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ABSTRACT: The United States currently relies on energy sources that imperil its national security, economic vitality, and ecological survival. The appetite for energy is growing, but expansion of the current mix of energy sources will worsen today's situation. The United States must take immediate action to develop and transition to renewable and sustainable sources of energy, transmitted and controlled through a 21PPst century infrastructure. Moreover, the United States must improve the ways in which it uses electricity and promote the ultimate guarantor of security, American innovation. Only bold and persistent leadership towards these ends will ensure energy security by 2030.

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- NATO Headquarters, Brussels, Belguim
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"Our military leaders recognize the security imperative of increasing the use of alternative fuels, decreasing energy use, reducing our reliance on imported oil, making ourselves more energy-efficient…. moving towards clean energy is about our security. It's also about our economy. And it's about the future of our planet….It's a challenge that requires us to break out of the old ways of thinking, to think and act anew."[1]

– President Barack Obama

INTRODUCTION

For more than forty years, scientists, engineers, and policy-makers have sought a solution to the "energy problem." Initially, this group defined the problem in terms of a dependence on foreign sources of energy. The quest for energy independence unleashed American entrepreneurs who harnessed domestic sources of energy. This group also encouraged conservation to help curb America's addiction to foreign oil. Despite these efforts, America's reliance on foreign oil continues unabated, primarily due to one factor: cost. More recently, concerns about anthropogenic climate change have added a nuance, it is no longer sufficient to find American sources of energy; those sources must also be clean and sustainable.

While oversimplified, this overview highlights several fallacies that underpin today's energy debates. First, while crude oil is an important fuel powering the U.S. economy, its influence is largely limited to the transportation sector. Coal, nuclear fission, solar, and other sources of energy provide the electricity that most Americans take for granted. Any discussion of the "energy problem," or its corollary, the "climate change problem," must take a holistic approach to U.S. energy consumption. Second, in an era of unparalleled globalization, it makes little sense to try to turn one sector of our economy, energy, into an island. No one speaks of the desire to achieve "manufacturing independence" or "financial services independence" despite the criticality of these sectors to the health of the U.S. economy. Finally, no single "silver bullet" solution exists. A viable energy policy must include coal, nuclear power, oil, natural gas, and the full array of renewable technologies.

Global demand for energy is increasing, and, without action, will increase reliance on fossil fuels. The International Energy Agency's (IEA) *World Energy Outlook for 2009* reflects a scenario where current laws and policies remain unchanged throughout the projection period. In this scenario, the IEA estimates world energy consumption to grow by 40% between 2007 and 2030. The most rapid growth in energy demand originates from nations outside the Organization for Economic Cooperation and Development (OECD). Total non-OECD energy demand increases by 41% in the IEA forecast, whereas OECD energy use increases only 5%. Strong projected economic growth among the non-OECD nations translates to robust growth in energy demand. The projected combined Gross Domestic Product (GDP) for all non-OECD regions increases by 4.6% per year on average, as compared with an average of 1.8% per year for OECD countries.

Many options exist to manage this increased demand for energy. As President Obama noted, clean energy ties to national security, to economic viability, and the long-term sustainability of the planet. This report's recommendations based on an extensive analysis of the energy industry will take the first step toward outlining a future of renewable and sustainable energy for 2030.[2]

A comprehensive national energy strategy must begin with an honest and thorough evaluation of the energy sector of the U.S. economy. First, we must recognize a critical nuance to analyze the energy industry holistically: each fuel has a specific purpose and is not usually interchangeable. This report analytically divides energy sources into two different sectors: those fueling the transportation sector (primarily oil) and those used to generate electricity for residential, commercial, and industrial sectors of the economy. This report does not separately address the direct use of natural gas for heating and cooling in residential, commercial, and industrial sectors. However, discussions herein relating to electricity usage and energy efficiency have obvious applicability.

Using this taxonomy, this report evaluates the global market for oil, along with possible substitutes for oil in both the near- and far-term. Even if manufacturers ceased producing vehicles with internal combustion engines tomorrow, today's cars and infrastructure will be in operation for decades. As such, a strategy must establish a long-term goal, with interim steps to incrementally improve energy usage. This report then applies the same methodology to the electricity-generation side of the energy industry. Separate appendices examine the criticality of energy leadership in U.S. foreign policy and in energy efficiency, along with the important contribution the Department of Defense must make to the nation's energy security.

The concluding section of the report presents five strategic recommendations that collectively form a national energy strategy. Those looking for quick, easy, and simple solutions should read no further. We face a daunting challenge to satisfy this country's and, indeed, the world's energy appetite with renewable and sustainable fuels. For the sake of this country's security, and the future of the planet at large, the United States must address this challenge now with new ideas and approaches.

DRIVING THE FUTURE: ENERGY FOR TRANSPORTATION

Today, petroleum is the largest single fuel source powering the U.S. economy. Most political discussions begin with the crude proclamation that the United States should strive for energy security by achieving independence from "foreign oil." To help correct the mistaken premises behind such rhetoric, the first section will begin with a strategic assessment of the current oil market. Since the transportation sector primarily uses petroleum, our analysis turns to solutions found in alternatives to petroleum, such as natural gas, biofuels, electricity, and hydrogen. A deliberate strategy that leverages the best combination of resources and introduces new solutions through a phased process can put the United States on the road to greater independence from all, not just foreign, oil.

The Present (and Future?) of Oil

Hydrocarbons, and oil refined as gasoline in particular, are the fuel for the world's economic engine. Continued worldwide economic growth and development require access to oil and, to a lesser extent, natural gas, primarily to fuel transportation that connects suppliers and consumers of goods, both within and among countries. The transportation sector accounts for 97% of the increase in world oil use between 2007 and 2030, resulting in an increase in the global demand for oil of approximately 1% per year.[3] Although slightly lower than previous forecasts as a result of the recent global economic downturn, the revised rate still yields an impressive 20% increase in overall oil demand by 2030 (from 84.7 to 105.2 million barrels/day). After establishing the global nature of this market, this section will highlight the necessity for change by revealing the true costs of America's dependence on oil.

Demand for oil is not spread uniformly across the globe; developing countries are the driving force behind the increase in oil demand. The IEA forecasts expect these countries' demand to increase 2.2% per year, with non-OECD demand exceeding the OECD's aggregate demand around the 2015-2016 timeframe.[4] Further scrutiny of these figures reveals that China and India are by far the largest consumers of oil in the developing world. The IEA expects China's increase in oil demand to be 3.5% per year, second only to India at 3.9%. As such, the future shapers of the oil market are in the industrializing world, rather than post-industrializing economies in the United States, Europe, and Japan. This reflects efforts by OECD economies to balance overall energy usage and the burgeoning affluence of India and China's middle classes.

While the share of natural gas in the world's energy mix should remain constant between 2007 and 2030, IEA expects demand in non-OECD countries to be responsible for over 80% of the increase in gas use.[5] As with crude oil, demand for natural gas in China and India is increasing at a faster rate than anywhere else in the world.

Turning from demand to supply, the IEA expects the global supply of oil to increase by 1% per year over the same forecast period, meaning that with economically efficient distribution of oil supplies, prices should remain in rough equilibrium.[6] The IEA also anticipates natural gas production to increase 1.5% per year between 2007 and 2030.[7] While hydrocarbon production may be ample to meet global demand, assuming the forecasts are correct, if those supplies do not reach consumers, the unmet demand will place upward pressure on global prices. The 1973 Arab oil embargo illustrated this phenomenon when the failure of oil to reach markets resulted in price spikes.

This point calls attention to the interaction between hydrocarbon consumers and suppliers in a globalized marketplace. Since oil and natural gas require transportation to their markets, if that transportation is flexible, then changes in demand in one location will have implications that spread like ripples in a pond and will affect prices globally. For example, the increased demand for oil and gas in China will result in higher prices around the world, assuming supply remains constant. As such, consumers at the pump in St. Louis will feel the impact of increased oil demand in Shanghai.

Oil-refined gasoline continues to be the dominant source of energy for the transportation sector because it is inexpensive. However, the price at the pump does not reflect the true price of oil, at least not in this country. In 2008, petroleum consumption in the United States accounted for 41.9% of the country's greenhouse gas emissions.[8] The U.S. government and domestic businesses will ultimately pay an economic price to reduce these emissions or otherwise adapt to their environmental effects. This indirect cost, known as a negative externality, should be included in the price of gasoline and diesel in the United States.

There is a further negative externality related to the security costs to assure access. Crude oil imports are a critical strategic vulnerability. The United States typically uses over 20 million barrels of oil per day, with approximately 57% of it imported.[9] While only 17% of this imported crude oil originates from Organization of Petroleum Exporting Countries (OPEC), the global nature of the oil market gives OPEC some influence over global oil prices.[10] Unfortunately, most OPEC nations are high profile targets of terrorism. In 2006, Al-Qaeda struck at the heart of Saudi Arabia's oil infrastructure, the Abqaiq oil refinery that processes 6.5 million barrels of oil every day.[11] The *failed* attempt caused world oil prices to jump $2/barrel. Successful attacks upon oil refineries, tankers, or other key chokepoints would devastate oil markets and send gasoline prices sky-high.[12]

Although the (current) low cost of oil makes it an attractive source of energy for the transportation sector, an examination of the environmental and security-related externalities highlights that the true cost of oil is too high for the United States to endure. The risk of terrorist attacks and the resulting impact on oil prices are readily apparent as a strategic vulnerability. Aside from the security vulnerability, crude oil is finite, and although the actual date of peak oil is uncertain, the inevitability of its occurrence is not. Most predictions place the supply-driven global peak production of oil between 2017 and 2036 (in the United States, peak production has already occurred).[13] This places "peak oil" as early as seven years away, leaving very little time to transition aggressively away from a petroleum-based transportation sector. The next sections examine potential near- and far-term alternatives to oil-refined gasoline: natural gas, biofuels, electric vehicles, and hydrogen-fuel cells. Such a transition will not happen overnight, but the security of the nation demands immediate planning to ensure a smooth conversion.

The Near-Term Case for Natural Gas

The United States has not widely embraced natural gas for transportation primarily due to the availability of inexpensive oil. The rising concern over the impact of greenhouse gases, dovetailed with consumer uneasiness about dependence on foreign oil, has pushed natural gas to the forefront as a cleaner and domestically available fuel for the transportation sector. While suboptimal relative to some renewable fuel sources, natural gas produces 20% fewer greenhouse gas emissions than oil-refined gasoline.[14]

Today there are more than 120,000 natural gas vehicles on the road and over eight million worldwide.[15] Light to heavy commercial vehicles, such as taxis, municipal buses, airport shuttles, school buses, street sweepers, and other heavy maintenance equipment comprise the most prevalent use. Natural gas use in non-fleet vehicles has been limited, with only a few models available to the public. Further, conversion for gasoline cars must conform to stringent Environmental Protection Agency (EPA) standards, making it prohibitively expensive.

Additionally, the limited range between refuel (often less than 200 miles) and the amount of space required for the fuel tanks has largely limited compressed natural gas (CNG) use to vehicles that travel short distances and operate as part of a fleet with access to private refueling stations. Some commercial vehicles have used other forms of gas, such as liquefied natural gas (LNG), propane, and gas-to-liquids in limited quantities, but all face similar limitations as CNG.

Nonetheless, the outlook for the supply of natural gas is positive through 2030. Gas exploration and development companies continue to develop advances in extraction methods that will make shale and other non-conventional sources of gas available and affordable in the near future. Recent decisions by the Obama Administration to open over one-half million square miles of potential gas and oil rich areas off the east coast of the United States, the Gulf of Mexico, and the west coast of Alaska provide even greater opportunity for gas development.

Increased fuel capacity to gain greater range and a nationwide refueling infrastructure are critical to achieving large-scale growth in natural gas use for transportation. In 2009, the U.S. Congress introduced legislation in both chambers to provide a wide range of tax incentives for buyers, manufacturers, and developers of refueling sites to influence the growth in natural gas powered vehicles. The American Power Act of 2009, passed by the House, mandates that 50% of all new vehicles purchased or placed in service by the U.S. government through 2015 be capable of operating on CNG or LNG.[16] The draft Senate bill includes similar requirements. The future of these bills is uncertain.

Passage of a law meeting the intent of these bills could provide strong support to move the United States forward in the use of natural gas vehicles by 2030. The widespread production and use of natural gas vehicles can reduce greenhouse gases emissions and reliance on foreign oil. However, while natural gas is superior to oil in terms of both the security and environmental externalities, transition to non-carbon based fuel sources remains the only way to ensure a future of sustainable and renewable fuels for the transportation sector.

The Limitations of Biofuels

Ethanol, highly touted as a renewable source of energy, derives from various crop sources. Blending ethanol with gasoline reduces the demand for petroleum. The current ethanol/gasoline blend is 10/90; however, recent tests by the automotive industry and the Department of Energy (DOE) have proven that blends up to 20% ethanol will have minimal impact on an internal combustion engine. Ethanol produced in larger concentrations, known as E85, has more limited applications since it requires vehicles with specially designed engines.

Presently, large government subsidies and tax incentives to both producers and consumers make ethanol fiscally attractive. In the absence of these incentives, and, to an extent, even with them, it is a negative profit industry and a niche market given the scale required to penetrate the transportation sector. However, expansion of ethanol use for transportation would have a deleterious impact on the agriculture industry as a whole. In a 2007 study conducted by the University of Iowa, researchers predicted that, if the demand for corn ethanol for E-85 vehicles increased to 29 billion gallons per year, land devoted to biofuels would have to increase to more than 112 million acres with concomitant reductions in output of soybean and corn for feedstock or export, raising food prices globally.[17]

Compared to petroleum, both ethanol and biodiesel have lower emissions, are biodegradable, and are safer for handling. In comparison to ethanol, biodiesel provides greater energy yield, higher efficiency, less land use, and costs less to produce. Like ethanol, current biodiesel production uses large quantities of water and land, a distinct disadvantage. However, third generation biodiesel sources, such as algae, can use cellulosic and genomic processes to produce large quantities of hydrocarbons from non-feed crop sources. Currently produced diesel engines require minimal changes to existing vehicle fleets or their supporting infrastructure to use biodiesel. Despite the apparent superiority of biodiesel, current federal subsidies to farmers favor corn ethanol production, delaying expansion of biodiesel use.

Transitioning to biofuels can help alleviate the negative externalities associated with petroleum. Fueling the transportation sector with biodiesel minimizes switching costs within the auto industry, creates efficiency gains in hybrid vehicles, and expands the refining and distribution market for energy companies. Nonetheless, agricultural trade-offs required to dramatically expand biodiesel production limits its effectiveness as a single-point solution. In the long term, after battery and fuel cell vehicles increase their market share, third generation biodiesel can become a source for hydrogen production and even supplant fossil fuels used for electricity generation.

A Bridge: Electric Vehicles

Exemplifying President Obama's call for new ways of thinking, electric vehicles offer the cleanest transportation option by dispensing with the internal combustion engine altogether (or, at least, partially). Electric vehicles convert as much as 75% of battery energy to functional power, much more efficient than the internal combustion engine, which converts around 20%. The strongest appeal of electric vehicles is that they offer a way to reduce greenhouse gas emissions by abandoning the combustion engine and its reliance on fossil fuels.

These vehicles, however, are not a panacea. Electric vehicles using lithium-ion batteries currently cannot match the 400-mile range of more fuel-efficient internal combustion engines (the 2011 electric Tesla Model S advertises 300 miles per charge). Most of these vehicles require four to eight hours to charge, a severe limitation. This charging time will hinder the adoption of electric cars until swapping or recharging batteries at service station outlets occurs in five to ten minutes, the average time a gasoline vehicle owner spends at gasoline stations. For now, car manufacturers can aggressively market electric vehicles to serve niches, such as commuter cars and some fleet vehicles. For example, the U.S. Postal Service is converting its fleet to electric vehicles.

Hybrid electric vehicles (HEVs) can help bridge the gap between liquid fuels and electric vehicles. By combining the power of the internal combustion engine and an electric motor, such as Toyota's Prius, HEVs can achieve an incredible range of 571 to 607 miles, about 50 miles per gallon. With the higher energy content of biodiesel fuel, these distances can be even greater.

Mass production of HEVs and plug-in HEVs will require a huge expenditure of capital to retool manufacturing plants and fund advanced research and development. As a result, automakers will not pursue them without clear signals from the marketplace or the government to encourage investment. The EPA and the National Highway Traffic Safety Administration recently mandated an average 5% reduction in greenhouse gases every year until 2016, ultimately resulting in 35.5 miles per gallon (mpg) for the light-duty vehicle fleet if the improvements were in fuel efficiency alone. The industry must decide on the best approach to minimize costs and still meet consumer demand, and it cannot do this without coordination and cooperation from other industries and the government.

The Goal: Hydrogen Fuel Cell Vehicles

Hydrogen vehicles offer the best long-term solution for the transportation sector. Hydrogen fuel cell vehicles (HFCV), consisting of hydrogen storage tanks, fuel cells, and a high output battery can generate electricity at efficiencies of up to 60%, a dramatic improvement over the 20% efficient internal combustion engine. HFCVs most significant benefit comes from their "emissions," which are free from greenhouse gases if the hydrogen is produced from non-hydrocarbon sources. Several auto manufacturers are conducting hydrogen fuel cell research with moderate success.

Although the hydrogen industry has made gains in heavy vehicle fleets, significant barriers to entry in the light duty vehicle market persist. Foremost is the fuel cell itself: it is heavy and expensive to produce, primarily due to the bi-polar plates and the platinum used as a catalyst. Advances in nanotechnology could yield a less costly catalyst. Next, any vehicle production must exceed a million vehicles for the auto industry to earn a profit. Considering that North American car and truck production exceeded 8.7 million vehicles in 2009, a lower than average output, this threshold should be achievable.[18]

Mass production of hydrogen requires an enormous infrastructure development. First, the production of hydrogen requires large amounts of energy. Hydrogen fuel stations are sparse and, in most cases, privately owned by demonstration fleets. However, if hydrogen fuel cell vehicles attain a significant share of the vehicle market, market forces should drive the oil and gas industry to leverage their existing distribution system and absorb the costs of hydrogen production and distribution, ideally using a renewable source (including biodiesel) rather than natural gas or oil. Such a move would ensure their continued competitiveness as the country transitions towards clean and renewable substitutes for petroleum.

The Future of Transportation

The mass production and distribution of economically efficient hydrogen fuel cells provide an ideal path to sustainable and renewable energy to power the U.S. transportation sector. Interim alternatives such as natural gas, biodiesel, and electric vehicles offer a comparative advantage over crude oil by reducing negative security and environmental externalities. Additionally, the commercialization of lightweight materials can improve fuel efficiency by 7% with only a 10% reduction of the vehicle’s weight.[19] While the presence of externalities indicates a market failure necessitating government intervention, an inter-industry approach is necessary from automobile manufacturers, the energy industry, as well as academia to reach economies of scale.

A push to move the transportation sector away from reliance on oil incrementally will not solve related climate issues if it merely pushes the emission of greenhouse gases upstream to an electric generation facility. Reforms in the U.S. electrification infrastructure, the focus of the next section, must accompany the transition in the transportation sector from gasoline to electric vehicles.

A BRIGHT FUTURE: ENERGY FOR ELECTRICITY

For most Americans, electricity generation and distribution are almost transparent until the monthly utility bill arrives. Even with this periodic reminder, most Americans do not understand how much electricity they consume, how much it costs, or what charges their bill includes. This section attempts to unravel the mystery behind utility bills, starting with an examination of the fuel sources used to generate electricity, to include their availability, cost, and environmental impact. This, however, covers only half the story, as the efficient transportation of the electricity from the source of generation, be it a coal plant or wind farm, to the ultimate end user forms the other half. This discussion of the electric grid reveals further challenges to the future of renewable and sustainable electricity for the United States.

The Present (and Future?) of Coal

The United States has been described as the “Saudi Arabia of coal,” a term so pervasive that it is hard to attribute it to an authoritative source. The United States has vast amounts of proven coal reserves totaling more than 25% of the world's coal reserves[20] with 275 billion tons,[21] equating to a 250-year supply at 2005 consumption rates.[22] In addition to the large stockpiles, the distribution of these coal reserves throughout the United States is a significant benefit. Appreciable amounts of coal exist in three different regions that cover 27 states across the country.[23] The size and distribution of these resources create a compelling argument for the United States to develop environmentally friendly coal uses.

Coal resources have been the cornerstone of U.S. energy production for decades, primarily fueling power plants that generate approximately 50% of the nation's overall electricity requirement.[24] "Since 1976, coal has been the least expensive fossil fuel used to generate electricity" based on cost per British Thermal Unit (BTU).[25] Environmental restrictions have increased costs over the years but they remain lower per BTU than natural gas or petroleum in most U.S. markets. However, like the negative externalities associated with oil, the current price of coal-generated electricity does not include the full extent of social costs associated with coal-fired plants.

Coal-fired power plants provide reliable sources of power but "represent the nation's largest source of carbon dioxide" (CO_2) emissions.[26] The United States has hundreds of coal-fired plants that cumulatively emitted approximately 36% of total U.S. emissions in 2006.[27] The market has failed to capture the impact of these CO_2 emissions, thus creating conditions where costs will inevitably rise. Either the government will intervene to correct for the market failure by taxing some or all segments of the coal supply chain, or other segments of the economy will absorb the costs as businesses and individuals adapt. While the United States possesses several centuries' worth of coal reserves, it must find economic ways to reduce carbon pollution associated with the burning of coal before fully expanding use of those resources.

Toward this end, the federal government should continue to provide incentives to develop exportable carbon capture and sequestration technologies specifically to enable existing coal-fired power plants to generate electricity with reduced CO_2 emissions. Recognizing that the United States shares the global climate, it should pursue an aggressive international effort to share the development and eventual use of sequestration technologies. As research in sequestration technologies continues, the United States must increase its reliance on diverse fuels to generate electricity in an ecologically sustainable manner.

Natural Gas Use for Electricity

In 2008, electricity generation from coal declined 10.8%, while generation from natural gas increased 5.1%, as lower natural gas prices motivated fuel switching.[28] When companies retire older nuclear and coal generation facilities, they have been replacing those facilities with natural gas generation plants. In 2009, the United States added over 23,000 megawatts (MW) of new electricity generation capacity, of which 12,000 MW operate on natural gas alone.[29] The Energy Information Administration (EIA) expects production to expand by another 2% in 2010.[30]

In some areas, electricity producers have installed smaller gas-fired combined cycle or cogeneration plants for distributed generation. These plants, suitable for urban areas and often placed completely out of sight, produce relatively low levels of electricity and, where needed, steam for heating buildings. These highly efficient production plants can easily supply the energy needs of colleges and universities, hospitals, large office buildings, and business parks.

Despite the relatively cleaner emissions compared to petroleum, natural gas remains a fossil fuel with concomitant environmental impacts. In the short-term, the cost of natural gas makes it an attractive alternative to coal, especially when cogeneration with steam makes economic sense. In the long-term, development of new technologies and renewable energy sources will limit the growth and ultimately replace the use of natural gas.

Harnessing the Atom

Nuclear energy is an important component of a diverse and viable energy portfolio. As a source of base load power, nuclear-generated electricity is relatively inexpensive and dependable. Currently, 104 reactors provide 20% of our nation's electricity. However, due to aging infrastructure and rising demand, the United States requires approximately 30 additional reactors by 2030 to maintain this 20% share.[31] In his 2010 State of the Union Address, President Obama argued for "a new generation of safe, clean nuclear power plants in this country."[32] Challenges facing the nuclear power industry include fears over safety; high construction costs coupled with long lead times to build and certify new plants; and concerns over uranium management and weapons proliferation. Viable solutions exist to each of these potential barriers, and expanding nuclear energy in the United States remains a valuable component of a diverse energy portfolio.

Chernobyl and Three Mile Island come to mind when nuclear safety is considered. However, companies no longer build reactor designs like that of Chernobyl, and only two major accidents have occurred in 12,000 cumulative reactor-years of electricity production, an impressive feat.[33] The industry must improve outreach and educational efforts that highlight the safety of nuclear power, especially compared with other dangers, such as the recent fatal coalmine tragedies in West Virginia and China.

New nuclear power plants can cost upwards of five billion dollars.[34] Over the 30+ year lifecycle of a power plant, this cost decreases significantly. Electricity from a nuclear power plant costs less than 4¢ / kilowatt hour (kWh) to produce, making it one of the most affordable sources of power.[35] Further, future nuclear power plants built from standardized designs, currently under development by the World Nuclear Association, facilitate reduced construction costs and streamlined licensing procedures.[36]

TTThese costs, however, do not include the cost to manage and store the nuclear waste (fuel within a nuclear reactor typically lasts 12-24 months). The radioactive half-life of this material dictates storage for 10,000 years.[37] However, the spent material contains little waste -- approximately 95% of the fuel's energy remains after use in a power plant reactor.[38] Post-processing of the spent material can remove waste products and then reprocess or recycle the uranium and plutonium into fresh fuel, reducing waste storage.[39] Instead of dealing with waste for 10,000 years, recycling reduces the half-life of the waste material to several hundred years and effectively increasing the global supply of uranium, which like carbon resources, is finite.[40]

Some policy-makers remain concerned with the potential for countries to use civilian nuclear power for nefarious purposes. Efforts such as the Global Nuclear Energy Partnership (GNEP) ensure legitimate users have access to uranium while limiting recycling to only those countries that meet stringent international standards.[41] A prime example is the relationship between Japan and the United Kingdom. Japan transports spent fuel to Britain for recycling via ship, and then

Britain returns the waste material to Japan for storage. This process has proven to be "a tried and tested method that is safe, highly regulated, and internationally approved."[42] Thus, transportation security should not be an excuse to eschew recycling when a "world bank" of nuclear fuel decreases the proliferation threat.[43] By becoming a member of the nations that recycle, the United States can assume a major leadership role in the GNEP and better control proliferation.

Nuclear energy provides a substitute to carbon-based energy sources, thereby holding strategic importance from environmental, political, and economic perspectives. While nuclear power can serve as a sustainable source of base-load electric generation capabilities, the United States must leverage diverse renewable sources to augment this source of energy.

The Power of Water

Hydroelectric power is one of many renewable sources of electricity and it plays an important role both domestically and internationally as part of an integrated electric system. While large-scale development of hydropower projects is occurring internationally, most large-scale facility construction has already occurred in the United States (comprising about 8% of all U.S. electricity generation).[44] The western United States produces most of the hydroelectric power with Washington, Oregon, and California accounting for 56% of all domestic hydroelectric production.[45] The United States also relies upon hydro-generated electricity from Canada, further belying the myth of "energy independence." The future of hydropower in the United States should maximize the use of current facilities through infrastructure upgrades and leverage technological improvements that mitigate environmental impacts.

The primary advantages of hydroelectric power are its reliability, inexpensive cost, clean footprint, and positive secondary benefits. Because water can be stored in large reservoirs for use when needed, hydropower provides predictable electrical generation.[46] Likewise, today's hydro turbines convert approximately 90% of available energy into electricity, while fossil fuel plants are about half as efficient.[47] This reliability and efficiency reduces consumer costs. Combining total expenses for fuel, operation, and maintenance, hydroelectricity costs were 90¢ /kWh, compared to $1.90 for nuclear, $2.10 for fossil-fueled steam, and $3.40 for gas turbine power.[48] Of equal importance, hydropower does not emit air pollutants or greenhouse gases.[49] The positive secondary impacts associated with dams, such as large reservoirs used for navigation, irrigation, and recreation, add significant economic value.

Despite these advantages, there are drawbacks associated with the use of hydroelectric power. Dams prevent the natural movement and flow of silt, which is essential for transporting critical nutrients through fragile ecosystems.[50] These large structures also alter the natural movement of fish, creating challenges for numerous species. Although DOE identified 5,677 sites conducive for large-scale hydropower development, the exorbitant present-day cost of dam construction, combined with the aforementioned environmental challenges, make new development unlikely.[51] Finally, hydroelectric generation is extremely sensitive to variations in climate and weather patterns, with even small changes having large impacts.[52]

Hydropower is an important resource in the comprehensive portfolio that provides a stable source of electricity, unlike some renewable sources that face challenges due to their intermittency. Beyond 2030, hydroelectric generation has great potential in tidal and wave power initiatives. Whether or not this potential becomes a reality on a large scale that augments the existing hydropower infrastructure will be largely dependent on the speed of technology development and commercialization.

The Power of Wind

The United States leads the world in wind energy production, with 35,062 MW of installed capacity in 2009 and another 3,188 MW under construction.[53] Yet this capacity, due to the intermittent nature of wind, translates to a mere 1.8% of the electricity produced in the United States.[54] A 2009 study by Stanford University ranked wind among the very best energy systems options based on its impact to global warming, pollution, water use, land use, wildlife, and other concerns.[55] Due to these advantages, DOE set a wind energy goal of 20% of U.S. electricity generation by 2030.

Two factors currently cause wind-generated electricity to be more expensive than fossil fuel generation, approximately 6¢ - 8¢ / kWh compared to about 4¢ / kWh for coal.[56] As previously mentioned, the negative externalities of fossil fuels results in the market under-pricing the true costs of those sources of electricity. Additionally, like nuclear and hydroelectric facilities, wind generated electricity requires high start-up capital costs. In fact, nearly 75% of the total cost of wind energy relates to the up-front costs such as the cost of the turbine, foundation, electrical equipment, and grid-connection. By comparison, conventional fossil fuel plants, such as a natural gas power plant, spend 40% to 70% of their total costs on fuel, operations, and maintenance rather than on initial capital outlays.[57]

Even if wind were less expensive, there would be challenges to meet the significant growth from 2% to 20% in 20 years. First, wind is an intermittent source of energy; the wind does not always blow when energy demand is highest or at speeds required to generate electricity. Recent studies of wind power installed on U.S. grids indicate the actual cost of intermittency is about 0.2¢ - 0.5¢ / kWh depending upon the amount of wind energy penetration, with increased costs for higher penetration.[58] Although there are methods to mitigate the intermittency impact, wind is better as a supplement to nuclear, solar, and hydroelectric facilities. Second, Congress has repeatedly allowed subsidies for wind power to expire. For example, wind energy's primary incentive, the Production Tax Credit (PTC) has expired multiple times since its creation in 1992.[59] The inability to depend upon a PTC creates a boom-bust cycle in the wind energy industry, discouraging businesses from making the needed investments to produce efficient economies of scale.[60] In contrast, subsidies for the fossil fuel and nuclear industries are larger and more stable.[61] The Government Accountability Office notes that tax incentives for electricity largely go to fossil fuels rather than renewable sources.[62]

Overall, America needs wind energy as part of its energy portfolio. Large wind installations can (and already do) provide critical support for the electricity grid. Wind systems provide a valuable supplement to base load generation and, with improved technology, could assume an increasing proportion of electricity generation, ultimately helping to replace fossil fuel sources.

The Power of Sunlight

Solar energy is one of the fastest growing sources of renewable energy in the world. Despite the economic woes of 2009, the solar energy industry grew in both employment and new installations. U.S. solar energy capacity surged past 2,000 MW in 2009, doubling the size of the residential photovoltaic market.[63] Three new utility-scale solar power plants also came on line in 2009 and there are more than 100 in various stages of development.[64] These projects represent enough clean power to supply over three million households.[65] This is a great start but for solar power to reach its potential and become a significant contributor to U.S. energy supply, the industry will have to grow significantly for decades.[66] To achieve this growth, solar energy must overcome three barriers: cost competitiveness, storage, and integration into the electricity transmission grid.

Cost competitiveness with other sources of electricity, so-called grid parity, is the "Holy Grail" for renewable energies such as solar. The most economically efficient way to reach it is through a tax that corrects the failures previously discussed in the hydrocarbon marketplace. As solar power reaches grid parity, utility-scale plants will provide fixed-price electricity during peak demand periods when electricity is at its highest price.

Due to the intermittent nature of renewable forms of power generation, it is imperative that utilities prepare for times when the sun does not shine. Utilities can address this issue by employing load-following power plants to quickly reduce power output when a renewable resource such as solar or wind is available and increase output when needed. Additionally, electrical storage requires further development in a number of technologies including batteries, molten salt (heat storage), flywheels, pumped hydro, and compressed air energy.[67] Solving the challenge of storage is essential to ensure renewable energy is available for transmission through the electric grid when needed by consumers.

A Smart Approach to the Electric Grid

The electric grid is the interconnection of lines and substations that transmit electricity from the generation source to the consumer. The U.S. transmission grid fails to meet the electrical demands of the 21st century because it consists of early 20th century technology and incrementally built mid-20th century facilities.[68] As consumers achieve electricity usage efficiencies downstream, thus reducing demand, transmission grid owners face challenges to justify expensive multi-year or multi-decade projects to improve the grid or to protect this critical component of the electricity infrastructure. These investments are affordable, however, when located at the intersection of security, economic, and environmental benefits of these changes.

From a security standpoint, the electricity grid clearly falls into the Department of Homeland Security's (DHS) definition of "critical infrastructures" as

> systems and assets, physical or virtual, so vital to the United States that the incapacitation or destruction of such systems and assets would have a debilitating impact on national security, national economic security, public health or safety, or any combination of those matters.[69]

DHS recognizes the interdependencies of electricity to fuel supply, transportation, communication, and emergency services, underscoring the criticality of the electric grid to the security of this country.[70]

Threats to the grid, both natural and manmade, can significantly affect our economic and personal security. The Federal Energy Regulatory Commission's (FERC) evaluation of the 2003 blackout that blanketed the northeast describes a cascading outage, originating with a "fault" disturbance that caused 265 power plants to shut down, including 20 U.S. and Canadian nuclear power plants.[71] The grid "transported" the cascading outage throughout the northeast, facilitated by structural issues and human error. Fifty million customers (individuals and businesses) lost power for two days and 11 people died. The estimated cost ranged between $6.8 and $10.3 billion due to spoilage, lost production/wages, and other indirect costs.[72] As the United Kingdom's MI5 so fondly comments, society is never more than four meals away from anarchy.

While grid improvements are clearly required from a security standpoint, transitioning from today's 20th century technology to a 21st century "Smart Grid" would better utilize renewable and sustainable sources of electricity by providing tools to manage demand efficiently. It is axiomatic that one cannot manage what is not measured. Today, most Americans do not have visibility into how much electricity they are using at any point in time, nor is there a mechanism to determine the market price of electricity in real-time, a necessity for consumers to make educated decisions about electricity usage. Bringing market forces into play by promoting transparency and consumer education is critical to improving electricity efficiency.

At its most basic level, the Smart Grid allows "utilities and customers to receive digital information from and to communicate with the grid" by exploiting information technology embedded in the transmission network.[73] Sensors along the grid transmit information to both providers and consumers, allowing them to understand real-time supply and demand factors and make informed decisions about pricing and usage. Programmable "smart appliances" enable consumers to take advantage of low electricity costs, thereby easing demand peaks during certain times of the day.[74]

The Smart Grid extends beyond the consumer and the smart home. Integrated deep within the transmission and distribution grid will be new self-healing grid components, advanced control systems, and management software to enable two-way communication between electric power companies and consumers. These upgrades TTpermit transmission of significant amounts of power from one region of the country to another; for example, solar power from the southwest could be transmitted to the northeast. Optimization of the transmission grid for renewable and sustainable energy sources improves infrastructure reliability, power quality, renewable energy integration, and energy storage.[75] The integration of diverse and dispersed renewable sources of electricity, such as solar and wind power, thus requires the modernization of the electric grid.

As previously noted, transmission difficulties have been a limiting factor in the development of renewable resources. A North American Electric Reliability Corporation (NERC) analysis of the past 14 years shows that construction of transmission lines must accelerate significantly to maintain reliability over the next ten years. Assuming the average construction of 6,000 miles over the past five years, construction in the next five-year window needs to increase by 10,000 miles to satisfy planned projections.[76] Improved reliability and the need to integrate renewable energy resources drive the vast majority of this expansion. The current challenge for regulators and electrical system operators is the creation of Smart Grid standards that keep pace with the rapid rate of technology development and deployment.

The economic recession and the emergence of demand-side management programs have led to decreased demand across most regions and increased capacity margins.[77] NERC projects this trend to continue until almost 2020. Demand response (to reduce demand when supply is insufficient) and energy efficiency have shown to be particularly effective in offsetting peak demand growth by nearly five years.[78] The United States must continue these trends. A vital part of a comprehensive effort to ensure energy security thus requires managing the growth in electricity demand, particularly by promoting energy efficiency.

The Future of Electricity

Clean energy in the form of renewables is an effective way to make a clear difference in fighting and reversing the trend of greenhouse gas emissions. The Obama Administration has promoted clean energy, committing support to create more than 15 gigawatts of new renewable energy.[79] Federal, state, and local governments must create and maintain incentives for renewable energy and remove the barriers that hinder widespread adoption.

Nuclear and hydroelectric facilities provide a steady, realizable source of electricity for the country's base load requirements, augmented when possible by wind and solar sources. Since the cost and size of coal relative to other natural resources will likely maintain coal-fired production as a source of electricity for some time, the United States must make a determined effort to reduce carbon emissions from these facilities. In the longer-term, with the advent of storage capacity, renewable energy resources can provide power at night and when the wind does not blow, further reducing reliance on fossil fuels.

Such diverse and dispersed energy architectures require improvements in the electric grid, not only to bring market forces to bear in the supply and demand for electricity but also to help ensure the security of the system. The Smart Grid offers great potential for efficiency, demand reduction, and integration of renewable energy sources such as solar, wind, and hydropower.

POLICY RECOMMENDATIONS

The United States must develop renewable and sustainable fuels for the transportation sector and electricity generated for residential, commercial, and industrial sectors of the economy. This is required for the future of our economy, our environment, and our national security. The effort will not be easy or quick, but implementing the following five recommendations will start the United States on the long journey toward energy security.

RECOMMENDATION 1: ORGANIZING FOR SUCCESS

DOE formed in 1977 out of the Federal Energy Administration, the Energy Research and Development Administration, and the Federal Power Commission. DOE has evolved over time, adding diverse missions and capabilities as politicians deemed necessary. As a result, anything energy related falls under the responsibility of the DOE, from the stewardship of the nuclear stockpile to the delivery of electricity. With such a wide spectrum of responsibility, DOE cannot prioritize effectively. To a large extent, the disjointed nature of the U.S. approach to the energy industry described in the previous sections is a result of this lack of focus. In Washington, advocates are measured by their access to decision-makers and funding; advocates for renewable and sustainable energy currently possess neither. If the Obama Administration is serious in its calls to develop a "green economy" that develops and leverages alternative forms of energy, it must first organize and empower DOE for success.

First, the Administration should create an agency-level organization within the DOE for Renewable and Sustainable Energy. This agency combines the responsibility and expertise of the Assistant Secretary of Renewable Energy and Energy Efficiency, the Assistant Secretary of Electricity Delivery and Energy Reliability, and the supporting elements from the Under Secretary for Science. DOE should evaluate other internal organizations with a view of consolidating responsibilities into the new agency, with the director reporting directly to the Secretary of Energy. Organizing along these lines will focus and elevate the management of renewable energy production, transmission, and use within the DOE.

Second, the new agency should categorize and track funds allocated to advance renewable and sustainable energy separately from other DOE expenditures as a Major Energy Program, similar to a Major Force Program within the Department of Defense (DoD). The Agency should be responsible for the oversight and management of these funds, even if another agency in the Department obligates those funds. To avoid reprioritization of scarce funds within DOE, the funds within the Major Energy Program should be "fenced" to prevent their re-programming for other purposes. This will enable policy-makers and the public to ascertain and track easily the efforts of the new Agency. Finally, Congress should adequately resource this Agency, increasing the funding over the current levels of its constituent parts by reallocating funding within the DOE. As will be discussed later, subsidies allocated for fossil fuels should gradually transition into the Major Energy Program.

Congress should charter the Director of the Agency for Renewable and Sustainable Energy to lead the development of a National Energy Strategy as the U.S. government's focal point. This Strategy will identify policy and regulatory reforms necessary to ensure that renewable and sustainable energy powers the national economy to the maximum extent practicable by 2030. While some segments of the economy will still use fossil fuels in 2030, the national priority should be to minimize those segments and industries, while developing an action plan to complete a transition to renewable energy by 2050. The development of the National Energy Strategy should be a "whole-of-government" effort, with active involvement of FERC, the Departments of State, Commerce, and Defense, the EPA, and in partnership with state and industry leaders. Federal departments should designate focal points within their organization to support the development of the National Energy Strategy and to oversee efforts to implement it. The strategy should have a strategic view toward 2030 and beyond; following promulgation, the actions taken to implement it should receive periodic review.

RECOMMENDATION 2: POWERING THE FUTURE

To reduce dependence on oil and lessen environmental impacts, a shift to cleaner renewable and sustainable energy sources is necessary. As previously discussed, this requires federal effort to correct for market failures as manifested in the negative externalities of coal and crude oil. Congress must address the disparity in pricing of energy to allow grid parity between fossil fuels and renewable and sustainable energy. Only when the price of coal and oil include the total social and economic costs for their production and consumption can consumers can make educated decisions in a functioning energy market.

First, the Administration should propose and Congress enact a revenue-neutral tax on petroleum spread across the value chain to reflect accurately the impact of the entire production stream from drilling and exploration through refining to consumption. A revenue-neutral tax does not increase net revenues to the Government; rather, the tax proceeds are reinvested back into the energy industry to correct for the negative externalities intrinsic to the hydrocarbon market. Owners of vehicles with lower miles per gallon efficiency and higher greenhouse gas emissions will pay higher taxes to create incentives for consumers to purchase HEV, plug-in HEV or hydrogen cars. The tax revenues will fund upgrades to the electricity grid and transportation infrastructure.

Second, the Administration should propose and Congress should enact a revenue-neutral tax on coal and natural gas (e.g., combustion generation facilities) spread across the value chain that accurately reflects the impact of the entire production stream from mining through generation and delivery of the final product. The tax revenues would be invested back into the energy industry, providing advanced renewable tariffs (ARTs) for expanding sustainable renewable energy sources including solar, wind, and hydro, along with investments in the research and development of carbon capture and sequestration technologies.

To date, the subsidies for the fossil fuel and nuclear industries have been larger and more consistent than for renewable energy sources.[80] Congress should allow these investment funds to expire gradually within the next ten years. Congress should then redirect those funds toward research and development in technology and manufacturing for efficiency gains and energy storage technologies as previously discussed to alleviate the intermittency issues associated with some renewable energy sources.

Although taxation, including revenue-neutral taxation, poses political challenges, the Administration must pursue this course of action. As President Obama's quotation at the beginning of this report noted, it is a matter of national security, economic prosperity, and the survival of the planet. While cynicism is *en vogue* inside the Beltway, bipartisan leadership from the executive and legislative branches must garner public support for revenue-neutral tax structures that create incentives for renewable, sustainable sources of energy.

In addition to these fiscal policy efforts to rectify market failures related to fossil fuels, the government should also encourage private industry to expand production of renewable and sustainable energy. Based on the new National Energy Strategy, the federal government should have a clear, stable, and transparent policy with specific actions to stimulate private industry investments.

First, the administration should mandate a National Renewable Portfolio Standard (NRPS) that is time-phased and tailored by region and resources. This will require partnerships with states that currently have implemented RPSs with accompanying lessons learned. For states without an RPS, an NRPS would mandate minimum standards. The mandate should include the development of new transmission lines to serve wind, solar, and other distributed renewable energy sources.[81] Specifically, the FERC should standardize interconnection protocols and net metering for connecting and measuring the output of renewable energy systems, both of which are critical to market penetration.[82]

Second, federal, state, and local governments should continue to provide stable incentives for renewable energy sources. Specifically, the government should implement ARTs to stimulate alternative energy industries and provide a long-term and stable incentive base on which renewable resource energy industries may compete. An ART is a more sophisticated variation of a feed-in tariff, simply a set price paid per kWh of electricity generated by a renewable resource. ARTs are preferred over feed-in tariffs since ARTs differentiate by technology, project size, and productivity of the resource. Given the demonstrated success in Europe, these tariffs are arguably the world's most successful policy mechanism for stimulating the rapid development of renewable energy.[83] ARTs allow long-term, bilateral contracts that provide predictable income to renewable energy sources, better investment funding, and insurance to the consumer against future electricity price increases. FERC, in coordination with the DOE's Agency for Renewable and Sustainable Energy, should set and standardize ARTs for the U.S. government.

Finally, the Administration should propose and Congress should enact loan guarantees for renewable energy sources such as wind and solar in a manner similar to that for the nuclear industry. While the up-front capital investment required for solar and wind is not as large as for nuclear energy, stable loan guarantees for renewable energy sources greatly enhance the probability of securing the capital investment funds, enabling businesses to make the needed investments in U.S.-based facilities to drive economies of scale and efficiencies.[84]

RECOMMENDATION 3: THE ENERGY BACKBONE

Smart Grid technologies are the backbone of energy security, and the new DOE Agency should work with FERC and states to improve coordination among regional power grids, accelerate dissemination of Smart Grid meters and appliances, and implement selective micro-grids for critical infrastructure.

The first step requires FERC to improve coordination among regional power grids. FERC should work with regional power grids to modernize the antiquated transmission and distribution methods. Modernization will enable sharing of reliable energy information among regional power grids and consumers, with resulting energy savings through curtailment and leveling of peak demand periods. Smart meters and improved networks would enable the cycling of power to devices as needed, freeing the power for use elsewhere during high demand periods. The use of wind and solar power can provide reliable energy, but the Smart Grid will distribute other sources of energy during periods of limited wind and sunlight. Furthermore, consumers may return energy to the Smart Grid when the prices are highest, resulting in cost savings for the consumer and an additional energy source.

The acceleration and dissemination of Smart Grid meters and appliances are highly dependent on the federal and state governments. The federal government supported the Smart Grid through the Energy Independence and Security Act (EISA) of 2007.[85] This law establishes funding incentives, standards, and rules for the Smart Grid. The EISA commits $100M in funding each year from 2008-2012 and includes a matching program for states and utilities for Smart Grid development. The Act also directs the development of standards and protocols though the National Institute of Standards and Technology. It is critical that the standards and protocols of the utility industries are the same for federal and the state governments so they can (inter)operate at both the macro and micro-grid level.

Companies and end users must see economic value in the Smart Grid, and this value will be in the form of savings realized and the reduction of overall energy use. Businesses and households must see true reductions in their energy bills. The overall economic outlook of the Smart Grid is a true value to the end consumer, business, and government. The government reduces energy consumption and cuts waste while businesses make profits and consumers save. While the cost savings can be debated, a DOE study shows the benefits range anywhere from $75B to $150B over the next 20 years.[86] The biggest winner from a business perspective will be the companies that produce hardware and software to monitor energy usage and the companies that use that information. The 2009 Smart Grid industry was valued at $21.9B and by 2014 could exceed $42B.[87]

RECOMMENDATION 4: DOING MORE WITH LESS

While the majority of this report focused on new supplies of renewable and sustainable energy, reducing demand for carbon-based fuels is an equally effective method to mitigate the economic, environmental, and national security threat posed by dependence on traditional sources of energy. Efficiency gains in energy generation, storage, delivery, and usage form the lynchpin for energy security as it simultaneously enhances energy security, relieves pressure on a stressed infrastructure, and shrinks the carbon footprint, all while transforming the U.S. economy from a 20th century industrial relic to a 21st century engine of sustained national power.

To date, calls to improve efficiency have become trite in that they lack real "teeth" to encourage and enforce adoption.[88] DOE must implement aggressive policies to realize available efficiency gains. In recognition of this urgency, this report proposes a series of sweeping initiatives in the residential, industrial, and transportation segments to capture the attention of the American public and create real, structural change in energy generation, storage, delivery, and usage.

Electricity Generation and Distribution

Current processes for electricity generation and transmission result in the most substantial amount of the total lost energy in the U.S. economy.[89] In addition to the Smart Grid efforts previously discussed, the U.S. government should undertake a number of efforts to reduce this loss. First, to reduce loss in projects requiring the movement of energy over long distances, the DOE should develop a program that provides grants for high-efficiency superconducting cables in renewable energy projects. DOE currently provides loan guarantees for superconducting cables in non-renewable energy projects.

Second, the government should decouple utility rates and energy use. The current utility rate structure acts as a disincentive to efficiency. If the utility's customers are more efficient, the utility loses revenue.[90] The American Recovery and Reinvestment Act of 2009 encouraged states "to seek to implement" rate structures that decouple utility rates from energy use.[91] This report advocates mandatory decoupling for states to receive future energy grants.

Buildings

The United States devotes approximately 70% of electricity to light, heat, and power buildings.[92] To improve the efficiency of electricity use in buildings, the government should start with its own infrastructure and mandate a minimum of Silver LEED (Leadership in Energy and Environmental Design) standards in all government buildings and homes. Further, the government should encourage the creation of positive energy buildings through tax rebates, micro-loans, or utility administered projects and establish standards for "plug and play" installation of residential renewable technologies as the House outlined in the American Power

Act of 2009. Toward this end, energy ratings for buildings similar to the "Energy Star" ratings for appliances could provide consumers with information to make informed decisions. Federal and state governments should also cooperatively promulgate building standards that set minimum standards for insulation, windows, lighting, water heating, and space heating/cooling systems. These standards would apply to all new residential and commercial construction and any properties completing major upgrades.

Finally, and perhaps most controversially, the government should modify the U.S. tax code to apply mortgage interest tax benefits to homes only if they meet federal building efficiency standards as specified in the House's American Power Act of 2009. This change could be phased-in to mitigate its impact, but the declaratory function of this effort would communicate to homebuilders and homebuyers alike that energy efficiency should be a top concern in the construction and purchase of a home.

Transportation

Many efforts are underway to improve efficiency within the transportation sector, but current approaches fall short of the revolutionary change required to gain needed, available efficiencies. To enhance efficiency within the transportation segment of the U.S. economy, the government should raise fleet CAFÉ standards to 75 mpg (or electrical equivalent) by 2025, followed by an annual increase of 1 mpg through 2050. DOE should also expand research and technology sharing of lower weight and high strength materials for use in heavy trucks and light duty vehicles. A parallel effort in the Department of Transportation should complement these efforts to improve public transportation networks and to study and establish standards for improved aerodynamics and efficiency in heavy-duty vehicles.

Finally, the government should encourage the use of new concepts for fleet and single purpose heavy vehicles that couple energy generation and high efficiency fleet vehicles. Employing local renewable generation of electricity at the work site with highly efficient electrical motors improves efficiency, reduces emissions, and reduces demand for fossil fuels. Other concepts for consideration should include hydrogen generation/refueling stations for fleet vehicle hubs.

RECOMMENDATION 5: RESEARCH AND INNOVATION

The United States finished the 2000s ranked sixth globally in overall innovation as measured by a compilation of 16 economic, social, and policy indicators.[93] The United States funds more research and development (R&D) than any other country, but not in energy-related R&D.[94] For example, China, Japan and South Korea have already passed the United States in production of clean energy technologies, and are projected to out-invest the United States by a factor of three to one through 2015.[95] To develop competitive advantages in energy technologies, the United States needs to focus R&D efforts on key energy technologies and leverage domestic and international resources to spur innovation.

Government-sponsored research should focus on storage technologies to take advantage of intermittent renewable resources, increase the efficiency of the electrical transmission grid through applied smart technologies, develop affordable carbon capture technologies for fossil fuels, and provide new materials and designs that dramatically increase the efficiency of buildings.[96] Further, the U.S. government should stimulate innovation through long-term basic research for game changing technologies such as nanotechnology, cost-effective hydrogen fuel cells, and nuclear fusion.[97]

It is critical that U.S. government R&D budgets remain stable. Traditionally, the United States supplies periodic funding infusions for research and innovation, but then allows them to expire. This cyclical funding makes it difficult to sustain the long-term momentum necessary to capture and apply innovation potential in the long term.

Funding new initiatives in the current tight fiscal environment is challenging, and the U.S. government cannot and should not do it alone. Washington should continue to shape policies that encourage public-private partnerships to drive long-term and market-based solutions through a variety of economic and policy incentives. Additionally, the United States should seek and facilitate international partnerships, including the recently formed U.S.-European Union Energy Council, to collaborate and work towards mutually beneficial goals on strategic energy policies and issues.[98] Establishing and pursuing common goals for research and technologies, energy security and markets, and energy policies and regulations will strengthen the partnerships.[99]

Finally, and perhaps most importantly, the United States must significantly improve educational efforts related to science, technology, engineering, and mathematics to reclaim a deteriorating competitive advantage. The first step includes improving the primary education system through partnerships with science and engineering stakeholders, and implementing initiatives targeting science and math standards, teaching credentials, and rewards for high performing schools.[100] Second, concerted efforts can increase the number of science and engineering majors at the collegiate level through increased scholarships and tax incentives for undergraduate and advanced degrees, and improvements in on-line education opportunities to reach more students.[101] Although not specifically focused on the energy industry, these types of broad-based education initiatives will have sweeping impacts on the nation's research and innovation capabilities as a whole, including energy. Finally, the United States should encourage private sector innovation through competitions designed to inspire and perpetuate American ingenuity. Government-sponsored, privately funded "E-Prizes" could encourage and reward innovation in areas such as energy management and conservation. A good example is the United Kingdom's 2008 Low Carbon Transition Plan that includes £10 million in prizes for communities pioneering green initiatives.[102]

V. CONCLUSION

The recommendations in this report, taken as a whole, will promote U.S. energy security by encouraging the development of a renewable and sustainable energy sources and infrastructure. While correcting market failures is an important first-step, the foundation of American security has been, and will continue to be, the American citizenry. True energy security can only arise from the quintessential American quest for innovation and progress, and the steps proposed here seek, most importantly, to unburden and encourage that talent and creativity.

APPENDIX I. INTERNATIONAL LEADERSHIP

The United States comprises roughly 4.5% of the world's population, but its inhabitants consume roughly one quarter of the world's energy. This is an oft-cited statistic and accusation employed to suggest that the United States consumes more than its "fair share" of world energy. However, this statistic fails to reflect the fact that the United States is the world's largest single economy (second only to the collective economies of the European Union countries); generates over 30% of the world's patents;[103] and funds about one-third of the world's investment in research and development.[104] The United States must become the world leader in the energy field not because it consumes more energy than any other country in the world but because leadership in energy will allow it to remain the world's leader in other areas.

Energy security is critical to U.S. global leadership in areas such as economics, trade, defense, education, and R&D, among others. The security of the energy supply determines the future of the country, its development, and its international standing. For these reasons, the United States must shape norms, practices, and agreements that emerge internationally on the development, use, and allocation of energy resources. There is too much at stake for the United States to relegate leadership in the energy domain to other countries. Furthermore, any system of norms, practices, and agreements will likely have limited credibility and efficacy without U.S. involvement. The United States, as the single largest consumer of energy and a significant producer of energy as well, has the capacity to affect the international energy market. Therefore, other states have little incentive to participate in a system that does not reflect U.S. input and does not apply to the United States in a similar fashion. As such, it is incumbent upon the United States to lead a global effort to establish a system of norms, practices, and agreements.

The United States can demonstrate its seriousness about investment in energy issues by making it a core pillar of its foreign policy. Whether in bilateral, regional, or multilateral relations, the United States should use the power of its voice and its pocketbook to support smart and responsible use of energy resources, development of energy infrastructure, and the adoption of energy efficient practices, among other pursuits. On a practical level, the United States can take up the necessary leadership role in three ways. First, it should participate in international forums, whether through the United Nations or through groups such as the G-20, to develop and promote an international structure to address the emerging energy issues described in this report. Second, the United States should fund and encourage collaborative R&D projects across international think tanks, institutes, and businesses. Third, the United States should incorporate energy concerns into its foreign policy, particularly in the implementation of foreign security and development assistance.

Proposed U.S. solutions to energy problems will not help the safety and security of our allies or solve our collective environmental challenges unless the solutions are developed and adopted globally. Aggressive leadership will help to lead and shape international energy developments, and will reflect the most basic, practical realization that it is a global effort. International leadership depends on domestic credibility, and thus the United States must begin a transition to renewable and sustainable energy at home before assuming the mantle of leadership globally.

APPENDIX II. THE ROLE FOR THE DEPARTMENT OF DEFENSE

There may be no direct military rationale compelling the Department of Defense (DoD) to become deeply involved with alternative fuels and energy conservation, but in a constrained fiscal environment, conservation and new energy sources can play a crucial role in DoD's ability to budget and execute the National Military Strategy. With regard to oil alone, every $10 increase in the price of oil equates to a $1.3 billion increase in DoD's operating costs.[105] Moreover, access to energy sources and instability in fossil fuel-based energy heavily influence the U.S. military instrument of power. To mitigate these adverse effects, DoD should reduce both its dependency on fossil fuels and its carbon footprint through demand reduction initiatives and by adopting alternative energy sources to create a niche demand for alternative transportation fuels.

The Department has a history of being an early adopter of new ideas and a demonstrator of new technologies. It also has a very large pool of well-trained personnel and the ability to modify their behavior. DoD institutions and facilities are ideal test bases for alternative energy sources and most importantly, it also has a large inventory of energy intensive vehicles, marine vessels, and aircraft. For these reasons, the DoD must be in the vanguard of federal efforts to transition toward renewable and sustainable energy.

As the largest institutional energy user in the nation, potentially the world, the DoD accounts for 93% of all U.S. government fuel use. This equates to 120 million barrels of oil in FY 2008 with a price tag of $16 billion, which does not include electricity and gas bills for operations and maintenance of DoD facilities.[106] To reduce these tremendous costs, the DoD needs to continue campaigns for demand reduction through energy conservation and increased energy efficiency. Energy conservation may be as simple as exchanging light bulbs, installing motion sensors in rooms with switches, installing electronic thermostats, and public awareness. It should also entail large scale adoption of vehicle fleets, ships, and aircraft powered by renewable energy or alternative fuels. Other options include creating Smart Grids on DoD installations to measure power demand and then modulate it to support the entire grid. With regard to building efficiency, the DoD should mandate that all new construction meets the highest level of environmental and energy standards and that old construction is upgraded, regardless of state-level requirements, which may be lower. Defense acquisition should also incorporate key performance parameters to require certain levels of efficiency and consider the fully burdened cost of fossil fuels for all systems.

In any economic model, there has to be a supply and a demand to create a market. If a reliable demand is created and has an economically sustainable supply, a market will form where goods and services are exchanged. Since the DoD is the nation's largest single user of electricity and petroleum, this provides a unique opportunity to create a demand for alternative energy sources. For instance, DoD installations and facilities should leverage cogeneration to increase reliability and security of its own power generation and for the national grid. Policies should also stimulate the adoption of renewable resources to increase energy diversity and security by working with local and regional power companies to increase the mix of renewable and sustainable energy sources.

With regard to creating a niche market for alternative fuels, jet fuel is the most inelastic market with limited alternatives and substitutes. It is reasonable to assume that the DoD could potentially purchase 50% synthetic fuels starting in 2012 after completion of all its aircraft certifications. This would create a potential market for 25 million barrels of jet fuel per year. This demand should be adequate to provide a small market for alternative jet fuel, with the aim of starting small and then expanding. Though current Defense Energy Support Center (DESC) acquisition policies for purchasing fuels has changed in the recent past, the current DoD policy still does not allow DESC to enter into "longer-term" contracts. This should be reformed in order to provide stability to the market.

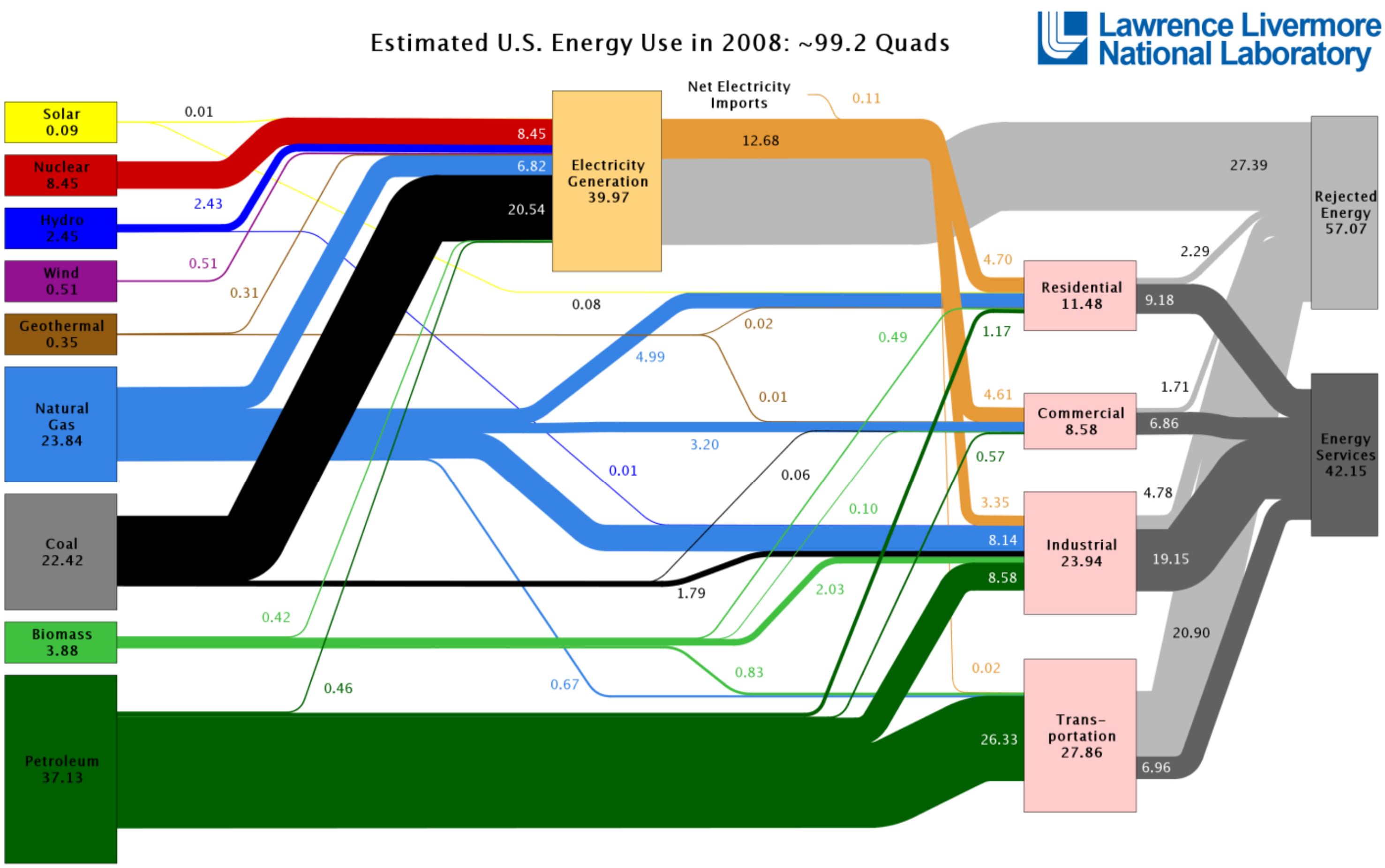
In order to develop long-term customers, DESC contract policy for fuels has to be crafted to allow alternative jet fuel companies to be profitable and competitive; to share and balance risks of short term oil price volatility and long term trends; and to encourage investors to fund alternative fuel projects. Ultimately, the private sector believes that the DoD has a lofty vision to encourage alternative fuel production, but the DoD is failing to change its processes and policies to take advantage of the potential supply and encourage early adoption. The DoD should purchase jet fuel using long-term fuel contracts with a reasonable premium reflecting the benefits of domestic production, the increased price stability of the substitute, and the overall national security benefits.

Ultimately, the objective is the U.S. government and private industry is to leverage the DoD for early adoption in order to shape the market for future expansion into the commercial sector. The market could possibly grow to 260 million barrels a year. This small supply of petroleum substitutes, along with aggressive U.S. energy conservation policy, will increase the elasticity of the energy market and decrease the threat to our national security and the global economy.

Although there is no short-term military benefit to early adoption of alternative fuels, there is a great and long-term benefit to energy security, and national security at large. Professor Kaufmann, an economist at Boston University, presented analysis that described the energy production of an entity over a 40-year period.[107] The economic analysis shows investments made to become early adopters resulted in small decreases in overall energy production in the first five years of transition; however, nearly a fivefold increase in total energy production occurred over the time span required for late adapters to return to steady state energy production. This increase in energy production, however, depends on early adopters, a role that the DoD is well positioned to fulfill. The end result of such efforts would be manifest in real long-term budget savings, increased gross domestic product, and enhanced national security.

APPENDIX III. THE IMPORTANCE OF EFFICIENCY

If efficiency appears to be a panacea of sorts, it is merely due to the amount of wasted energy in the United States. Of the energy generated for consumption, an astounding 57% of the energy is simply lost in the process of generation, storage, transport, or use of the energy. The figure below visually depicts U.S. energy use by sector in 2008, highlighting that more than half the energy created was wasted, underscoring the importance of doing more with less. [108]



Source: LLNL 2009. Data is based on DOE/EIA-0384(2008), June 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports flows for non-thermal resources (i.e., hydro, wind and solar) in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 80% for the residential, commercial and industrial sectors, and as 25% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

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