate change, there is enormous domestic and international pressure to curtail CO_2 emissions. Unfortunately, lowering CO_2

emissions with today's technology will exacerbate problem number one, the economy, by raising energy prices and throttling one of the most productive sectors in U.S. industry.[77] Therefore, the U.S. must again prioritize and embark on an "Economy First" strategy. A window of opportunity has recently opened to use energy policy to turn around a struggling economy while simultaneously preparing to defeat enemy number two, carbon emissions.

Every President since Nixon has sought to achieve energy independence by reducing our reliance on foreign oil. Advances in deep water drilling and hydraulic fracturing technology have changed the domestic energy landscape. The U.S. now sits on enormous quantities of *recoverable* oil and natural gas, leading President Obama to call the U.S. the "Saudi Arabia of natural gas."[78] Local economies are booming where hydraulic fracturing is utilized to extract oil and natural gas. Pennsylvania saw tax revenue from shale gas production increase from $175M in 2006 to $419M in 2011.[79] North Dakota has the lowest unemployment in the country, due to development of the Bakken Shale field.[80] In 2009, the federal government collected almost $6B in royalties from companies drilling offshore in the Gulf of Mexico and $3B for terrestrial drilling on federal lands. In the Gulf region alone, oil production supports 170,000 jobs; 50,000 more jobs than were created federally in the month of March 2012.[81] Increasing permits for offshore and onshore production would be a huge boon to the economy and increase the diversity of supply to the energy industry. While the energy sector may not solve all U.S. economic problems, it would certainly provide a strong boost to the recovery. As the economy recovers, the government will be better able to invest in green energy infrastructure and R&D.

To better leverage this boom, the government must clear the way for industry to responsibly increase their revenue potential. Specifically:

1) Dramatically increase permitting for deep and shallow water drilling. Permitting is at a historical low in federal waters, with the time required to receive a permit increasing and the number of permits approved decreasing almost 70 percent from the historical average.[82]
2) Fast track the Keystone XL Pipeline. President Obama has threatened to veto XL[83], but with 85,000 miles of crude oil pipelines in the U.S.[84], this is environmentally the safest way to transport oil. Regardless of jobs created (5,000 to 100,000[85]), Keystone would transport more than half as much oil each year from Canada than currently imported from Saudi Arabia[86] dramatically improving diversity and security of supply.
3) Increase natural gas and oil development on federal lands. According to the EIA, fossil fuel production on federal lands is at a nine year low and natural gas production is down 10 percent from 2010 and 60 percent from 2003.[87] During the same period, natural gas extraction on private lands has increased by a factor of five.[88] This includes opening areas such as Arctic National Wildlife Reserve. Drilling would occur on less than .01 percent of the reserve and is supported by a large segment of the general U.S. population, in addition to overwhelming support from Alaskans and Inuit tribes.[89] Conservative estimates place the reserves at 10.4 billion barrels,[90] which equates to three years of petroleum imports.
4) Fast track permitting for coal and natural gas export facilities. Asia's demand for coal and natural gas is enormous, yet the U.S. does not have a single coal export facility on the west coast and only one liquid natural gas (LNG) export terminal, in Alaska.[91] The supply of natural gas in the U.S. is so large that at less than $2 per thousand cubic ft, it is becoming unprofitable to produce it. Natural gas sells in Asia for nearly $1 per million BTU.[92]
5) Mandate a flex-fuel standard for all U.S. automobiles. For less than $150 in production cost per vehicle, a fuel mixture sensor, a fuel injection micro-chip and corrosion resistant fuel

lines can be added to allow a car to run on gasoline, ethanol, methanol, butanol or any mixture thereof.[93] Within 10 years there would be enough flex fuel vehicles on the road to make it profitable for energy producers to provide these alternative fuels. As of the writing of this paper the national average gasoline cost was about $4.00 per gallon. Methanol costs about $1.13 per gallon to produce and can be made from readily available feedstock such as coal, natural gas and organic waste.[94] Methanol has about half the energy per gallon so a consumer would burn roughly twice as much per mile.[95] If sold at $1.50 per gallon, it would still be smart choice for most consumers as it would be $1.00 less per equivalent gallon of gas. A similar story may exist in the near future if a technological breakthrough allows ethanol and/or butanol to be produced from cellulose based feedstock. If this breakthrough does occur, and there are insufficient vehicles on the road to take advantage of it, then there will be little incentive for industry to scale up production.

6) The federal government should incentivize the production of LNG fueling stations along the Interstate Highway System. In the 2012 State of the Union address, the President touted a heavy trucking fleet powered by natural gas.[96] The price of natural gas is currently so low that no trucking company would use diesel if their trucks could run on LNG, but a fleet of LNG powered trucks will never come to be if the infrastructure does not exist to fuel them.
7) Legislate a liquid fuels comparison standard by energy content. As the U.S. increases its energy security by diversifying liquid fuels, consumers need to understand exactly what it is that they are purchasing. Different liquid fuels have different energy contents. When a consumer buys gasoline they are not really purchasing a gallon of gas. They are buying energy, and specifically they are buying distance; how far that gallon of gasoline moves their car. A gallon of methanol would propel the same car half the distance. So if methanol were priced at $2.50 per *gallon*, it would look cheaper than gasoline at $4.00 per gallon, when in reality it is more expensive per *mile*. The comparison mandate would require retailers to price fuels in dollars per gallon of gasoline equivalent (GGE). In the above example, the billboard at the gas station would show methanol priced at $5.00 GGE. The energy comparison then becomes simple for the consumer.

These steps are only a small sampling of possible governmental efforts to increase exports (refined fuel from Canadian crude, coal, natural gas), increase GDP, add jobs, diversify energy supply, mitigate the impact of price shocks in the global energy markets and move consumers toward cleaner forms of energy without harming their bottom line. A revived economy will strengthen national security and also allow the U.S. to take on problem number two, CO_2 emissions. In the near term, a portion of the increase in revenue due to the energy boom must be devoted to R&D of renewable, low/zero emission energy technologies. There are many promising technologies currently in development on this front such as high efficiency solar panels, carbon capture and sequestration (CCS), bio fuels and battery storage. At present, these technologies are not economically competitive with other sources of energy and the U.S. economy does not have spare resources to invest. An infusion of cash into R&D, with the goal of making these green technologies economically viable, is an indispensable part of this strategy. If a person can build a house with a similarly priced solar panel roof that looks no different than a regular tar-tiled roof, why would they continue to buy electricity produced by a local coal-fired plant? They wouldn't. No government mandate needed. Similarly, if a comparably priced electric car can travel 300+ miles on a charge, has unlimited range with an on-board standby gas generator (plug-in hybrid) or in road wireless charging,[97] and is vastly cheaper to operate… that

vehicle would take over the market without any help from tax incentives or HOV privileges. Once green is better it will take over on its own. R&D must focus on making renewables economical, not on incentives and subsidies that artificially make alternatives competitive.

Policy Option

The U.S. government should immediately eliminate uncertainty within the energy industry by taking the concept of carbon pricing in the near future, through either a carbon tax or carbon trading, off the table.

In a complimentary action, the government should move to ease unnecessary regulations and restrictions on U.S. energy production and unleash U.S. energy on the world market. As President Obama said, the U.S. is the Saudi Arabia of natural gas. It is also the Saudi Arabia of coal, with almost as much in coal reserves as the next two countries combined - Russia and China. The U.S. has myriad untapped hydrocarbon resources and the government must address realistic environmental concerns while unleashing the full energy potential.

Unobtrusive mandates that encourage diversity in the transportation sector should be quickly implemented, including a flex fuel mandate, liquid fuels comparison standard, and LNG/CNG infrastructure investment.

A portion of the increased revenues from expanded hydrocarbon resource leases and revenues resulting from a growing economy must be diverted to the pursuit of alternate energy sources and reducing the negative externalities of carbon based fuels. The most effective method would be to fence a certain amount of the budget toward energy R&D and appoint DOE as the steward of these funds.

Finally, after allowing the economy to recover and technologies to mature, this policy option recognizes the requirement for *future* carbon pricing. In the next 10-15 years, the U.S. should establish a program to price carbon, starting slowly and increasing over time. Any carbon pricing program in the near term is unrealistic, both economically and politically.

This policy option will strengthen national security by unlocking a reliable supply of energy from North American sources and decreasing the impact of debt on national security. Additionally, by enhancing R&D efforts for alternate energy sources, the U.S. can lead global renewable energy innovation efforts and speed the attainment of a more diverse energy supply.

Conclusion

This option poses a paradoxical danger to the United States if successful in growing and stabilizing the U.S. economy. Recall ADM Mullen's concern that debt is the biggest threat to national security. This option does not solve the underlying *causes* of the growing debt, entitlements. If adopted without simultaneously tackling the growing entitlement problem, this option will lead to politicians kicking the can further down the road, where the economic cliff is steeper and more treacherous. The time is quickly approaching when technology will allow clean and renewable energy sources to become economically advantageous and make U.S. reserves of fossil hydrocarbons worthless. The U.S. should take advantage of its vast energy potential while the window of opportunity is open and use the increased revenue to bolster national security.

POLICY OPTION #3 – PRICE CARBON[98]

"For society's sake we need to fund energy research much more aggressively. We also need a carbon tax. We need policy that drives innovation and conservation."[99] -- Bill Gates

To secure U.S. economic and national security goals, the U.S. must work to make clean energy affordable in real, unsubsidized terms.[100] It has long been evident that the burning of fossil fuels such as coal, oil and natural gas has serious health, safety and security consequences, aside from the risks posed for climate change and global warming.[101] Despite this, many of the costs or damages resulting from the production and use of these fuels are not currently internalized in their market prices, producing negative externalities.[102] These negative externalities include air pollution emitted by power plants and cars, oil spills, sludge from coal mines, street and highway congestion and increased GHG emissions.[103] The majority of monetized damages[104] resulting from these negative externalities are due to health damages, including premature mortality and morbidity, such as chronic bronchitis and asthma.[105] Securing the goal of clean, affordable energy requires smart energy policies that take into account the full costs (both private and social) of energy.[106] Pricing carbon can "promote cost-effective abatement, deliver powerful innovation incentives, and ameliorate rather than exacerbate government fiscal problems."[107]

Pricing energy to more fully reflect the true costs gives consumers a strong incentive to make better decisions about their energy consumption and gives firms an incentive to invest in low-carbon technology and alternate fuels.[108] Electricity generated from coal has an estimated external cost of 70 percent of its market price, while the social cost of petroleum equals about 25 percent of the price of gasoline. In contrast, the external cost of electricity produced from natural gas equals about 19 percent of its market price.[109] However, "[b]ecause energy is such a large part of consumer budgets and so central to our advanced economies, people are reluctant to allow energy prices to reflect the true social costs of energy consumption."[110] Policy makers must seriously address the market failures associated with energy production and appropriately account for their external social costs. Recent technological innovations, which have dramatically expanded U.S. domestic natural gas and oil production, provide a unique opportunity to reduce emissions by eschewing the most polluting fuels, while lessening dependence on imported oil.

In 2010, the National Research Council of the National Academies estimated that *non-climate change* costs resulting from the production and use of energy in 2005 exceeded $120B, most of which stemmed from air pollution, particularly emissions of oxides of nitrogen (NO_x), sulfur dioxide (SO_2) and particulate matter (PM), and its effects on health and welfare.[111] This estimate did not include damages the council was unable to quantify, such as damages related to some pollutants, climate change, ecosystems, infrastructure and security. In 2010, the U.S. Interagency Working Group on the Social Cost of Carbon analyzed the social cost of carbon, which refers to the damages associated with release of an additional ton of CO_2 in the atmosphere, estimating the central value at $21/ton of CO_2 emissions.[112]

A variety of options exist to address negative externalities, including taxes, transferrable pollution allowances (such as those used in cap-and-trade or emission-reduction credit systems), and command-and-control regulations, such as performance standards and technology-based standards.[113] Market-based approaches such as carbon tax or cap-and-trade[114] are the most effective ways to decrease carbon emissions[115] because firms and consumers are in the best position to make decisions about how they can reduce carbon emissions at the lowest cost.[116] Pricing carbon provides a market signal and swift incentive to change behavior.[117]

A carbon tax (or trading of emission permits) would create market incentives for the production of energy-efficient goods and could facilitate phasing out the existing patchwork of federal energy incentives.[118] Taxing energy-related activities which generate negative externalities is likely to enhance the efficiency of energy tax policy as compared to subsidizing cleaner energy alternatives, bringing the external costs of hydrocarbons to bear on consumers and producers avoids the government's proclivity to "pick winners," which can result from granting subsidies to specified sectors within the broader clean energy arena.[119] A carbon tax also provides price certainty to firms that need a predictable environment to make smart investments in long-lived energy infrastructure.[120] Investors continue to wait for Congress to enact comprehensive climate and energy legislation that would establish long-term certainty for investment decisions.[121] Setting a carbon tax to provide a price floor for carbon will provide increased certainty to investors in low-carbon technologies.[122]

Experts have concluded that pricing carbon will be a crucial but insufficient component of a national climate change response strategy.[123] Such a strategy will also need to include well targeted complementary policies, such as measures to increase energy efficiency and develop and demonstrate power plants equipped with carbon capture and sequestration (CCS).[124]

The electricity/power sector merits special focus because it is responsible for approximately 40 percent of current and projected CO_2 emissions in the U.S.[125] and is expected to yield two-thirds to three-quarters of CO_2 emissions reductions under economy-wide carbon pricing.[126] With the levying of a carbon tax, the power sector would be most significantly transformed as coal-fired power plants are retrofitted with CCS or replaced with natural gas or renewables.[127] Expansion of natural gas demand for power generation spurred by a carbon price will increase natural gas production, resulting in more natural gas liquids that can serve as an oil substitute, thus increasing supply.[128]

A carbon tax would also decrease demand for oil in the transport sector.[129] Many proposals which would price carbon in the range of $20 per ton of CO_2 emitted appear to result in an approximate 10-25 cents/gallon increase in prices at the pump, increasing only gradually over time.[130] While this is far below what some noted economists estimate as gasoline's $2/gallon negative externality cost,[131] it would provide a price signal to more accurately reflect the true costs of gasoline. A gradually increasing oil or gasoline tax that rose more quickly if oil prices fell could also temper price volatility, providing a floor on the price which could help to sustain demand for more fuel-efficient vehicles, including hybrid or plug-in models, even if oil and gasoline prices moderated from their current levels.[132]

The downside of a carbon tax is that it raises the average cost of energy for consumers and firms.[133] It is precisely this increase in prices that will lower demand, reduce imported crude oil, and improve both the U.S. trade deficit and the terms of trade. Policies to reduce domestic oil demand will also reduce the world oil price and result in lower prices for both imported and domestic oil.[134] Concerns regarding a carbon tax's impact on the economy and the possibility of reduced competitiveness require attention. Studies of the estimated impact of both actual and proposed carbon taxes on economic performance vary widely, but a number indicate that the impacts may be lower than predicted, given that the "majority of emissions in developed countries occur in non-traded sectors, such as electricity, transportation, and residential buildings."[135] Energy-intensive manufacturing firms producing goods competing in international markets may face competitive pressure to relocate to countries that do not internalize carbon emissions costs.[136] Such firms are likely to advocate for border adjustments, or a tax on imports equivalent to the implicit tax on the same domestically produced goods, to retain their

competitiveness.[137] Concerns about domestic competitiveness underscore the importance for coordinated, international action to address shared energy and climate change challenges.

The adoption by British Columbia of a carbon tax in 2008[138] has received positive assessments, both from the 54 percent of residents who support it[139] and observers such as *The Economist*, saying "British Columbia (BC) has shown the rest of Canada, a country with high carbon emissions per head, that a carbon tax can achieve multiple benefits at minimal cost."[140] Per capita fuel consumption in BC has fallen more than elsewhere in Canada, 4.5 percent since the tax's introduction, while growth is slightly higher than the national average. Additionally, unemployment is slightly lower. BC residents also enjoy lower income tax rates and businesses have had time to adjust their carbon use as a result of identifying gradual increases in advance.[141] Brookings similarly concluded that the impact of a carbon tax on the U.S. economy would be minimal. The Brookings analysis considered a combined proposal for a carbon tax beginning at $30/ton of carbon dioxide equivalent in 2010 (increasing by 5 percent thereafter), coupled with a tax credit to incentivize energy efficiency.[142] The result: an estimated 61 percent reduction in CO_2 emissions by 2040, with a reduction of GDP growth rates of less than 0.1 percent.[143]

Carbon taxes have also been levied in several northern European countries (including Norway, Sweden, Denmark and Finland) since the 1990s, resulting in substantial variations in the effective tax per ton of CO_2, but demonstrating reductions in GHG emissions and generation of revenues to lower income tax rates and/or fund government expenditure.[144] The European Union (EU) Emissions Trading Scheme (ETS), a cap-and-trade system, is the largest carbon pricing regime, covering approximately 11,500 large downstream emitters.[145] The EU extended its ETS system to the aviation sector in 2012,[146] triggering complaints and legal challenges by other nations objecting to application of the EU ETS provisions to international carriers flying to and from EU airports. Australia has also moved to price carbon, adopting a carbon tax on the 500 largest polluters in the country, slated for implementation in July 2012. The expansion of international carbon pricing systems appears likely to trigger more clashes between those jurisdictions currently imposing a price on carbon and those that do not.

Recycling Revenues Can Spur Innovation and Lower the Costs of a Carbon Tax

"Efficient use of carbon tax revenues can substantially lower the cost of any climate policy."[147] The revenue generated by a carbon tax would largely be a fiscal transfer from firms and consumers to the government.[148] Revenue recycling could play a number of important roles, including supporting complementary efforts, e.g. funding research and development and energy efficiency; reducing the financial burden of carbon pricing on low-income groups, for whom energy costs represent a higher proportion of household income; reducing distortionary taxes on factors of production, or reducing the current budget deficit.[149] Analysis indicates that the advantages of a carbon tax over other policy instruments, including more limited sector approaches, depends heavily on recycling revenues to reduce distortionary taxes in order to capture efficiency gains.[150]

Advancing technological innovation was the focus of a recent joint report by a group of scholars from the American Enterprise Institute, Brookings Institution and the Breakthrough Institute.[151] The proposal would channel potential funding sources, including modestly increased royalties for oil and gas production, a small fee on imported oil, a small surcharge on electricity sales, and/or dedicated revenues from a very small carbon price of $4-$5 per ton of CO_2 to fund $25B/year in investments into a reformed energy innovation system, while reforming existing energy subsidies and expanding ARPA-E efforts to procure and demonstrate cutting-edge energy

technologies.[152] Using revenue from a carbon tax to cut marginal income taxes or payroll labor taxes could also improve competitiveness by offsetting higher energy costs with lower labor costs, stimulating economic activity and reducing the risk of firm relocation to jurisdictions with lower energy costs.

Policy Option

The U.S. should introduce a carbon tax, which phases in gradually, beginning at $15/ton of net CO_2 emissions equivalent in 2015, increasing annually by $1 until it reaches $30, and adjusted for inflation thereafter. The tax should generally be levied on "upstream"[153] fossil fuel suppliers to facilitate administrative efficiency,[154] though a "downstream" approach may be preferable for power plants, which already monitor CO_2 emissions in accordance with Environmental Protection Agency regulations and could have a greater incentive to deploy CCS technology if their emissions were directly subject to the tax.[155] Revenues from the tax, which could reach approximately $80B by 2016,[156] should primarily be used to reduce distortionary payroll and/or marginal income taxes for individuals and corporations. A modest portion of the revenues (no more than 20 percent), should fund the following complementary policies: increasing research, development and demonstration of innovative energy technology, including CCS, and providing energy efficiency tax incentives that will provide low marginal cost, near-term reductions in carbon emissions.[157]

The U.S. should leverage such a significant domestic policy initiative to actively engage other major emitters to broaden coordinated, international efforts to address the global challenge of climate change. Concurrently, the U.S. should expand international energy policy and technology cooperation to improve the stability and reliability of global oil markets and accelerate development and deployment of technology to expand global energy supplies, including cleaner energy alternatives.[158]

Conclusion

Given the nation's current fiscal crisis, there is no fiscal space to incentivize a transition to cleaner, more sustainable forms of energy by relying solely on continuing subsidies and tax credits. The U.S. must unleash market forces to provide the powerful price signals needed to spur needed, cost-effective changes in the nation's energy production and consumption patterns, promote technological innovation, especially in cleaner, more sustainable forms of energy, and develop a more resilient economy less vulnerable to oil shocks. The introduction of a relatively low, but gradually increasing carbon price now will immediately incentivize the diversification of the U.S. energy supply footprint and can also provide a "least regrets" option regarding the risks of serious climate change impacts largely ignored by current U.S. energy policy. Further delay in leveling the playing field for cleaner sources of energy risks more difficult and costly decisions in the future. The time to begin building a more secure, resilient and sustainable national energy policy is now.

POLICY OPTION RECOMMENDATION

The option to price carbon, through the enactment of a carbon tax, offers the best path to generate the supply diversity required to guarantee energy security. Pricing carbon allows alternate energy sources to compete on a level playing field and mitigates the negative externalities associated with fossil fuels. The U.S. has traditionally been a market leader in energy, playing a central role by innovating new technologies and bringing those innovations to consumers. Appropriately pricing carbon emissions will allow the U.S. to reassert global leadership by incentivizing firms to aggressively innovate and lead the world in alternative energy solutions.

Each option presented has individual elements that should be pursued as part of a comprehensive energy plan. However, the option to price carbon is the most strategic as it economically solves the problem of attaining energy diversity and gracefully allows parallel pursuit of complementary approaches found in the other options. For example, the study group endorses an expansion of nuclear power capacity in the U.S. and also endorses the mandate for flex fuels in the transportation sector. These elements are also more likely to be adopted as a result of a tax on carbon because of their low carbon footprint compared to the status quo. By pricing carbon and implementing complementary policies to encourage cost reduction and adoption of new technologies, the U.S. can achieve a greater degree of energy diversity, retain the advantages of market competition and enhance national security.[159] Legislating a carbon tax that is implemented gradually and fairly across the board will provide certainty in energy markets and allow U.S. firms to plan confidently in an increasingly competitive global business market. A carbon tax that is used to offset corporate and consumer taxes while increasing funding for R&D will induce more effective public-private partnerships and account for the social costs of energy production while minimizing impact to the economy.

Finally, a successful carbon tax would be temporary. Fossil fuels will continue to dominate the energy industry for many years, but resources are finite and increases to proven reserves, driven by technology, will eventually flatten and reverse. By strategically diversifying the U.S. energy footprint, a mature market for fossil fuel substitutes will be available when fossil fuel resources hit their eventual peak and commodity prices skyrocket. The energy security of the U.S. in 2050 demands a diverse energy supply that is resistant to global prices shocks and flexible in the face of future global instability.

CONCLUSION

The challenge to adopt a vision for energy security and diversity has been demonstrated by the inability to significantly change America's energy footprint over the last 40 years. This report defines the current U.S. Energy Industry, describes energy challenges and calls for the development of a federal energy policy. Three policy options were offered as a means to establish a centerpiece for a more directed federal energy policy. All three options have value and portions of each can be used in a complementary manner. If only one of the three policy options could be implemented; then a tax on carbon appears most compelling. In order to assert global leadership and enhance energy security, the United States Federal Government must take advantage of the current window of opportunity afforded by recent technological breakthroughs in domestic energy production and move purposefully to marshal public opinion and the necessary resources to achieve a comprehensive energy strategy.

ENDNOTES

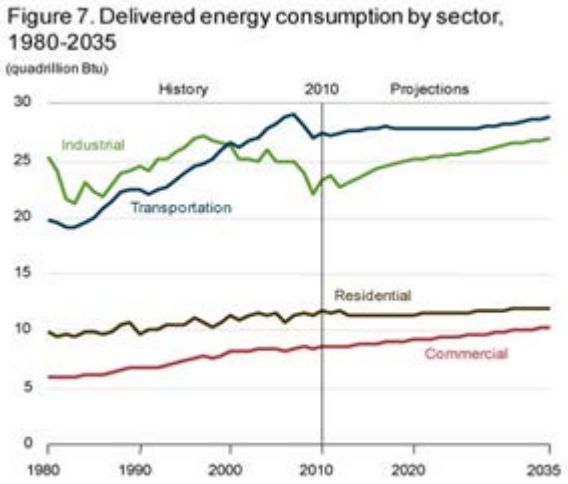
[1] Richard Nixon, "Statement Announcing Additional Energy Policy Measures," June 29, 1973. Online by Gerhard Peters and John T. Woolley, *The American Presidency Project*. http://www.presidency.ucsb.edu/ws/?pid=3886. (accessed February 14, 2012)

[2] U.S. Energy Information Administration. *Annual Energy Outlook 2012: Analysis & Projections* (Washington, DC: U.S. Department of Energy, 2012).

[3] Ibid.

[4] Ibid.

[5] U.S. Energy Information Administration, *What are the major sources and users of energy in the United States*? (Washington, DC:U.S. Department of Energy, October 25, 2011) http://www.eia.gov/energy_in_brief/major_energy_sources_and_users.cfm (accessed April 18, 2012).



[6] Ibid.

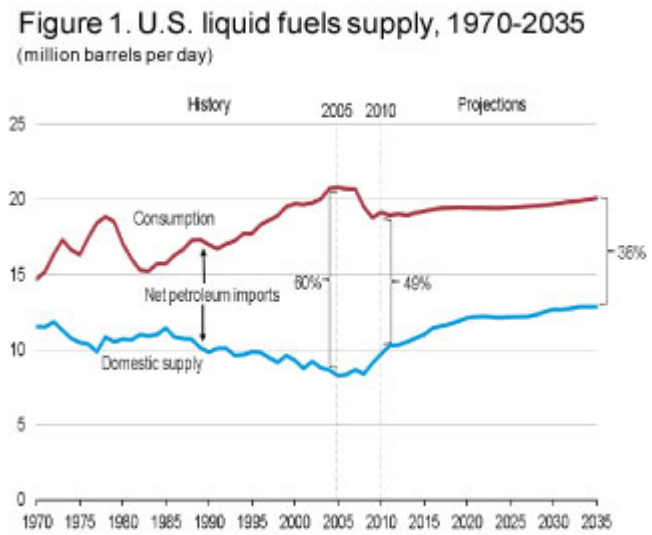
[7] Barbara Powell, "US was net oil product exporter for first time since 1949," Bloomberg, http://www.bloomberg.com/news/2012-02-29/u-s-was-net-oil-product-exporter-in-2011.html, (accessed May 16, 2012).

[8] Gail Tverberg, "World Energy Consumption Since 1820 in Charts", *Energy Bulletin* http://www.energybulletin.net/stories/2012-03-16/world-energy-consumption-1820-charts, (accessed May 15, 2012).

[9] The World Factbook. https://www.cia.gov/library/publications/the-world-factbook/rankorder/2178rank.html (accessed April 18, 2012).

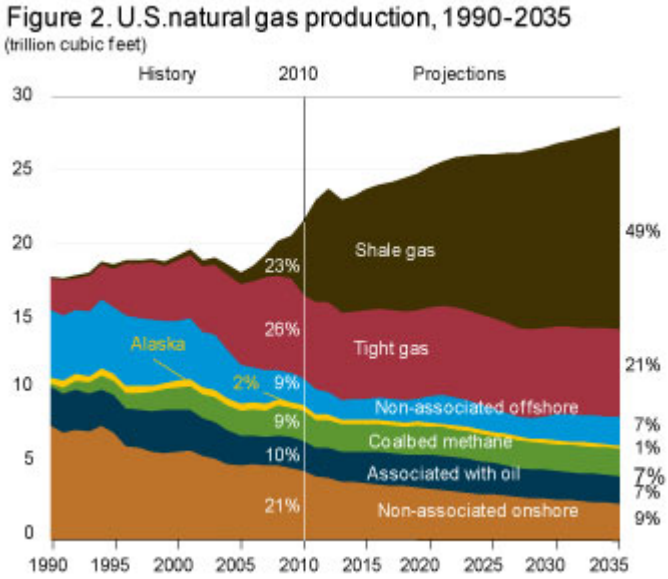
[10] Ibid.

[11] U.S. Energy Information Administration. *Annual Energy Outlook 2012: Executive Summary* (Washington DC: U.S. Department of Energy, 2012).
Projections in the Annual Energy Outlook 2012 (AEO2012) Reference case focus on the factors that shape U.S. energy markets in the long term, under the assumption that current laws and regulations remain generally unchanged throughout the projection period. The AEO2012 Reference case provides the basis for examination and discussion of energy market trends and serves as a starting point for analysis of potential changes in U.S. energy policies, rules, or regulations or potential technology breakthroughs. Some of the highlights in the AEO2012 Reference case include:
Projected growth of energy use slows over the projection period, reflecting an extended economic recovery and increasing energy efficiency in end-use applications
Projected transportation energy demand grows at an annual rate of 0.2 percent from 2010 through 2035 in the Reference case, and electricity demand grows by 0.8 percent per year. Energy consumption per capita declines by an average of 0.5 percent per year from 2010 to 2035. The energy intensity of the U.S. economy, measured as primary energy use in British thermal units (Btu) per dollar of gross domestic product (GDP) in 2005 dollars, declines by 42 percent from 2010 to 2035.
Domestic crude oil production increases
Domestic crude oil production has increased over the past few years, reversing a decline that began in 1986. U.S. crude oil production increased from 5.1 million barrels per day in 2007 to 5.5 million barrels per day in 2010. Over the next 10 years, continued development of tight oil, in combination with the ongoing development of offshore resources in the Gulf of Mexico, pushes domestic crude oil production in the Reference case to 6.7 million barrels per day in 2020, a level not seen since 1994. Even with a projected decline after 2020, U.S. crude oil production remains above 6.1 million barrels per day through 2035.
With modest economic growth, increased efficiency, growing domestic production, and continued adoption of nonpetroleum liquids, net petroleum imports make up a smaller share of total liquids consumption



U.S. dependence on imported petroleum liquids declines in the AEO2012 Reference case, primarily as a result of growth in domestic oil production by more than 1 million barrels per day by 2020; an increase in biofuels use to more than 1 million barrels per day crude oil equivalent by 2024; and modest growth in transportation sector demand through 2035. Net petroleum imports as a share of total U.S. liquid fuels consumed drop from 49 percent in 2010 to 36 percent in 2035 in AEO2012 (Figure 1). Proposed fuel economy standards covering vehicle model years 2017 through 2025 that are not included in the Reference case would further reduce projected liquids use and the need for liquids imports.

Natural gas production increases throughout the projection period



Much of the growth in natural gas production is a result of the application of recent technological advances and continued drilling in shale plays with high concentrations of natural gas liquids and crude oil, which have a higher value in energy equivalent terms than dry natural gas. Shale gas production increases from 5.0 trillion cubic feet in 2010 (23 percent of total U.S. dry gas

production) to 13.6 trillion cubic feet in 2035 (49 percent of total U.S. dry gas production) (Figure 2).

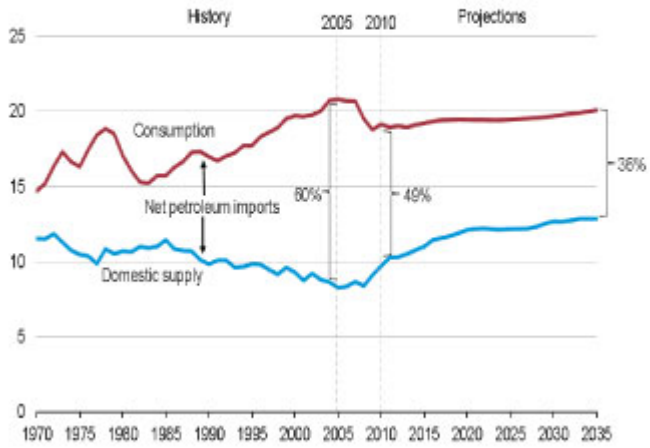
Expected changes in the *AEO2012* complete release

The Reference case results shown in the AEO2012 Early Release will vary somewhat from those included in the complete Annual Energy Outlook (AEO) that will be released in spring 2012, because some data and model updates were not available for inclusion in the Early Release. In particular, the complete AEO2012 will include the Mercury and Air Toxics Standards issued by the U.S. Environmental Protection Agency (EPA) in December 2011; updated historical data and equations in the transportation sector, based on revised data from the National Highway Traffic Safety Administration (NHTSA) and the Federal Highway Administration; a new model for cement production in the industrial sector; a revised long-term macroeconomic projection based on an updated long-term projection from IHS Global Insight, Inc.; and an updated representation of biomass supply.

U.S. production of natural gas is expected to exceed consumption early in the next decade

Total U.S. energy-related carbon dioxide emissions remain below their 2005 level through 2035

Figure 1. U.S. liquid fuels supply, 1970-2035
(million barrels per day)



[12] Ibid.

[13] Ibid.

[14] Ibid.

[15] U.S. Congressional Budget Office, "Federal Financial Support for the Development and Production of Fuels and Energy Technologies," (Washington, DC: March 2012): 1. http://www.cbo.gov/sites/default/files/cbofiles/attachments/03-06-FuelsandEnergy_Brief.pdf (accessed May 15, 2012).

[16] Ibid, 2.

[17] Ibid.

[18] Ibid, 1.

[19] Stan Mark Kaplan, "Wind Power in the United States: Technology, Economic and Policy Issues," CRS Report for Congress, (Washington, DC: October 21, 2008), 21-23.

[20] Massachusetts v. EPA et al.: April 2007. http://www.c2es.org/federal/analysis/judicial/massachusetts-et-al-v-epa-et-al (accessed May 14, 2012).

[21] U.S. Environmental Protection Agency, "EPA FACT SHEET: Proposed Carbon Pollution Standard for New Power Plants," http://epa.gov/carbonpollutionstandard/pdfs/20120327factsheet.pdf, (accessed May 14, 2012).

[22] Keith Johnson, Rebecca Smith, and Kris Maher, Wall Street Journal, "New Rules Limit Coal Plants; EPA Tips Scales Toward Natural Gas in Power Generation; Miners, GOP Cry Foul," *The Wall Street Journal*, March28, 2012. http://online.wsj.com/article/SB10001424052702303404704577307524051798192.html (accessed May 16, 2012).

[23] U.S. Energy Information Administration, *Review of Emerging Resources: U.S. Shale Gas and Shale Oil Plays* (Washington, DC: U.S. Department of Energy). http://www.eia.gov/analysis/studies/usshalegas (accessed April 15, 2012).

[24] U.S. Energy Information Administration, *Natural Gas Navigator* (Washington, DC: U.S. Department of Energy). http://www.eia.gov/dnav/ng/hist/na1170_nus_8a.htm (accessed February 24, 2012).

[25] John Larson, "Shale Gas Supports More Than 600,000 American Jobs Today," *IHS Global Insight* (2011). http://press.ihs.com/press-release/energy-power/shale-gas-supports-more-600000-american-jobs-today-2015-shale-gas-predict (accessed February 12, 2012).

[26] U.S. Energy Information Administration, *Review of Emerging Resources: U.S. Shale Gas and Shale Oil Plays* (Washington, DC: U.S. Department of Energy). http://www.eia.gov/analysis/studies/usshalegas, (accessed April 15, 2012).

[27] David LaGesse, "Shale Oil Boom Takes Hold on the Plains," *National Geographic News* (2011). http://news.nationalgeographic.com/news/energy/2011/09/110928-shale-oil-boom-colorado-great-plains (accessed April 15, 2012).

[28] Ibid.

[29] Jinsheng Wang, David Ryan, and Edward Anthony, "Reducing the Greenhouse Gas Footprint of Shale Gas," *Energy Policy*, October 2011. http://www.journals.elsevier.com/energy-policy/ (accessed on February 29, 2012).

[30] John Armbruster, “Researcher Discusses Ohio Fracking, Earthquakes,” interview by Milissa Block, *All Things Considered*, Jan 3, 2012.

[31] U.S. Department of Energy, *Modern Shale Gas Development: A Primer*, (Washington, DC: U.S. Department of Energy, April 2009), ES-4.

[32] Abrahm Lusgarten, “Years After Evidence of Fracking Contamination, EPA to Supply drinking Water to Homes in Pa. Town”, ProPublica, Jan 20, 2012. http://www.propublica.org/article/years-after-evidence-of-fracking-contamination-epa-to-supply-drinking-water (accessed on March 12, 2012).

[33] U.S. Department of Energy, *Modern Shale Gas Development: A Primer*, 25.

[34] The White House, *Blueprint for a Secure Energy Future*, March 30, 2011.

[35] Secretary of Energy Advisory Board, *Shale Gas Production Subcommittee: Second Ninety Day Report*, (2011):10.

[36] Barclay Nicholson and Kadlan Blanson, “Trends Emerge on Hydraulic Fracturing Liltigation,” *Oil & Gas Journal*, 109, 19 (2011): 80-85.

[37] Abrahm Lusgarten, “Underused Drilling Practices Could Avoid Pollution,” ProPublica, December 14, 2009. http://www.propublica.org/article/underused-drilling-practices-could-avoid-pollution-1214 (accessed on February 29, 2012).

[38] Burzynski, Andrea. "Yergin's "Quest" takes broad look at energy resources." *Reuters.* September 20, 2011. http://www.reuters.com/article/2011/09/20/us-books-danielyergin-idUSTRE78J4L220110920 (accessed April 19, 2012).

[39] U.S. Energy Information Agency, *How dependent are we on foreign oil*? (Washington, DC: U.S. Department of Energy, June 24, 2011). http://205.254.135.7/energy_in_brief/foreign_oil_dependence.cfm (accessed April 18, 2012).

[40] U.S. Energy Information Agency, *World Oil Transit Chokepoints* (Washington, DC: U.S. Department of Energy, December 30, 2011). http://www.eia.gov/countries/regions-topics.cfm?fips=WOTC (accessed April 19, 2012).

[41] Tverberg, Gail E. "The U. S. electric grid: will it be our undoing?" *Post Carbon Institute: Energy Bulletin.* 7 May, 2008. http://www.energybulletin.net/node/43823 (accessed April 19, 2012).

[42] Siobhan Gorman, "Electricity Grid in U.S. Penetrated By Spies." *Wall Street Journal.* April 8, 2009. http://online.wsj.com/article/SB123914805204099085.html (accessed April 19, 2012).

[43] Ibid.

[44] "Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack." Volume 1: Executive Report, 2004.

[45] U.S. Energy Information Agency, *International Energy Outlook 2011* (Washington, DC: U.S. Department of Energy, 2011). http://www.eia.gov/forecasts/ieo/index.cfm (accessed April 19, 2012).

[46] World Energy Outlook. http://www.worldenergyoutlook.org/docs/weo2011/factsheets.pdf (accessed April 19, 2012).

[47] International Energy Agency, *World Energy Outlook 2011 Factsheet.* http://www.iea.org/weo/docs/weo2011/factsheets.pdf (accessed April 19, 2012).

[48] Justin Gillis, "Carbon Emissions Show Biggest Jump Ever Recorded" *New York Times*, December 5, 2011. http://www.nytimes.com/2011/12/05/science/earth/record-jump-in-emissions-in-2010-study-finds.html?_r=1 (accessed April 19, 2012).

[49] Ibid.

[50] Scott Jacobs and Rob McNish, "The U.S. stimulus program: Investing in Energy Efficiency," *The McKinsey Quarterly*. http://www.mckinseyquarterly.com/The_US_stimulus_program_Investing_in_energy_efficiency_2385.

[51] Michael Hess, *Energy Innovation Hubs: Achieving Our Energy Goals with Science*, (energy.gov). http://energy.gov/articles/energy-innovation-hubs-achieving-our-energy-goals-science.

[52] *Bloomberg New Energy Finance. Global Trends in Renewable Energy Investments 2011*. Frankfurt School UNEP Collaborating Centre for Climate & Sustainable Energy Finance. http://www.unep.org/pdf/BNEF_global_trends_in_renewable_energy_investment_2011_report.pdf. (accessed May 15, 2012).

[53] Advanced Research Projects Agency - Energy (ARPA-E), *Proposed Appropriation Language* (Washington, DC: U.S. Department of Energy). http://arpa-e.energy.gov/LinkClick.aspx?fileticket=HJ-gg0689ME percent3d&tabid=184 (accessed April 19, 2012).

[54] U.S. Energy Information Administration, *Renewable Energy Consumption by Major Source.* (Washington, DC: U.S. Department of Energy), http://www.eia.gov/totalenergy/data/annual/pdf/sec10_2.pdf (accessed April 19, 2012).

[55] Ester Tanquintic-Misa, "China Leads Global Investments in Renewable Energy," *International Business Times.* http://au.ibtimes.com/articles/261083/20111205/china-leads-global-investments-renewable-energy.htm. (accessed May 12, 2012).

[56] American Energy Innovation Council, "A Business Plan for America's Energy Future," September 2011. http://americanenergyinnovation.org/the-business-plan-2010/. (accessed April 20, 2012).

[57] Gregory DL Morris, "What is the Real Cost of Cheap Energy?" *Wharton Magazine*, January 26, 2012. http://whartonmagazine.com/issues/winter-2012/what-is-the-real-cost-of-cheap-energy/. (accessed April 18, 2012).

[58] Rex Tillerson. North America's Historic Energy Transformation. Speech delivered at CERA Week, Houston, TX on March 9, 2012. http://www.exxonmobil.com/Corporate/news_speeches_20120309_rwt.aspx. (accessed April 18, 2012).

[59] This Policy Option was authored by Dr. Michael "Hoff" Ondas.

[60] Dwight D. Eisenhower, "Address to the 470th Plenary Meeting of the United Nations General Assembly," International Atomic Energy Agency (IAEA), http://www.iaea.org/About/history_speech.html (accessed February 5, 2012).

[61] U.S. Nuclear Regulatory Commission, "NUREG-1350, Vol. 23" *Information Digest 2011-2012* (August 2011), 14 and 28. http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1350/v23/sr1350v23.pdf (accessed March 15, 2012).

[62] John Deutch, Ernest J. Moniz and et al, *The Future of Nuclear Power: An Interdisciplinary MIT Study* (Cambridge, MA): Massachusetts Institute of Technology, 2003, 3. http://web.mit.edu/nuclearpower/pdf/nuclearpower-full.pdf (accessed February 12, 2012).

[63] "Coming Clean about Nuclear Power," *Scientific American*, June 2011, 14.

[64] The Blue Ribbon Commission on America's Nuclear Future, "Report to the Secretary of Energy", January 26, 2012, 14. http://brc.gov/sites/default/files/documents/brc_finalreport_jan2012.pdf (accessed March 15, 2012).

[65] Cliff W. Hamal, Julie M. Carey, and Christopher L. Ring, *Spent Nuclear Fuel Management: How Centralized Interim Storage can Expand Options and Reduce Costs*, 2011, 14. http://www.brc.gov/sites/default/files/documents/centralized_interim_storage_of_snf.pdf (accessed March 15, 2012).

[66] Ibid, 56.

[67] Adam Piore, "Planning for the Black Swan," *Scientific American*, June 2011, 52.

[68] Ibid, 50.

[69] Ibid, 53.

[70] Deutch, Moniz and et al, *The Future of Nuclear Power: An Interdisciplinary MIT Study*, 9.

[71] This Policy Option was authored by LTCOL Tim "Rabid" Sundvall and CAPT Larry "Bingo" Vincent.

[72] Geoff Colvin, "Adm. Mike Mullen: Debt is still biggest threat to U.S. security," CNN Money, 10 May 2012, http://management.fortune.cnn.com/2012/05/10/admiral-mike-mullen/?section=magazines_fortune, (accessed 15 May 2012).

[73] John Merline, "Nearly One Million Workers Vanished Under Obama," *Investor's Business Daily*, January 20, 2012. http://news.investors.com/article/597581/201201121629/jobless-figures-hide-real-problems.htm?p=full (accessed April 24, 2012).

[74] "U.S. Government Spending as a Percentage of GDP from FY1903 to FY2010" http://www.usgovernmentspending.com/spending_chart_1903_2010USp_13s1li0181441_621cs_F0t_US_Government_Spending_As_Percent_Of_GDP (accessed May 14, 2012); Tax Policy Center, "Historical Revenues as a Percentage of GDP," (Brookings Institution) http://www.taxpolicycenter.org/taxfacts/displayafact.cfm?Docid=205 (accessed May 14, 2012).

[75] "World's Biggest Debtor Nations," CNBC, http://www.cnbc.com/id/30308959/The_World_s_Biggest_Debtor_Nations?slide=2 (accessed May 14, 2012).

[76] U.S. Congressional Budget Office, "CBO's 2011 Long-Term Budget Outlook," (Washington, DC: June 22, 2011). http://www.cbo.gov/publication/41486, (accessed 15 May 2012).

[77] Daniel Klitsch, "New Taxes on Oil Industry Would be Like Cooking the Golden Goose," U.S. News and World Report, August 3, 2011. http://www.usnews.com/opinion/blogs/on-energy/2011/08/03/taxing-oil-industry-is-like-cooking-the-golden-goose (accessed May 14, 2012).

[78] Jason Koebler, "Obama: U.S. Saudi Arabia of Natural Gas," U.S. News and World Report, January 26, 2012. http://www.usnews.com/news/articles/2012/01/26/obama-us-saudi-arabia-of-natural-gas (accessed May 14, 2012).

[79] Maia Warren, Information Specialist PA Department of Revenue, e-mail message to author April 25, 2012.

[80] Bureau of Labor Statistics, "Local Area Unemployment Statistics," http://www.bls.gov/web/laus/laumstrk.htm (accessed May 14, 2012).

[81] Ibid.

[82] Charlie Savage, "Drilling Ban Blocked; U.S. Will Issue New Order," New York Times, June 22, 2010. http://www.nytimes.com/2010/06/23/us/23drill.html (accessed April 24, 2012); Robin Millican, "President Obama Can Give the Economy a new Lease on Life with More Permits," *Institute for Energy Research*, February 16, 2012. http://www.instituteforenergyresearch.org/2012/02/16/president-obama-can-give-the-economy-a-new-lease-on-life-with-more-permits/ (accessed April 24, 2012).
One year after the Obama administration's moratorium was overturned by a federal judge, only four permits were given for drilling or exploration, and those were all companies that had permits re-issued. Even now, with the administration publicly voicing support for offshore drilling, shallow and deep-water issues of permits are 57 percent and 68 percent below their historical average and in 2011, permit reviews took 48 days longer than the historical average. Finally, only 23 percent of drilling plans have been approved, a 69 percent reduction from the historical averageIt is understandable that the administration would move cautiously after Deep Water horizon, but these numbers need to improve.

[83] Roberta Rampton, "White House Renews Veto Threat Over Keystone," *Reuters*, April 17, 2012, http://www.reuters.com/article/2012/04/18/usa-keystone-idUSL2E8FHI0P20120418, (accessed 18 May, 2012) .

[84] "Pipeline 101," http://www.pipeline101.com/overview/energy-pl.html (accessed April 24, 2012).

[85] Tamara Keith, "Just How Many Jobs Would the XL Pipeline Create," NPR, December 11, 2012. http://www.npr.org/blogs/itsallpolitics/2011/12/14/143719155/just-how-many-jobs-would-the-keystone-pipeline-create (accessed April 12, 2012).

[86] Michael Levi, "Five myths about the Keystone XL pipeline." *The Washington Post*, January 18, 2012. http://www.washingtonpost.com/opinions/five-myths-about-the-keystone-xl-pipeline/2011/12/19/gIQApUAX8P_story.html (accessed May 14, 2012).

[87] "Sale of Fossil Fuels Produced from Federal and Indian Lands," Energy Information Institute, March 2012, http://www.eia.gov/analysis/requests/federallands/pdf/eia-federallandsales.pdf, (accessed May 14, 2012).

[88] Dave Summers, "The Growth of the Natural Gas Industry," Oil Price, July 26, 2011, http://oilprice.com/Energy/Natural-Gas/The-Growth-Of-The-Natural-Gas-Industry.html, (accessed May 14, 2012).

[89]"ANWR Information Brief – Native Facts," Frontier Communications. http://www.anwr.org/features/pdfs/native-facts.pdf. (accessed Aprill 20,2012); Lydia Saad, "U.S. Oil Drilling Gains Favor with Americans," Gallup Polling. http://www.gallup.com/poll/146615/oil-drilling-gains-favor-americans.aspx. (accessed March 11,2012); Lisa Demer, "Alaskan Lawmakers Head to DC to Lobby for ANWR Drilling," *Anchorage Daily News*, February 11, 2012. http://www.thenewstribune.com/2012/02/09/2020168/legislators-plan-dc-trip-to-sell.html. (accessed May14, 2012).
- 49 percent of Americans support drilling in ANWR vice 45 percent who do not.
- 78 percent of Alaskans support drilling in the ANWR.

[90] Kenneth J. Bird and David Houseknecht, "Arctic National Wildlife Refuge, 1002 Area, Petroleum Assessment, 1998, Including Economic Analysis," U.S. Geological Survey, http://pubs.usgs.gov/fs/fs-0028-01/fs-0028-01.htm (accessed May 14, 2012).

[91] "Natural Gas Import and Export Terminals," Center for Liquefied Natural Gas. http://www.lngfacts.org/LNG-Today/Import-Terminals.asp (accessed May 14, 2012).

[92] Javier Blas, "Japan Pushes Asia Gas Price Close to High," *Financial Times*, May 17, 2012, http://www.ft.com/intl/cms/s/0/22943afa-a022-11e1-90f3-00144feabdc0.html#axzz1vExVCOGt, (accessed 18 May 2012).

[93] Tom Ridge and Mary E. Peters, "The Methanol Alternative to Gasoline," *The New York Times*, February23, 2012. http://www.nytimes.com/2012/02/24/opinion/methanol-as-an-alternative-to-gasoline.html, (accessed 25 March 2012).

[94] Ibid.

[95] Ibid.

[96] Barack H Obama, 2012 State of the Union Address, www.whitehouse.gov/state-of-the-union-2012 (accessed May 17, 2012).

[97] Rachel Kaufman, "Recharge and Roll: Electric Carmakers Plan to Cut the Cord," *Scientific American*, October 28, 2011, http://www.scientificamerican.com/article.cfm?id=wireless-electric-car-charging, (accessed March 25, 2012).

[98] This Policy Option was authored by Ms. Debra "JD" Juncker.

[99] Heather King, "Bill Gates on the Five Miracles Needed for Energy and Climate Challenges," Triple Pundit web site. http://www.triplepundit.com/2012/03/bill-gates-five-miracles-needed-energy-climate-challanges/ (accessed March 29, 2012).

[100] Steven F. Hayward, Mark Muro, Ted Nordhaus and Michael Shellenberger, "Post-Partisan Power: How a Limited and Direct Approach to Energy Innovation Can Deliver Clean, Cheap

Energy, Economic Productivity and National Prosperity," October 2010, 13. http://thebreakthrough.org/blog/Post-Partisan%20Power.pdf. (accessed April 23, 2012).

[101] Ibid., 6.

[102] National Research Council of the National Academy of Sciences, "Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use," 2010, 29. http://www.nap.edu/catalog.php?record_id-12794. (accessed April 23, 2012).
The NRC defined an externality as "an activitity of one agent…that affects the well-being of another agent and occurs outside the market mechanism."

[103] William D. Nordhaus, "Energy: Friend or Enemy?," *The New York Review of Books*, October 27, 2011. http://www.nybooks.com/articles/archives/2011/oct/27/energy-friend-or-enemy/?pagination=false. (accessed April 23, 2012).

[104] Ibid, 49-53.
In the section "Damage Estimation: Monetizing Impacts," the NRC defines the monetized value of an externality as the maximum amount that an individual would be willing to pay to obtain the good and discusses its methodology for attaching monetary values to impacts of externalities.

[105] Ibid., 4-5.

[106] Michael Greenstone and Adam Looney, The Hamilton Project, "A Strategy for America's Energy Future: Illuminating Energy's Full Costs," Brookings, May 2011, 15.

[107] Joseph E. Aldy and Robert N. Stavins, "The Promise and Problems of Pricing Carbon: Theory and Experience," Resources for the Future Discussion Paper RFF DP 11-46, October 2011, for a special issue of *The Journal of Environment and Development*, 2. http://www.rff.org/RFF/Documents/RFF-DP-11-46.pdf

[108] Greenstone and Looney, The Hamilton Project, "A Strategy for America's Energy Future: Illuminating Energy's Full Costs," 21.

[109] William D. Nordhaus, "Energy: Friend or Enemy?"

[110] Ibid.

[111] National Research Council of the National Academy of Sciences, "Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use," 21; Aldy and Stavins, "The Promise and Problems of Pricing Carbon: Theory and Experience," 2-7.

[112] Interagency Working Group on Social Cost of Carbon, United States Government, "Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866," February 2010, 4-5 (http://www.epa.gov/oms/climate/regulations/scc-tsd.pdf);

Greenstone and Looney, The Hamilton Project, "A Strategy for America's Energy Future: Illuminating Energy's Full Costs," 13.
The central value is the average social cost of carbon across three integrated assessment models (DICE, PAGE and FUND), at a discount rate of 3 percent.

[113] National Research Council of the National Academy of Sciences, "Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use," 55.

[114] The primary difference between a carbon tax and a cap-and-trade system is that while a tax sets prices on emissions and lets the quantities of emissions vary, cap-and-trade sets emission quantity limits and lets prices vary. See, e.g. National Research Council of the National Academies, "Limiting the Magnitude of Future Climate Change," 7; Climate Policy Memo #1 "Cap and Trade v Taxes," Pew Center on Global Climate Change, March 2009.

[115] National Research Council of the National Academy of Sciences, "Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use," 55.

[116] Ibid.

[117] Ibid.

[118] William G. Gale and Benjamin H. Harris, "Reforming Taxes and Raising Revenue: Part of the Fiscal Solution," *Oxford Review of Economic Policy*, Volume 27, Number 4, 2011: 563-588, 582.

[119] Molly Sherlock, "Energy Tax Policy: Historical Perspectives on and Current Status of Energy Tax Expenditures," *Congressional Research Service Report R41227*, May 2, 2011, 27.

[120] Ibid., 22.

[121] Pew Charitable Trust, "Who's Winning the Clean Energy Race?," 15.

[122] Mikael Skou Anderson and Paul Ekins, eds. *Carbon Energy Taxation: Lessons from Europe*, (Oxford University Press, November 2009).

[123] National Research Council of the National Academies, *"Limiting the Magnitude of Future Climate Change,"* 134.

[124] Ibid.

[125] Alan J. Krupnick, Ian W.H. Parry, Margaret Walls, Tony Knowles, and Kristin Hayes, "Toward a New National Energy Policy: Assessing the Options," National Energy Policy Institute and Resources for the Future, November 2010, 69.

[126] Karen Palmer, Anthony Paul and Matt Woerman, "Electricity Sector Impacts of a Carbon Tax, Resources for the Future" presentation, Fiscal Reform and Climate Protection: Considering a U.S. Carbon Tax, October 18, 2011, Washington, D.C., 2.

[127] Trevor Houser and Shashank Mohan, "American's Energy Security Options," Peterson Institute for International Economics Policy Brief, Number PB11-10, June 2011, 12.

[128] Ibid., 13.

[129] Ibid., 9, 12, describing an American Enterprise Institute proposal to replace various energy subsidies, credits and regulations with a carbon tax in 2013 that reaches $26/ton CO_2 by 2017 and increases by 5.6 percent thereafter is estimated to reduce U.S. oil demand by 652,000 barrels per day (bpd) through 2035, lowering U.S. oil expenditures by $64 billion/year. See also Joseph Antos, Andrew Biggs, Alex Brill and Alan Viard, "A Balanced Plan For Fiscal Stability or Growth," American Enterprise Institute, The Solutions Initiative, http://www.google.com/url?sa=t&rct=j&q=American+Enterprise+Institute+carbon+tax+2013+percent2426+per+ton&source=web&cd=11&ved=0CCoQFjAAOAo&url=http percent3A percent2F percent2Fpgpf.org percent2F~ percent2Fmedia percent2F31D0BDC87B8742BA94A8F81E0B18C7F6&ei=W32RT4XNK9HG6AGa7IixBA&usg=AFQjCNHxYo7y1lIl5DDu1ftaXS-FmlOo9Q (accessed April 20, 2012).

[130] Alan S. Blinder, "The Carbon Tax Miracle Cure," *The Wall Street Journal*, January 31, 2011.

[131] N. Gregory Mankiw, "A Better Tax System (Assembly Instructions Included)", *The New York Times*, January 21, 2012, http://www.nytimes.com/2012/01/22/business/four-keys-to-a-better-tax-system-economic-view.html?_r=1&scp=1&sq=mankiw percent20gas percent20tax&st=cse&pagewanted=all.

[132] Kelly Sims Gallagher, ed. *Acting in Time on Energy Policy* (Washington, D.C.: Brookings Institution Press, May 2009); Carlos Pascual and Jonathan Elkind, eds. *Energy Security: Economics, Politics, Strategies, and Implications* (Washington, D.C.: Brookings Institution Press, 2010), 225-230.

[133] Houser and Mohan, "American's Energy Security Options," 13.

[134] National Research Council of the National Academy of Sciences, "Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use," 20.

[135] Aldy and Stavins, "The Promise and Problems of Pricing Carbon: Theory and Experience," 5.

[136] Ibid.

[137] Ibid, 19.

[138] *The Economist*, July 23, 2011, Fol. 399, Issue 8743, pp. 35-36.
British Columbia initially set its carbon tax at C$10 per ton of carbon dioxide emissions, increasing by C$5 per year to C$30 in 2012. The law introducing the tax required that its proceeds be recycled as cuts in income taxes to individuals and companies.

[139] Ibid.

[140] Ibid.

[141] Ibid.

[142] Warwick J. McKibbin, Adele C. Morris, and Peter J. Wilcoxen, "Subsidizing Energy Efficient Household Capital: How Does It Compare To A Carbon Tax?," Brookings the Climate and Energy Economics Project Climate and Energy Economics Discussion Paper, October 13, 2010.
The study, which analyzed proposals for (1) a carbon tax beginning at $30/ton of carbon dioxide equivalent in 2010 and increasing by 5 percent thereafter, (2) a tax credit to incentivize energy efficiency, and (3) a combination of these two options, indicated the first option reduced emissions by 60 percent against the reference case by 2040, while resulting in an estimated peak reduction in GDP of about one-half percent/year. The energy efficiency tax credit alone reduced emissions only by about 1.5 percent by 2040, while the combination option reduced emissions by 61 percent by 2040 while reducing GDP by less than 0.1 percent.

[143] Ibid, 11, 15.

[144] Aldy and Stavins, "The Promise and Problems of Pricing Carbon: Theory and Experience," 5.

[145] Ibid, 10.

[146] European Commission Climate Action website, http://ec.europa.eu/clima/policies/transport/aviation/index_en.htm (accessed April 20, 2012).

[147] Ted Gayer, comments delivered at the Fiscal Reform and Climate Protection: Considering a U.S. Carbon Tax event hosted by Resources for the Future and the Peterson Institute of International Economics, October 18, 2011, http://www.brookings.edu/speeches/2011/1018_carbon_tax_gayer.aspx?p=1

[148] Houser and Mohan, "American's Energy Security Options," 13.

[149] National Research Council of the National Academies, "Limiting the Magnitude of Future Climate Change," 133; Ian W. H. Parry and Roberton C. Williams III, "Moving U.S. Climate Policy Forward: Are Carbon Taxes the Only Good Alternative," Resources For The Future Discussion Paper RFF DP 11-02, February 2011, 22.

[150] Ibid, 23.

[151] Hayward, Muro, Nordhaus and Shellenberger, "Post-Partisan Power: How a Limited and Direct Approach to Energy Innovation Can Deliver Clean, Cheap Energy, Economic Productivity and National Prosperity," 6, 9, 25-26.

[152] Ibid.

[153] A carbon tax may be applied "upstream" on fossil fuel suppliers based on the carbon content of fuel sales (e.g. on refineries and importers of petroleum products, on coal-mine operators at the mine mouth, and on natural gas companies at the wellhead or pipeline for imports), or "downstream" on final emitters at energy generation point. "Upstream" options ease administration, involving a few thousand covered firms, vs. "hundreds of millions of smokestacks, tailpipes, etc. that emit CO2 after fossil fuel combustion." See Aldy and Stavins, "The Promise and Problems of Pricing Carbon: Theory and Experience," 4.

[154] Aldy and Stavins, "The Promise and Problems of Pricing Carbon: Theory and Experience," 4.

[155] Jonathan L. Ramseur and Larry Parker, "Carbon Tax and Greenhouse Gas Control: Options and Considerations for Congress," Congressional Research Service, R40242, March 10, 2009, 26.

[156] Alan S. Blinder, "The Carbon Tax Miracle Cure," *The Wall Street Journal*, January 31, 2011; Aldy and Stavins, "The Promise and Problems of Pricing Carbon: Theory and Experience," 4; Warwick J. McKibbin, Adele C. Morris, and Peter J. Wilcoxen, "Subsidizing Energy Efficient Household Capital: How Does It Compare To A Carbon Tax?," 15.
For a range of estimated carbon tax revenue projections.

[157] National Research Council of the National Academies, "Limiting the Magnitude of Future Climate Change," 8.

[158] Houser and Mohan, "American's Energy Security Options," 13, 16.

[159] D.B. Climate Change Advisors, Deutsche Bank Group, "Paying for Renewable Energy: TLC at the Right Price," Dec 2009, pp 14-16.

Bibliography

Advanced Research Projects Agency - Energy (ARPA-E), *Proposed Appropriation Language* (Washington, DC: U.S. Department of Energy). http://arpa-e.energy.gov/LinkClick.aspx?fileticket=HJ-gg0689ME percent3d&tabid=184.

Aldy, Joseph E. and Robert N. Stavins, "The Promise and Problems of Pricing Carbon: Theory and Experience," Resources for the Future Discussion Paper RFF DP 11-46, October 2011, for a special issue of *The Journal of Environment and Development*. http://www.rff.org/RFF/Documents/RFF-DP-11-46.pdf .

Anderson, Mikael Skou and Paul Ekins, eds. *Carbon Energy Taxation: Lessons from Europe*, (Oxford University Press: USA), 2009.

American Energy Innovation Council, "A Business Plan for America's Energy Future," September 2011. http://americanenergyinnovation.org/the-business-plan-2010/.

Anderson, Mikael Skou and Paul Ekins, eds. *Carbon Energy Taxation: Lessons from Europe*, (Oxford University Press, November 2009).

Antos, Joseph, Andrew Biggs, Alex Brill and Alan Viard, "A Balanced Plan For Fiscal Stability or Growth," American Enterprise Institute, The Solutions Initiative, http://www.google.com/url?sa=t&rct=j&q=American+Enterprise+Institute+carbon+tax+2013+ percent2426+per+ton&source=web&cd=11&ved=0CCoQFjAAOAo&url=http percent3A percent2F percent2Fpgpf.org percent2F~ percent2Fmedia percent2F31D0BDC87B8742BA94A8F81E0B18C7F6&ei=W32RT4XNK9HG6AGa7IixBA&usg=AFQjCNHxYo7y1lIl5DDu1ftaXS-FmlOo9Q.

"ANWR Information Brief – Native Facts." Frontier Communications. http://www.anwr.org/features/pdfs/native-facts.pdf.

Armbruster, John. "Researcher Discusses Ohio Fracking, Earthquakes." *All Things Considered* 2012. Blue Ribbon Commission on America's Nuclear Future, "Report to the Secretary of Energy" (January 26, 2012). http://brc.gov/sites/default/files/documents/brc_finalreport_jan2012.pdf.

Bird, Kenneth J. and David Houseknecht, "Arctic National Wildlife Refuge, 1002 Area, Petroleum Assessment, 1998, Including Economic Analysis," U.S. Geological Survey, http://pubs.usgs.gov/fs/fs-0028-01/fs-0028-01.htm.

Blas, Javier. "Japan Pushes Asia Gas Price Close to High." *Financial Times*, May 17, 2012. http://www.ft.com/intl/cms/s/0/22943afa-a022-11e1-90f3-00144feabdc0.html#axzz1vExVCOGt.

Blinder, Alan S. "The Carbon Tax Miracle Cure," *The Wall Street Journal*, January 31, 2011.

Bloomberg New Energy Finance. Global Trends in Renewable Energy Investments 2011. Frankfurt School UNEP Collaborating Centre for Climate & Sustainable Energy Finance. http://www.unep.org/pdf/BNEF_global_trends_in_renewable_energy_investment_2011_report.pdf.

Bureau of Labor Statistics, "Local Area Unemployment Statistics," http://www.bls.gov/web/laus/laumstrk.htm.

Burzynski, Andrea. "Yergin's "Quest" takes broad look at energy resources." *Reuters.* September 20, 2011. http://www.reuters.com/article/2011/09/20/us-books-danielyergin-idUSTRE78J4L220110920.

CNBC. "World's Biggest Debtor Nations" http://www.cnbc.com/id/30308959/The_World_s_Biggest_Debtor_Nations?slide=2.

Colvin, Geoff. "Adm. Mike Mullen: Debt is still biggest threat to U.S. security," CNN Money, 10 May 2012, http://management.fortune.cnn.com/2012/05/10/admiral-mike-mullen/?section=magazines_fortune.

"Coming Clean about Nuclear Power." *Scientific American* (June 2011): 14.

Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack. *Volume 1: Executive Summary* (2004). http://empcommission.org/docs/empc_exec_rpt.pdf.

D.B. Climate Change Advisors, Deutsche Bank Group, "Paying for Renewable Energy: TLC at the Right Price," Dec 2009.

Demer, Lisa. "Alaskan Lawmakers Head to DC to Lobby for ANWR Drilling," *Anchorage Daily News*, February 11, 2012. http://www.thenewstribune.com/2012/02/09/2020168/legislators-plan-dc-trip-to-sell.html.

Deutch, John, Ernest J. Moniz, and et al. *The Future of Nuclear Power: An Interdisciplinary MIT Study*. Cambridge, MA: Massachusetts Institute of Technology, 2003. http://web.mit.edu/nuclearpower/pdf/nuclearpower-full.pdf.

Eisenhower, Dwight D. "Address to the 470th Plenary Meeting of the United Nations General Assembly." International Atomic Energy Agency (IAEA), accessed February 5, 2012, http://www.iaea.org/About/history_speech.html.

European Commission Climate Action website, http://ec.europa.eu/clima/policies/transport/aviation/index_en.htm (accessed April 20, 2012).

Gale, William G. and Benjamin H. Harris, "Reforming Taxes and Raising Revenue: Part of the Fiscal Solution," *Oxford Review of Economic Policy*, Volume 27, Number 4, 2011: 563-588.

Gallagher, Kelly Sims, ed. *Acting in Time on Energy Policy* (Washington, D.C.: Brookings Institution Press), May 2009.

Gayer, Ted. Comments delivered at the Fiscal Reform and Climate Protection: Considering a U.S. Carbon Tax event hosted by Resources for the Future and the Peterson Institute of International Economics, October 18, 2011, http://www.brookings.edu/speeches/2011/1018_carbon_tax_gayer.aspx?p=1.

Gillis, Justin. "Carbon Emissions Show Biggest Jump Ever Recorded" *New York Times*, December 5, 2011. http://www.nytimes.com/2011/12/05/science/earth/record-jump-in-emissions-in-2010-study-finds.html?_r=1.

Gorman, Siobhan. "Electricity Grid in U.S. Penetrated By Spies." *Wall Street Journal.* April 8, 2009. http://online.wsj.com/article/SB123914805204099085.html (accessed April 19, 2012).

Government of Australia Clean Energy Future web site, http://www.cleanenergyfuture.gov.au/clean-energy-future/securing-a-clean-energy-future/#content04.

Greenstone, Michael and Adam Looney, The Hamilton Project, "A Strategy for America's Energy Future: Illuminating Energy's Full Costs," Brookings. May 2011.

Hamal, Cliff W., Julie M. Carey, and Christopher L. Ring. *Spent Nuclear Fuel Management: How Centralized Interim Storage can Expand Options and Reduce Costs*, 2011. http://www.brc.gov/sites/default/files/documents/centralized_interim_storage_of_snf.pdf.

Hayward, Steven F. (American Enterprise Institute), Mark Muro (Brookings Institution), Ted Nordhaus and Michael Shellenberger (Breakthrough Institute). "Post-Partisan Power: How a Limited and Direct Approach to Energy Innovation Can Deliver Clean, Cheap Energy, Economic Productivity and National Prosperity." October 2010.

Hess, Michael. *Energy Innovation Hubs: Achieving Our Energy Goals with Science*, (energy.gov). http://energy.gov/articles/energy-innovation-hubs-achieving-our-energy-goals-science.

Holt, Mark. *Nuclear Energy Policy (RL33558*). Washington, D.C.: Congressional Research Service, November 25, 2011.

Homeland Security NewsWire. "U.S. power and water utilities face daily cyberattacks ." *Homeland Security NewsWire.* April 6, 2012.

http://www.homelandsecuritynewswire.com/dr20120406-u-s-power-and-water-utilities-face-daily-cyberattacks.

Houser, Trevor and Shashank Mohan, "American's Energy Security Options," Peterson Institute for International Economics Policy Brief, Number PB11-10. June 2011.

International Energy Agency, *World Energy Outlook 2011 Factsheet.* http://www.iea.org/weo/docs/weo2011/factsheets.pdf.

Interagency Working Group on Social Cost of Carbon, United States Government, "Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866," February 2010, http://www.epa.gov/oms/climate/regulations/scc-tsd.pdf.

Jacobs, Scott and Rob McNish, "The U.S. stimulus program: Investing in Energy Efficiency," *The McKinsey Quarterly.* http://www.mckinseyquarterly.com/The_US_stimulus_program_Investing_in_energy_efficiency_2385.

Johnson, Keith Johnson, Rebecca Smith, and Kris Maher, "New Rules Limit Coal Plants; EPA Tips Scales Toward Natural Gas in Power Generation; Miners, GOP Cry Foul," *The Wall Street Journal*, March28, 2012. http://online.wsj.com/article/SB10001424052702303404704577307524051798192.html.

Kaplan, Stan M. "Wind Power in the United States: Technology, Economic and Policy Issues," CRS Report for Congress, (Washington, DC: October 21, 2008).

Kaufman, Rachel. "Recharge and Roll: Electric Carmakers Plan to Cut the Cord," *Scientific American*, October 28, 2011, http://www.scientificamerican.com/article.cfm?id=wireless-electric-car-charging.

Keith, Tamara. "Just How Many Jobs Would the XL Pipeline Create," NPR, December 11, 2012. http://www.npr.org/blogs/itsallpolitics/2011/12/14/143719155/just-how-many-jobs-would-the-keystone-pipeline-create.

King, Heather. "Bill Gates on the Five Miracles Needed for Energy and Climate Challenges," http://www.triplepundit.com/2012/03/bill-gates-five-miracles-needed-energy-climate-challanges/.

Klitsch, Daniel. "New Taxes on Oil Industry Would be Like Cooking the Golden Goose," U.S. News and World Report, August 3, 2011. http://www.usnews.com/opinion/blogs/on-energy/2011/08/03/taxing-oil-industry-is-like-cooking-the-golden-goose.

Koebler, Jason. "Obama: U.S. Saudi Arabia of Natural Gas," U.S. News and World Report, January 26, 2012. http://www.usnews.com/news/articles/2012/01/26/obama-us-saudi-arabia-of-natural-gas.

Krupnick, Alan J., Ian W.H. Parry, Margaret Walls, Tony Knowles and Kristin Hayes, "Toward a New National Energy Policy: Assessing the Options," National Energy Policy Institute and Resources For The Future. November 2010.

LaGesse, David. "Shale Oil Boom Takes Hold on the Plains," *National Geographic News* (2011). http://news.nationalgeographic.com/news/energy/2011/09/110928-shale-oil-boom-colorado-great-plains.

Larson, John. "Shale Gas Supports More Than 600,000 American Jobs Today." IHS Global Insight, (2011). http://press.ihs.com/press-release/energy-power/shale-gas-supports-more-600000-american-jobs-today.

Levi, Michael. "Five myths about the Keystone XL pipeline." *The Washington Post*, January 18, 2012. http://www.washingtonpost.com/opinions/five-myths-about-the-keystone-xl-pipeline/2011/12/19/gIQApUAX8P_story.html.

Lusgarten, Abrahm. "Years After Evidence of Fracking contamination, EPA to Supply drinking Water to Homes in Pa. Town." ProPublica, 2012. http://www.propublica.org/article/years-after-evidence-of-fracking-contamination-epa-to-supply-drinking-water.

Lusgarten, Abrahm. "Underused Drilling Practices Could Avoid Pollution." ProPublica, 2009. http://www.propublica.org/article/underused-drilling-practices-could-avoid-pollution-1214.

Mankiw, N. Gregory. "A Better Tax System (Assembly Instructions Included)", *The New York Times*, January 21, 2012, http://www.nytimes.com/2012/01/22/business/four-keys-to-a-better-tax-system-economic-view.html?_r=1&scp=1&sq=mankiw percent20gas percent20tax&st=cse&pagewanted=all.

Massachusetts v. EPA et al.: April 2007. http://www.c2es.org/federal/analysis/judicial/massachusetts-et-al-v-epa-et-al.

McKibbin, Warwick J., Adele C. Morris, and Peter J. Wilcoxen. "Subsidizing Energy Efficient Household Capital: How Does It Compare To A Carbon Tax?," Brookings, The Climate and Energy Economics Project, Climate and Energy Economics Discussion Paper. October 13, 2010.

Merline, John. "Nearly One Million Workers Vanished Under Obama," *Investor's Business Daily*, January 20, 2012. http://news.investors.com/article/597581/201201121629/jobless-figures-hide-real-problems.htm?p=full.

Millican, Robin. "President Obama Can Give the Economy a new Lease on Life with More Permits," *Institute for Energy Research*, February 16, 2012. http://www.instituteforenergyresearch.org/2012/02/16/president-obama-can-give-the-economy-a-new-lease-on-life-with-more-permits/.

Molovi, Justin. “Oil Drilling and Gas Extraction in the U.S.,” *IBISWorld Industry Report. 21111* (2011).

Moniz, Ernest. "Why we Still Need Nuclear Power: Making Clean Energy Safe and Affordable." *Foreign Affair*s 90, No. 6 (Nov/Dec 2011): 83-94. http://search.proquest.com/docview/900492751?accountid=12686.

Morris, Gregory DL. “What is the Real Cost of Cheap Energy?” *Wharton Magazine*, January 26, 2012. http://whartonmagazine.com/issues/winter-2012/what-is-the-real-cost-of-cheap-energy/.

Naff, Clay Farris. "After Fukushima: Can We Still Think Straight about Nuclear Power?" *The Humanis*t 71, No. 3 (May/Jun 2011): 17-21. http://search.proquest.com/docview/866755173?accountid=12686.

National Research Council of the National Academy of Sciences, “Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use.” 2010.

National Research Council of the National Academies, “Limiting the Magnitude of Future Climate Change.” 2010.

“Natural Gas Import and Export Terminals,” Center for Liquefied Natural Gas. http://www.lngfacts.org/LNG-Today/Import-Terminals.asp.

Nicholson, Barclay and Blanson, Kadlan. “Trends Emerge on Hydraulic Fracturing Litigation.” *Oil & Gas Journal*, 109, no. 19 (2011).

Nixon, Richard M. "Statement Announcing Additional Energy Policy Measures," June 29, 1973. Online by Gerhard Peters and John T. Woolley, *The American Presidency Project*. http://www.presidency.ucsb.edu/ws/?pid=3886.

Nordhaus, William D. “Energy: Friend or Enemy?,” the New York Review of Books, October 27, 2011 http://www.nybooks.com/articles/archives/2011/oct/27/energy-friend-or-enemy/?pagination=false.

"Nuclear's Next Generation." *The Economist* 393, No. 8661 (Dec 12, 2009): 15-16. http://search.proquest.com/docview/223978517?accountid=12686.

Obama, Barack H. 2012 State of the Union Address. www.whitehouse.gov/state-of-the-union-2012.

Palmer, Karen, Anthony Paul and Matt Woerman, “Electricity Sector Impacts of a Carbon Tax, Resources for the Future” presentation, Fiscal Reform and Climate Protection: Considering a U.S. Carbon Tax, Washington, D.C. October 18, 2011,

Parry, Ian W. H. and Roberton C. Williams III. "Moving U.S. Climate Policy Forward: Are Carbon Taxes the Only Good Alternative," Resources For The Future Discussion Paper RFF DP 11-02. February 2011.

Pascual, Carlos and Jonathan Elkind, eds. *Energy Security: Economics, Politics, Strategies, and Implications* (Washington, D.C.: Brookings Institution Press). 2010.

Pew Center on Global Climate Change, Climate Policy Memo #1 "Cap and Trade v Taxes." March 2009.

Pew Charitable Trust, "Who's Winning the Clean Energy Race?," Washington, D.C. 2010.

Piore, Adam. "Planning for the Black Swan." *Scientific America*n (June 2011): 49-53.

"Pipeline 101," http://www.pipeline101.com/overview/energy-pl.html.

Powell, Barbara. "US was net oil product exporter for first time since 1949," Bloomberg, http://www.bloomberg.com/news/2012-02-29/u-s-was-net-oil-product-exporter-in-2011.html.

Rampton, Roberta. "White House Renews Veto Threat Over Keystone," *Reuters*, April 17, 2012, http://www.reuters.com/article/2012/04/18/usa-keystone-idUSL2E8FHI0P20120418.

Ramseur, Jonathan L. and Larry Parker. "Carbon Tax and Greenhouse Gas Control: Options and Considerations for Congress," *Congressional Research Service*, R40242. March 10, 2009.

Ridge, Tom and Mary E. Peters, "The Methanol Alternative to Gasoline," *The New York Times*, February23, 2012. http://www.nytimes.com/2012/02/24/opinion/methanol-as-an-alternative-to-gasoline.html.

Saad, Lydia. "U.S. Oil Drilling Gains Favor with Americans," *Gallup Polling*. http://www.gallup.com/poll/146615/oil-drilling-gains-favor-americans.aspx.

"Sale of Fossil Fuels Produced from Federal and Indian Lands," Energy Information Institute, March 2012. http://www.eia.gov/analysis/requests/federallands/pdf/eia-federallandsales.pdf.

Savage, Charlie. "Drilling Ban Blocked; U.S. Will Issue New Order," *New York Times*, June 22, 2010. http://www.nytimes.com/2010/06/23/us/23drill.html.

Secretary of Energy Advisory Board. *Shale Gas Production Subcommittee: Second Ninety Day Report*, Washington D.C: Department of Energy, (2011).

Sherlock, Molly. "Energy Tax Policy: Historical Perspectives on and Current Status of Energy Tax Expenditures," *Congressional Research Service* Report R41227. May 2, 2011.

Summers, Dave. "The Growth of the Natural Gas Industry," Oil Price, July 26, 2011. http://oilprice.com/Energy/Natural-Gas/The-Growth-Of-The-Natural-Gas-Industry.html.

Tanquintic-Misa, Ester. "China Leads Global Investments in Renewable Energy," *International Business Times.* http://au.ibtimes.com/articles/261083/20111205/china-leads-global-investments-renewable-energy.htm.

Tax Policy Center, "Historical Revenues as a Percentage of GDP," (Brookings Institution) http://www.taxpolicycenter.org/taxfacts/displayafact.cfm?Docid=205.

The Blue Ribbon Commission on America's Nuclear Future, "Report to the Secretary of Energy", January 26, 2012, 14. http://brc.gov/sites/default/files/documents/brc_finalreport_jan2012.pdf.

The Economist, July 23, 2011, Fol. 399, Issue 8743.

The White House. *Blueprint for a Secure Energy Future.* (Washington D.C: 2011).

The World Factbook. https://www.cia.gov/library/publications/the-world-factbook/rankorder/2178rank.html.

Tillerson, Rex. North America's Historic Energy Transformation. Speech delivered at CERA Week, Houston, TX on March 9, 2012.

Tverberg, Gail E. "The U. S. electric grid: will it be our undoing?" *Post Carbon Institute: Energy Bulletin.* 7 May, 2008. http://www.energybulletin.net/node/43823.

Tverberg, Gail E. "World Energy Consumption Since 1820 in Charts", *Energy Bulletin* http://www.energybulletin.net/stories/2012-03-16/world-energy-consumption-1820-charts.

UN Secretary-General's Advisory Group on Energy and Climate Change. *Energy for a Sustainable Future.* Report and Recommendations, New York: United Nations, 2010.

U.S. Congressional Budget Office, "CBO's 2011 Long-Term Budget Outlook," (Washington, DC: June 22, 2011). http://www.cbo.gov/publication/41486.

U.S. Congressional Budget Office, "Federal Financial Support for the Development and Production of Fuels and Energy Technologies," (Washington, DC: March 2012). http://www.cbo.gov/sites/default/files/cbofiles/attachments/03-06-FuelsandEnergy_Brief.pdf.

U.S. Department of Energy. *Modern Shale Gas Development: A Primer*, (Washington, DC: U.S. Department of Energy, 2009).

U.S. Energy Information Administration. *Annual Energy Outlook 2012.* Analysis & Projections, (Washington DC: U.S. Department of Energy, 2012).

U.S. Energy Information Agency, *How dependent are we on foreign oil*? (Washington, DC: U.S. Department of Energy, June 24, 2011). http://205.254.135.7/energy_in_brief/foreign_oil_dependence.cfm.

U.S. Energy Information Agency, *International Energy Outlook 2011* (Washington, DC: U.S. Department of Energy, 2011). http://www.eia.gov/forecasts/ieo/index.cfm.

U.S. Energy Information Administration. *Natural Gas Navigator.* U.S. Department of Energy, http://www.eia.gov/dnav/ng/hist/na1170_nus_8a.htm.

U.S. Energy Information Administration, *Renewable Energy Consumption by Major Source.* (Washington, DC: U.S. Department of Energy). http://www.eia.gov/totalenergy/data/annual/pdf/sec10_2.pdf.

U.S. Energy Information Administration, *Review of Emerging Resources: U.S. Shale Gas and Shale Oil Plays* (Washington, DC: U.S. Department of Energy). http://www.eia.gov/analysis/studies/usshalegas.

U.S. Energy Information Administration, *What are the major sources and users of energy in the United States*? (Washington, DC:U.S. Department of Energy, October 25, 2011) http://www.eia.gov/energy_in_brief/major_energy_sources_and_users.cfm.

U.S. Energy Information Administration, *World Oil Transit Chokepoints* (Washington, DC: U.S. Department of Energy, December 30, 2011). http://www.eia.gov/countries/regions-topics.cfm?fips=WOTC.

U.S. Environmental Protection Agency, "EPA FACT SHEET: Proposed Carbon Pollution Standard for New Power Plants" http://epa.gov/carbonpollutionstandard/pdfs/20120327factsheet.pdf.

"U.S. Government Spending as a Percentage of GDP from FY1903 to FY2010" http://www.usgovernmentspending.com/spending_chart_1903_2010USp_13s1li0181441_621cs_F0t_US_Government_Spending_As_Percent_Of_GDP.

U. S. Nuclear Regulatory Commission. "Backgrounder on the Three Mile Island Accident" (March 15, 2011). http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html.

U. S. Nuclear Regulatory Commission. "NUREG-1350. Volume 23" *Information Digest 2011-2012*, (August 2011). http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1350/v23/sr1350v23.pdf.

Wang, Jinsheng, David Ryan, and Edward Anthony, "Reducing the Greenhouse Gas Footprint of Shale Gas," *Energy Policy*, October 2011. http://www.journals.elsevier.com/energy-policy/.

Warren, Maia. Information Specialist PA Department of Revenue, e-mail message to author April 25, 2012.

World Energy Outlook. http://www.worldenergyoutlook.org/docs/weo2011/factsheets.pdf.